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Space engineering

Ground systems and operations — Part 1: Principles and requirements

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Foreword

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

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

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

This Standard has been prepared by the ECSS Ground systems and operations Working Group, reviewed by the ECSS Technical Panel and approved by the ECSS Steering Board.

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Introduction

Ground systems and operations are key elements of a space system and as such play an essential role in achieving mission success. Mission success is defined here as the achievement of the target mission objectives as expressed in terms of the quantity, quality and availability of delivered mission products and services within a given cost envelope.

Mission success requires successful completion of a long and complex process covering the definition, design, implementation, validation, in flight operations and post operational activities, involving both the ground segment and also space segment elements. It involves technical activities, as well as human and financial resources, and encompasses the full range of space engineering disciplines. Moreover it necessitates a close link with the design of the space segment in order to ensure proper compatibility between both elements of the complete space system.

This Standard provides a high level description of all ground segment elements, the domain specific aspects of the associated engineering processes and defines related guidelines and requirements.

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Scope

Within the frame of the overall engineering standards for space missions, this Standard contains the basic rules, principles and requirements to be applied to the engineering of the ground segment and mission operations, which form an integral part of the overall system implementing a space mission.

This Standard includes development of ground segment, operations preparation activities, mission planning activities, mission evaluation activities, the conduct of operations proper, and all post-operational activities. The ground segment comprises the ground systems (i.e. all ground facilities, hardware and software) and all operational aspects such as personnel and related data repositories required on ground to perform mission operations.

For reasons of recognized commonality, ground segment within the meaning of this Standard includes those elements and facilities required for the purpose of implementing the mission and fulfilling the missions requirements while the relevant space segments are in-orbit. It covers ground elements used for purposes of assembly, integration and verification of the space segment, to the extent needed for ground segment end-to-end verification activities. It also covers elements integrated into the ground segment after completion of space segment AIT; space segment AIT proper being considered outside the scope of this Standard.

It does not however cover the spacecraft activities and facilities interfacing the launch service segment. Furthermore, while this Standard is applicable to all classes of missions it does not consider aspects that are specific to manned space missions.

This Standard is structured as follows:

- identification of the ground systems and operations domain;
- overview of ground segment engineering processes in relation to the project life cycle;
- detailed description of specific aspects of the ground segment elements and engineering tasks.

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

NOTE Tailoring is a process by which individual requirements of specifications, standards and related documents are evaluated, and made applicable to a specific project by selection, and in some exceptional cases, modification of existing or addition of new requirements.

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Normative references

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

ECSS-P-001	Glossary of terms
ECSS-P-002 [1)]	Project documentation model
ECSS-E-00	Space engineering - Policy and principles
ECSS-E-10	Space engineering - System engineering
ECSS-E-40	Space engineering - Software
ECSS-E-50 [1)]	Space engineering - Communication
ECSS-E-70 Part 2 [1)]	Space engineering - Ground systems and operations - Part 2: Document requirements definitions (DRDs)
ECSS-M-00	Space project management - Policy and principles
ECSS-M-30	Space project management - Project phasing and planning
ECSS-M-70	Space project management - Integrated logistics support
ECSS-Q-30A	Space product assurance - Dependability
ECSS-Q-40A	Space product assurance - Safety

Below are the level-3 documents referenced by this Standard.

ECSS-E-10-02	Space engineering - Verification
ECSS-E-10-03 [1)]	Space engineering - Testing
ECSS-E-70-11 [1)]	Space engineering - Space segment operability
ECSS-E-70-41 [1)]	Space engineering - Telemetry and telecommand packet utilization

1) To be published.

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Terms, definitions and abbreviated terms

3.1 Terms and definitions

For definition of the following term refer to ECSS-E-10:

system engineering

For definition of the following terms refer to ECSS-E-10-02:

assembly

inspection

test

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

3.1.1
entity
combination of facility plus respective personnel or operations organization

3.1.2
facility
combination of ground system elements required by a ground operations organization to perform an operational task

3.1.3
flight operations
all activities related to the planning, execution and evaluation of the control of the space segment (or subsets thereof) when in orbit

3.1.4
ground operations
all activities related to the planning, execution and evaluation of the control of the ground segment (or subsets thereof) facility

3.1.5
ground segment
all ground facilities and personnel involved in the preparation or execution of mission operations

3.1.6
ground segment supplier
organization responsible for the supply of the ground segment and operations

3.1.7
ground systems
all ground infrastructure elements that are used to support the preparation activities leading up to mission operations, the conduct of mission operations and all post-operational activities

3.1.8
integration and technical verification and validation
part of the ground segment verification process completing the ground systems implementation phase, it also covers to the maximum possible extent operational aspects.

NOTE 1 Its main objective is to confirm, through an incremental integration and testing process, the conformance of the ground systems to their requirements.

NOTE 2 It also provides preliminary validation of the ground systems and of their constituting elements.

3.1.9
mission
the specific function to be accomplished by a space system (i.e. definition of ECSS-P-001 restricted to the space system) as characterized by its expected products in terms of quantity, quality and availability

3.1.10
mission exploitation
activity consisting in the planning, utilization and evaluation of the products of the space mission

3.1.11
mission information
all information required by the ground segment during both pre-launch and post-launch phases

NOTE 1 It typically includes, space segment design and operations characteristics, space segment test and operations procedures, telemetry and telecommand characteristics.

NOTE 2 It is composed of source data originating from the space segment customer and derived data produced by the ground segment teams.

3.1.12
mission operations
all activities related to the planning, execution and evaluations of the control of the space and ground segments during phases E and F of a space system (i.e. combination of flight and ground operations)

3.1.13
mission operations data
subset of the mission information used to execute the in-orbit operations (i.e. it includes, for example, operations procedures, rules and databases)

3.1.14
mission products
products and services delivered by the space segment as the result of its in-orbit exploitation (e.g. communications services, science data and space samples)

3.1.15
operational validation
ultimate part of the ground segment verification process, the objective of which is to establish the operational validation of the whole ground segment (including operations personnel) and its readiness to support the space mission in-orbit

3.1.16
space system customer
highest level entity responsible for the complete space system comprising both the space and the ground segment (i.e. interfaces with the entity responsible for the ground segment through a customer to supplier relationship)

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this Standard.

Abbreviation	Meaning
AIT	assembly, integration and test
CCSDS	Consultative Committee for Space Data Systems
COTS	commercial off-the-shelf
CRD	customer requirements document
CSSRD	customer services support requirements document
DDF	design definition file
DRD	document requirements definition
FCP	flight control procedure
FOP	flight operations plan
G/S	ground segment
GCS	ground communications subnet
GOP	ground operations plan
GSBD	ground segment baseline definition
GSCDR	ground segment critical design review
GSEG	ground segment
GSPDR	ground segment preliminary design review
GSRR	ground segment requirements review
GSS	ground segment and operations supplier
GSTS	ground station system
GSTS-SSC	ground station system - space segment control
GSTS-ME	ground station system - mission exploitation
GSTS-M&C	ground station system - monitoring and control
GSTVVR	ground segment technical verification and validation review
GSTVVRR	ground segment technical verification and validation readiness review
GSYS	ground system
HCI	human-computer interaction
I/F	interface
IOOR	in-orbit operations review

IOQR	in-orbit qualification review
LEOP	launch and early orbit phase
LORA	level of repair analysis
LS	logistic support
LSP	logistics support plan
MCC	mission control centre
MCOR	mission close-out review
MCS	mission control system
MEC	mission exploitation centre
MES	mission exploitation system
MOCD	mission operations concept document
MRD	mission requirements document
MTA	maintenance tasks analysis
OAR	operations anomaly report
OCC	operations control centre
OCS	operation control system
OPS	operations
ORR	operational readiness review
OTP	operations training plan
OVP	operational validation plan
OVRR	operational validation readiness review
PCC	payload control centre
PCS	payload control system
RAMS	reliability, availability, maintainability and safety
RCMA	reliability centred maintenance analysis
REP	report
RF	radio frequency
SCOE	special check-out equipment
SDE	software development environment
SGICD	space-to-ground interface control document
SPEC	specification
SSC	space system customer
SSORD	space segment operability requirements document
SSUM	space segment user manual
SVF	software validation facility
TM/TC	telemetry/telecommand
TT&C	telemetry, tracking, and command

4

Ground systems and operations domain

4.1 General

Within a space system, mission operations shall comprise the subset of mission engineering activities, identifiable for flight operations, ground operations and logistics engineering, which is required to operate the space segment. Mission operations implement the mission in accordance with the stated, implied or redefined mission objectives in terms of providing plans and services, conducting experiments, producing, providing and distributing materials or goods, or collecting data.

In this context the domain of ECSS-E-70 covers the ground segment. In addition, it also considers those aspects of the space segment system of relevance to mission operations. In accordance with the definition of mission operations, launcher operations are not included in this domain.

4.2 Ground segment composition

The domain of ECSS-E-70 is shown in Figure 1 in the context of the ground segment. The ground segment is composed of two main components.

- Ground operations organizations, comprising the human resources performing the various operations tasks and preparing the mission operations data (e.g. procedures, documentation, mission parameters, mission description data).
- Ground systems, consisting of the major ground infrastructure elements that are used to support the preparation activities leading up to mission operations, the conduct of operations themselves and all post-operational activities. These systems grouped together from an organizational viewpoint constitute facilities.

Figure 1, indicates a direct correspondence between ground systems and operations organizations. The combination of an operations organization and its corresponding supporting facility constitutes a ground segment entity. An example of an entity is a control centre from where the elements of an operations organization control an element of the mission such as a space segment or ground station. In the case of space segment control, an element of the operations organization is the flight control team who uses the operations control system as a support facility.

NOTE The domain of ECSS-E-70 extends into the space segment as far as data, operational interfaces (e.g. operability issues of the spacecraft design) and mission products (i.e. products

or services provided by the space segment) are concerned. This applies in particular to the on-board data handling functions. However it does not consider the space operations organization (e.g. astronauts).

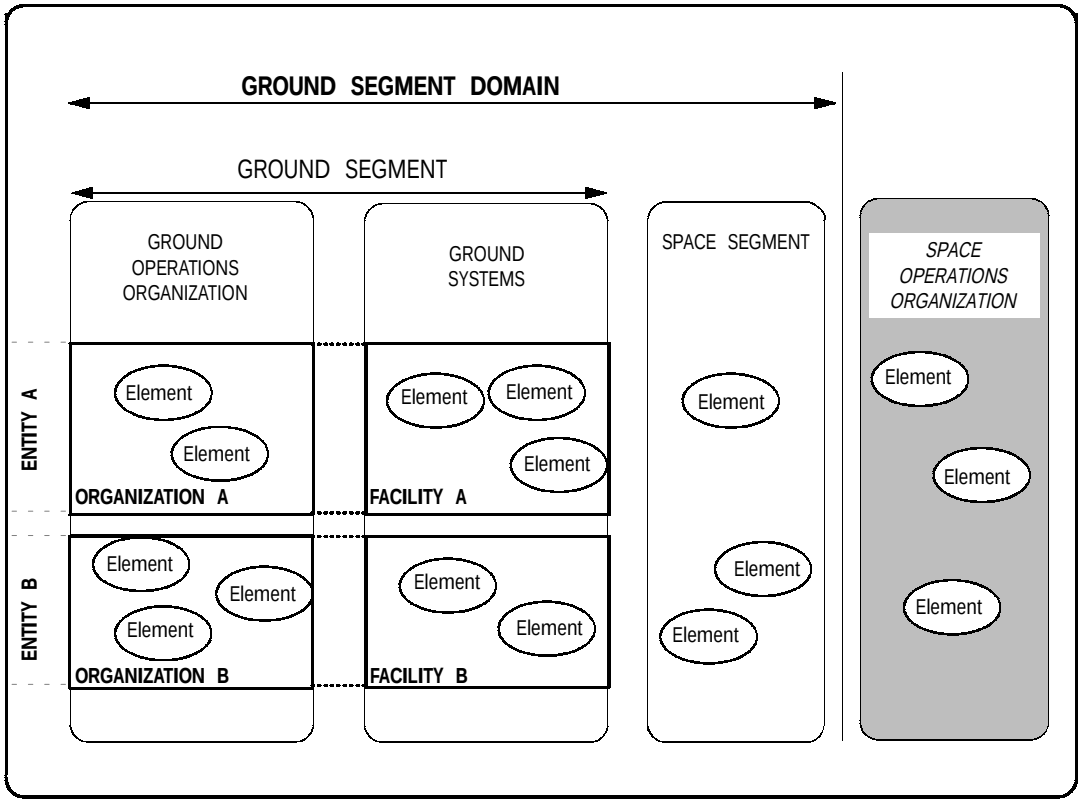


Figure 1: Ground segment context

4.3 Ground system elements

The ground systems, as shown in Figure 2, usually consist of the following main elements:

- Mission control system (MCS)
- Electrical ground support equipment (EGSE)
- Ground station system (GSTS)
- Ground communication subnet (GCS)

4.3.1 Mission control system (MCS)

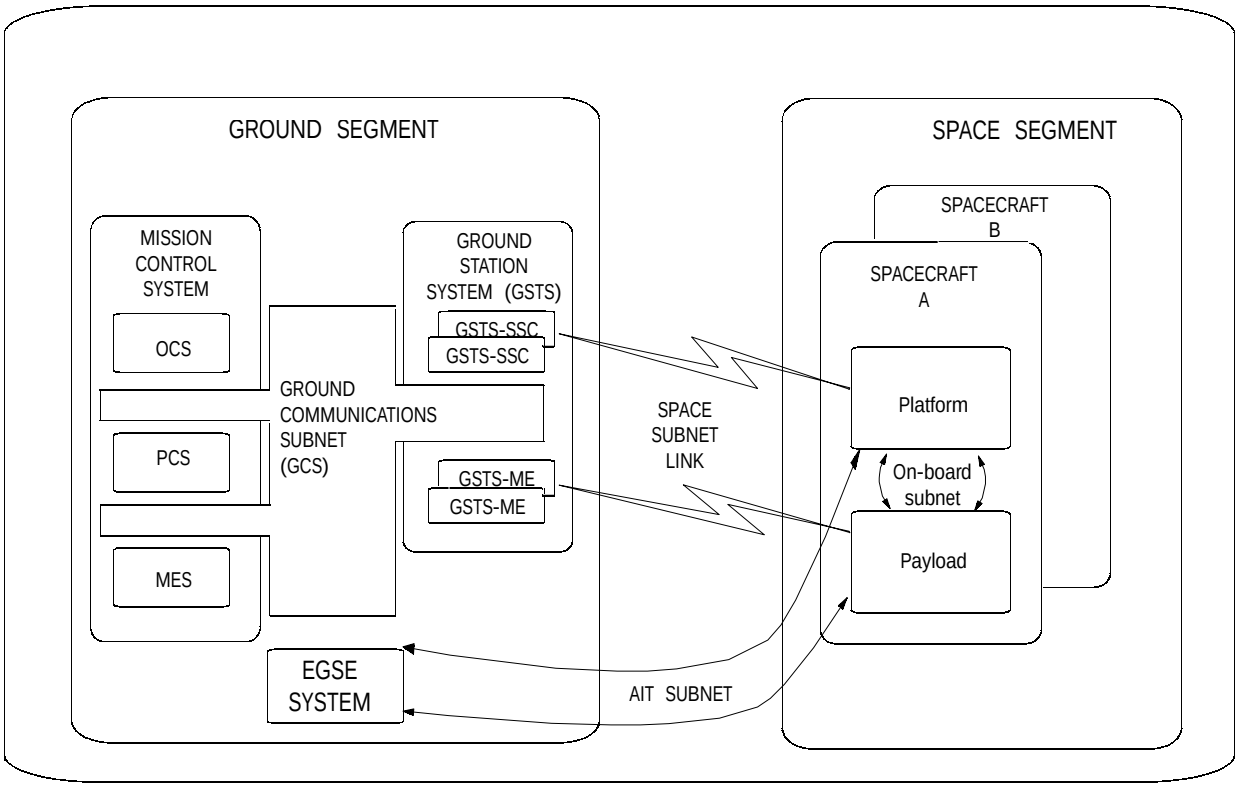
The MCS shall comprise all the elements required to control the mission and to exploit its products. It should be logically decomposed in the following functional elements:

a. Operations control system (OCS), mainly supporting planning, monitoring and control, and performance evaluation of the platform elements of the space segment. It also includes the flight dynamics support element which may be considered as a system in its own right.

b. Payload control system (PCS), providing the same functions as the OCS but dedicated to the control of the payload elements of the space segment.

c. Mission exploitation system (MES), supporting the users of the mission products in establishing high level production plan and in providing them with mission products and with all data required for their planning and utilization.

The above decomposition is of a logical nature and in practice, these functions may be physically grouped in accordance with the type of missions and the ground segment organization. For example, often OCS and PCS are grouped in the same system (the space segment control system, SCS) and be carried-out by the same operations organization, while the MES is often implemented as a separate system.



OCS: Operation Control System
PCS: Payload Control System
MES: Mission Exploitation System

GSTS-SSC: Space Segment Control Station
GSTS-ME: Mission Exploitation Station
EGSE: Electrical Ground Support Equipment

Figure 2: Breakdown of the ground and space segment

4.3.2 Electrical ground support equipment (EGSE)

The EGSE system shall be part of the overall ground support equipment (GSE), supporting the verification of the space segment during assembly, integration and test (AIT).

4.3.3 Ground station system (GSTS)

The GSTS shall constitute the direct interface with the space segment while in-orbit and with the MCS. It provides support functions for controlling the space segment elements and exploiting the mission products. Two logical instances of GSTSs are considered with respect to their utilization as follows:

a. GSTS-SSC: for the ground station system(s) in support of space segment control (i.e. providing telemetry, telecommand and tracking services) for both the platform and the payload.

b. GSTS-ME: for the ground station system(s) in support of mission exploitation; e.g. for transmission and reception of payload service data such as telecommunications signal, Earth images, science data.

4.3.4 Ground communication subnet (GCS)

The GCS shall connect all operational ground facilities. The GCS constitutes the ground part of the end-to-end data path. Other sub-networks are the space link subnet, the on-board subnet and the AIT subnet used only during space segment AIT to connect the space segment with the EGSE. The space link subnet is partially covered under GSTS where the space-to-ground protocol is terminated.

4.3.5 Supporting infrastructure

In addition to the above systems and elements the ground systems shall also include the supporting infrastructure (i.e. building, rooms, power, air conditioning).

NOTE The decomposition of the ground segment into entities and systems elements depends on the organizational structure of the ground segment project (e.g. management structure, location of facilities). Therefore the elements shown on Figure 2 should be seen as a conceptual grouping of functions for a specific project mapped into different physical elements.
This also applies to decomposition of the ground segment into its constituent ground segment entities. However, one category of entities plays an essential role in the ground segment domain that is the control centre (CC) which is in charge of the execution of the operations for a particular subset of the space or ground segment. A control centre includes the related control systems and elements, the supporting logistics infrastructure (e.g. rooms), and the corresponding operation team(s) and operations data.

4.3.6 Control centres

Depending on the organizational structure of the ground segment and in relation with the decomposition of the ground systems into main elements, the following typical instances of control centres shall be identified:

a. Mission control centre (MCC): it is composed of the MCS as primary ground system and is in charge of the in-orbit operations of the whole space segment.

b. Operations control centre (OCC): it is composed of the OCS as primary Ground System and is in charge of the in-orbit control of the platform elements of the space segment.

c. Payload control centre (PCC): it is composed of the PCS as primary ground system and is in charge of the in-orbit control of all or part of the payloads on board of the space segment.

d. Mission exploitation centre (MEC): it is composed of the MES as primary ground system. It is typically in charge of establishing the high level plans for the generation of the mission products and providing the end users of the mission with both the mission products and all data required for their planning and utilisation. For example, in the case of a science mission, the MEC may be in direct liaison with the scientific user community, coordinating requests (to be converted into plans to be passed to the PCC for implementation), and providing the data required for scientific processing and evaluation.

5

Ground segment engineering processes

5.1 General

In accordance with the applicable ECSS life cycle as defined in ECSS M-30, the ground engineering processes shall be partitioned in phases. These phases shall include the activities described in this clause and summarized in Figure 3.

The ground segment life cycle phases are not necessarily concurrent with those of the space segment, however there is extensive interaction between the two. Furthermore, other project life cycle models may be used for the development of individual system elements.

The EGSE life cycle should be shifted in time with respect to ground segment elements for mission operations, due to its role in the space segment assembly, integration and verification process. Moreover, the requirement to have EGSE in a usable state in preparation for the test activities can lead to development in advance of the normal space segment project phasing.

The following general ground segment engineering requirements shall apply:

a. Ground segment aspects shall be taken into account from phase 0/A of the space system.

b. Each phase of the ground segment life cycle shall end with a formal review.

c. The ground segment activities shall involve two main actors:

   - the space system customer (SSC), responsible for the procurement of the ground segment;
   - the ground segment supplier (GSS), responsible for the supply of the ground segment or its subsequent utilization, in accordance with the requirements established by the space system customer.

For each ground segment phase, this clause identifies the main activities, their inputs, outputs and the major review(s) for each ground segment phase. The list of activities and products are summarized in Tables 1 to 7. When applicable, reference to the relevant document requirements definition (DRD) is also made.

While the process model does not specifically address space missions of an incremental nature (such as ISS or the European ATV), the ground segment life cycle and basic processes identified herein shall also be applicable to each mission increment.

5.2 Ground segment phase 0/A: Feasibility studies and conceptual design

5.2.1 Purpose of phase 0/A

a. During this phase, the requests initially expressed by the space system customer (SSC) are analysed in order to identify and characterize the ground segment, in terms of operational feasibility and needs, expected performance and RAMS objectives (reliability, availability, maintainability, and safety).

b. Several ground segment options are identified and assessed in order to demonstrate the feasibility of the mission.

c. An evaluation of the operational constraints involved in the mission are performed in this phase. For this purpose, experience from current operational programmes should be used.

5.2.2 Inputs to phase 0/A

The input to the phase shall be the mission requirements document (MRD) from the space system customer, which identifies the starting point for both space and ground segments.

5.2.3 Activities during phase 0/A

The following main activities shall be carried out during phase 0/A:

a. analysis of the MRD;

b. preliminary definition of requirements on the ground segment (including programmatic elements such as schedule or cost estimates);

c. preliminary mission analysis;

d. proof of operational feasibility;

e. preliminary definition of the mission operations concept;

f. preliminary definition of space-to-ground interfaces;

g. preliminary definition of the ground segment functions and architecture compatible with the mission requirements;

h. preliminary analysis of logistics support for the ground systems;

i. assessment of use or sharing of planned or existing facilities.

5.2.4 Products of phase 0/A

The products of phase 0/A shall include the following:

a. draft mission operations concept document (MOCD), see DRD ECSS-E-70 Part 2A, annex C;

b. draft customer requirements document (CRD) for the ground segment specifying the requirements of the customer onto the ground segment, see DRD ECSS-E-70 Part 2A, annex A;

c. draft space-to-ground interface control document (SGICD);

d. mission operations feasibility study reports for the various proposed solutions;

e. draft issue of mission analysis report covering the various proposed solutions;

f. draft logistics support concept.

5.2.5 Milestones and reviews of phase 0/A

a. The feasibility studies and conceptual design phase shall be concluded by the ground segment requirements review (GSRR), the main objective of which shall be to select a ground segment baseline.

b. For this review, all products of phase 0/A shall be presented to the SSC for review and agreement.

5.3 Ground segment phase B: Preliminary design

5.3.1 Purpose of phase B

a. The purpose of this phase is to achieve a precise definition of the ground segment baseline in order to confirm its feasibility, to prepare the choice of supplier(s) and support the decision to start the implementation of the ground segment.

b. During phase B the ground segment is decomposed into its main elements.

c. At the end of phase B, the SSC requirements and external constraints for the ground segment shall be frozen.

5.3.2 Inputs to phase B

The following items shall be available in order to perform phase B:

a. all output from phase 0/A updated in accordance with the recommendations of the GSRR;

b. specifications (or design) of all non-project dedicated facilities (including interfaces);

c. the user's manuals for the candidate launchers and their facilities;

d. EGSE requirements from the SSC.

5.3.3 Activities during phase B

The following main activities shall be carried out during phase B:

a. finalization of definition of customer requirements on the ground segment;

b. definition of the ground segment requirements down to facility level;

c. contribution to the ground segment configuration management plan;

d. ground segment analysis and design, including definition of ground segment logical and physical architecture with allocation of functions and requirements to facilities;

e. consolidation of the space-to-ground interfaces;

f. preliminary definitions of interfaces with external and internal entities;

g. analysis of space segment operability;

h. preliminary definition of services and support requirements from the space system customer and from third parties;

i. consolidated analysis of the logistics support;

j. consolidation of mission operations concept;

k. continuation of mission analysis;

l. analysis of commonality between EGSE and other ground segment elements (in particular MCS).

5.3.4 Products of phase B

The products of phase B shall include formal issue of the following:

a. customer requirements document (CRD) for the ground segment;

b. ground segment baseline definition (GSBD), which shall consist of the technical definition of the ground segment, including, for example, its architecture, mission analysis, mission operations, see DRD ECSS-E-70 Part 2A, annex B. It shall constitute the highest level specification of the ground segment to which all ground system specifications shall be traced. It shall in itself demonstrate traceability to the CRD;

c. ground segment requirements documents (down to facility level);

d. ground segment specifications (down to facility level);

e. ICDs for internal and external entities;

f. space-to-ground interface control document (SGICD);

g. space segment operability requirements document (SSORD);

h. services support requirement documents identifying all products and support services to be provided by the SSC and third parties in order to enable a proper implementation of the ground segment and conduct of the mission. In particular, this shall include the customer services support requirements document (CSSRD) which identifies the support services to be provided by the SSC;

i. mission operations concept document (MOCD);

j. mission analysis report;

k. logistics support concept.

5.3.5 Milestones and reviews of phase B

Phase B shall end with a ground segment preliminary design review (GSPDR). Successful GSPDR shall constitute approval of the ground segment design baseline including operations aspects.

5.4 Ground segment phase C: Design

5.4.1 Purpose of phase C

a. The purpose of the ground segment design phase is to complete the design of the ground segment to element level and to start implementation.

b. Phase C includes the definition of the operations organization and the start of production of mission operations data (operational procedures, database and detailed mission analysis).

5.4.2 Inputs to phase C

The following items shall be available in order to perform phase C:

a. all output from previous phases updated in accordance with the recommendations of the GSPDR;

b. from the SSC, preliminary versions of:

- space segment user manual (SSUM), including all information required for the design and subsequent operations of the ground segment, see DRD ECSS-E-70 Part 2A, annex D;
- mission specific ground software requirements;
- space segment database (including the telemetry and telecommand list).

c. Revised issue of mission analysis report.

5.4.3 Activities during phase C

The following main activities shall be carried out during phase C:

a. completion of ground segment design;

b. functional and operational requirements engineering of facilities and elements;

c. preparation of design specifications of facilities and elements;

d. finalization of interfaces between internal entities and with external entities;

e. preparation of ground segment integration and technical verification and validation;

f. operations validation engineering in preparation for ground segment operational validation;

g. definition and initial build-up of operations teams;

h. preparation for training of operations personnel;

i. functional and operational requirements engineering of tools for simulations, test and training;

j. preparation of design specification of tools for simulations, tests and training;

k. preliminary definition of flight control procedures;

l. logistics support planning, including identification of resources;

m. finalization of the space-to-ground interfaces;

n. finalization of the space segment operability analysis;

o. finalization of services and support requirements;

p. continuation of mission analysis.

5.4.4 Products of phase C

The products of phase C shall include the following:

a. ground segment baseline definition (GSBD) in final version;

b. ground systems requirements documents, containing functional and operational requirements documents for facilities and elements, in final versions;

c. ground systems design specifications for facilities and elements in final version;

d. simulation, test and training tools requirements documents in final versions;

e. simulations, tests and training tools specifications;

f. interface control documents for internal and external entities in final version;

g. logistics support plan (see ECSS-M-70) including identification of resources;

h. integration plan and technical verification and validation plan;

i. ground segment integration plan covering validation of ground systems and of their elements/facilities;

j. operations validation plan (OVP) for the ground segment, including definition of overall simulations and rehearsal activities leading to a fully validated ground segment, see DRD ECSS-E-70 Part 2A, annex E;

k. operations teams definition documents and preliminary teams;

l. draft issue of the operations training plan (OTP) , defining training of operation teams;

m. space-to-ground interface control document (SGICD) in final version;

n. space segment operability requirements document (SSORD) in final version;

o. services support requirement documents including the customer services support requirements document (CSSRD) in final version;

p. ground segment mission analysis document, using as input the mission analysis report from SSC and including preliminary sequence of events.

5.4.5 Milestones and reviews of phase C

Phase C shall be concluded by the ground segment critical design review (GSCDR). The GSCDR shall confirm the verification of the detailed design of the ground segment down to element level, in terms of specification, organization, planning, cost and level of quality, so that production can start.

5.5 Ground segment phase D: Production

5.5.1 Purpose of phase D

The ground segment production phase extends from the GSCDR to the launch of the spacecraft. The purpose of the phase is to procure all ground segment facilities and elements and to integrate them into an operational ground segment that shall be ready to support the in-orbit operations and exploitation of the space segment.

5.5.2 Inputs to phase D

The following items shall be available in order to perform phase D:

a. all output from previous phases updated in accordance with the recommendations of the GSCDR;

b. from the space system customer final versions of
   - space segment user manual (SSUM),
   - mission specific ground software requirements,
   - space segment database,
   - space segment software code and associated documentation,
   - mission analysis report,
   - mission specific launcher interface control document,
   - representative space segment TM data samples, and in addition
   - RF suitcase.

5.5.3 Activities during phase D

The following main activities shall be carried out during phase D:

a. production engineering or procurement of facilities and elements;

b. finalization of flight operation procedures and production of flight operation schedules;

c. definition of ground segment operations down to entity level including schedules and procedures;

d. population of operational databases of ground elements;

e. production engineering or procurement of tools for simulation, test and training;

f. preparation for, and verification and validation of tools for simulation, test and training;

g. preparation for, and validation of the mission operations data (procedures and databases);

h. preparation for, and execution of integration and technical verification and validation of the ground segment elements and facilities;

i. fully manned operations teams;

j. preparation for and training of operation teams;

k. procurement of initial logistics support (LS) resources;

l. operational validation of the ground segment;

m. Finalization of mission analysis.

5.5.4 Products of phase D

The products of phase D shall include the following:

a. fully validated ground segment, including personnel and procedures, ready for in-orbit operations and exploitation;

b. validated flight operation plan (FOP), see ECSS-E-70 Part 2A, annex F, including flight operation schedules and flight control procedures (FCP), see DRD ECSS-E-70 Part 2A, annex I, covering both nominal and contingency recovery operations in final version;

c. ground segment operation schedule in final version consisting in a high level schedule of the all ground segment entities in relation to the main mission events/activities as defined in the flight operations schedule;

d. validated ground operations plans (GOP), see DRD ECSS-E-70 Part 2A, annex G, including schedules and operation procedures for each ground segment entity;

e. validated, populated operational databases of ground segment elements;

f. mission operations data test plans and reports;

g. accepted tools for simulation, test and training and associated test reports;

h. ground segment integration reports including test results;

i. ground segment technical verification and validation reports;

j. ground segment operational validation report;

k. fully manned operations teams;

l. operations training plan (OTP) in final version;

m. training material and trained personnel;

n. initial logistics support resources;

o. mission analysis reports in final version, including final sequence of events.

5.5.5 Milestones and reviews of phase D

a. Phase D shall be subdivided into three main steps (see Figure 3) which differ in nature and perspective, as follows:

   1. Production, concentrating on the production and procurement proper of the ground facilities and elements.

   2. Integration, and technical verification and validation, the main objective shall be to confirm, through an incremental integration and testing process, the conformance of the ground systems to requirements and the compatibility of all interfaces (internal, external and the space segment).
   This shall also cover operational aspects, by involving operations staff in the validation of the facilities which shall be delivered to them, and by using a preliminary set of mission operations data, the availability of which is also required for verification of ground systems and elements. It therefore provides preliminary validation of the ground systems and their elements.

   3. Operational validation, the objective of which shall be to exercise the complete ground segment, the operations and support teams plus the full set of mission operations data, in simulations of realistic operational scenarios. It shall constitute the operational qualification of the whole ground segment.

   These three steps, as shown on Figure 3, are sequential, however, for practical reasons, they may overlap.

b. The ground segment integration and technical verification and validation shall be completed by a formal ground segment technical verification and validation review (GSTVVR), during which the results of the tests are scrutinized, and the successful completion of which shall be a pre-requisite for proceeding to the operational validation activities.

c. The operational validation shall be concluded by a formal operational readiness review (ORR), which shall complete the operational validation activities.

d. The ORR , as defined in ECSS M-30, shall be held at the end of phase D, after completion of simulations and rehearsals, to ensure full readiness of the ground segment (including personnel and procedures) for in-orbit operations. The ORR shall

- make a decision on the results of simulations and rehearsals,
- ensure that all procedures have been validated,
- ensure that teams are operational, and
- authorize use of the ground segment for space segment in-orbit operations.

e. The results of ORR shall be presented at the flight readiness review (FRR), as defined in ECSS-M-30.

f. The ground segment integration and technical verification and validation and the operational validation activities shall both be preceded, in accordance with ECSS-E-10-02, by a ground segment technical verification and validation readiness review (GSTVVRR) and a ground segment operational validation readiness review (OVRR).

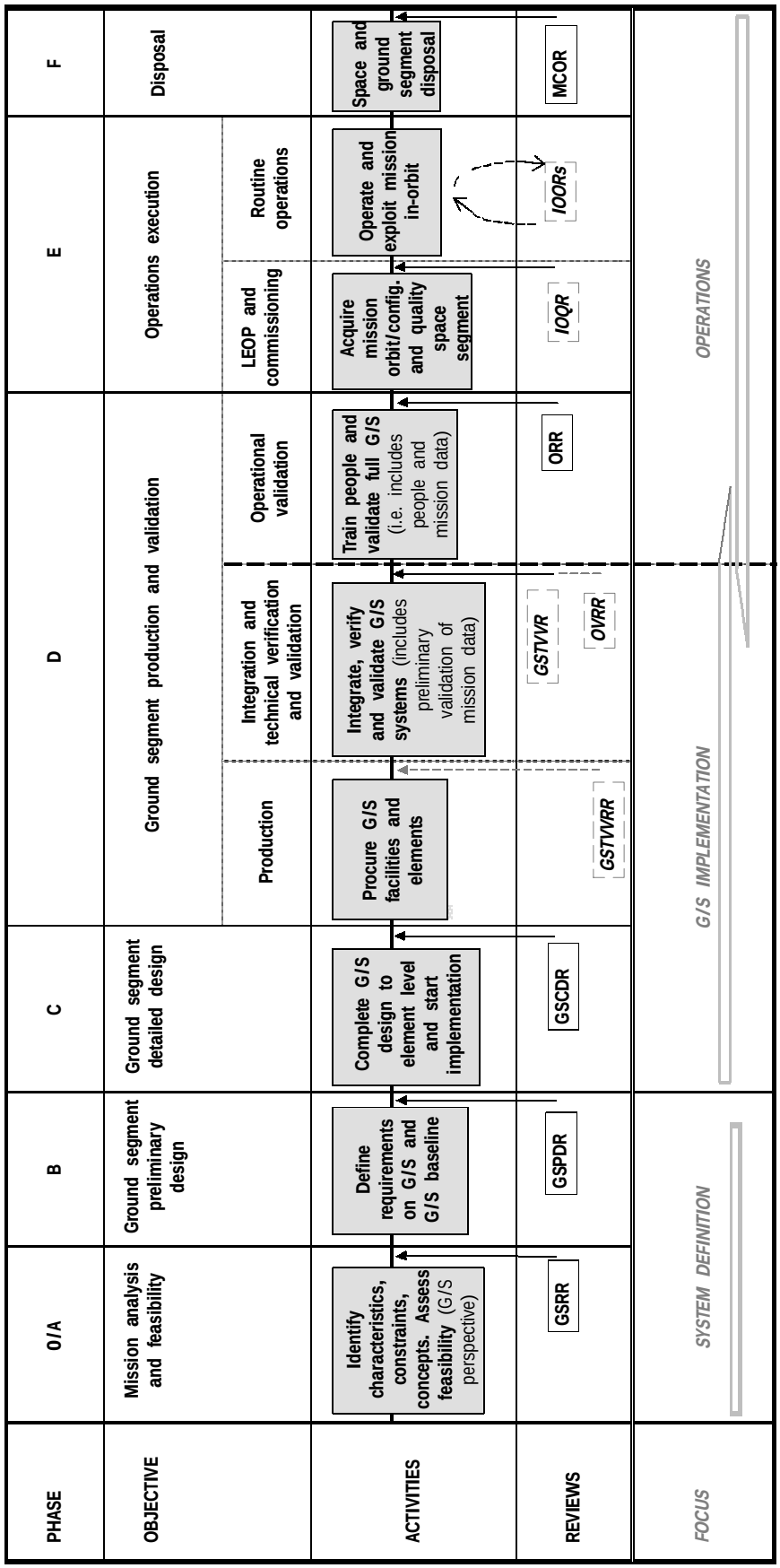


Figure 3: Ground segment phases

5.6 Ground segment phase E: In-orbit operations

5.6.1 Purpose of phase E

The purpose of the phase E is to operate the space segment in accordance with the mission plan, maintain the ground segment in accordance with the maintenance plan and to correct any spacecraft anomalies that can occur.

5.6.2 Inputs to phase E

The input to phase E shall be a fully qualified ground segment, including personnel and procedures (in accordance with the recommendations of the ORR), and a launched space segment.

5.6.3 Activities during phase E

The following main activities shall be carried out during phase E:

a. early orbit operations;

b. mission orbit acquisition;

c. in-orbit calibrations, test and commissioning;

d. space segment routine in-orbit operations;

e. planning and scheduling of space segment utilization and of supporting round segment entities;

f. space segment performance and trend analysis;

g. handling of space and ground segments anomalies;

h. payload utilization operations;

i. payload data acquisition and distribution;

j. control of orbit and attitude;

k. servicing of space segment;

l. maintenance of logistics resources;

m. landing, post-landing and recovery operations as required;

n. ground facilities operations;

o. maintenance of ground entities including facilities and operations teams;

p. ground sustaining engineering and refurbishment.

5.6.4 Products of phase E

The products of phase E shall include the following:

a. space segment elements in proper orbits and configuration for mission exploitation and associated report (e.g. LEOP report);

b. commissioned space segment and associated report (commissioning report);

c. mission products;

d. mission history data archive (e.g. telemetry, telecommand history);

e. performance and trend analysis data and associated reports;

f. mission operations reports covering routine operations (e.g. weekly reports);

g. operations anomaly report (OAR), see DRD ECSS–E–70 Part 2A, annex H;

h. fully operational ground systems including trained ground teams.

5.6.5 Milestones and reviews of phase E

a. Phase E shall include the in-orbit qualification review (IOQR). This review shall be held after completion of the space segment in-orbit commissioning, in order to assess performance and declare readiness for in-orbit exploitation.

b. The IOQR shall be followed by regular in-orbit operations reviews (IOORs) to be held on a periodical basis (e.g. yearly).

5.7 Ground segment phase F: Mission termination

5.7.1 Purpose of phase F

During phase F the space segment is withdrawn from service, after preparation and planning in liaison with the space segment customer. This may include transferring the spacecraft to another orbit, with eventual landing or destructive re-entry.

5.7.2 Inputs to phase F

The inputs to phase F shall be the mission termination decision.

5.7.3 Activities during phase F

The following main activities shall be carried out during phase F:

a. preparation and execution of mission termination and space segment disposal operations;

b. preparation and execution of ground segment disposal;

c. documentation of mission experience.

5.7.4 Products of phase F

The products of phase F shall include the following:

a. disposed space and ground segments;

b. mission reports including mission operations experience and lessons learned, summary of spacecraft in-orbit performance, results of end-of-life tests, cost aspects;

c. data archives including post flight consolidated data and relevant access tools.

5.7.5 Milestones and reviews of phase F

Phase F shall be concluded by a mission close-out review (MCOR). Its purpose shall be to assess the performance of the services provided and to confirm proper disposal of space and ground segments.

5.8 Ground engineering processes summary

The ground segment engineering processes described in the above subclauses are summarized in Figure 3 and Tables 1 to 7. An activity in the table does not always lead to an immediate release of the product, as the product may be released in a subsequent phase. For clarity, the maintenance of documents in subsequent phases is also omitted.

- Figure 3 provides an overview of the phases together with their objectives, main activities and milestones.
- Tables 1 to 6 provide for each phase a list of the corresponding activities and key products.
- Table 7 provides a list of the key ground segment documents.

Table 1: Activities and products of phase 0/A

Responsible	Activities	Products
SSC	Analysis of the mission requirements document (MRD)	
SSC	Preliminary definition of SSC requirements on the ground segment	Customer requirement document (CRD) (draft) DRD ECSS–E–70 Part 2A, annex A
SSC/GSS	Preliminary definition of space-to-ground interfaces	Space-to-ground interface control document (SGICD) (draft)
SSC/GSS	Preliminary mission analysis	Draft issue of mission analysis report covering the various proposed solutions
GSS	Proof of operational feasibility	Mission operations feasibility study reports for the various proposed solutions
GSS	Preliminary definition of the mission operations concept	Mission operations concept document (MOCD) (draft) DRD ECSS–E–70 Part 2A, annex C
GSS	Preliminary definition of the ground systems compatible with the mission requirements	
GSS	Assessment of use or sharing of planned or existing facilities	
GSS	Preliminary analysis of logistics support for the ground systems	Logistics support concept (draft)

Table 2: Activities and products of phase B

Responsible	Activities	Products
SSC	Finalization of definition of customer requirements on the ground segment	Customer requirements document (CRD) in final version
SSC/GSS	Consolidation of the space-to-ground interfaces	Space-to-ground interface control document (SGICD)
SSC/GSS	Analysis of space segment operability	Space segment operability requirements document (SSORD)
SSC/GSS	Preliminary definition of services and support requirements from the space system customer and from third parties	Services support requirements documents including the customer services support requirements document (CSSRD)
SSC/GSS	Analysis of commonality between EGSE and MCS	
SSC/GSS	Continuation of mission analysis	Mission analysis report
GSS	Ground segment design	D Ground segment baseline definition (GSBD) DRD ECSS–E–70 Part 2A, annex B D Contribution to ground segment configuration management plan D Ground segment design definition file D Ground segment design justification file
GSS	Definition of ground segment requirements down to facility level	D Ground segment requirements documents D Ground segment specifications
GSS	Preliminary definition of interfaces with external and internal entities	ICDs for internal and external entities
GSS	Consolidation of mission operations concept	Mission operations concept document (MOCD)
GSS	Consolidated analysis of the logistics support	logistics support concept

Table 3: Activities and products of phase C

Responsible	Activities	Products
SSC/GSS	Finalization of the space-to-ground interfaces	Space-to-ground interface control document (SGICD) in final version
SSC/GSS	Finalization of the space segment operability analysis	Space segment operability requirements document (SSORD) in final version
SSC/GSS	Finalization of services and support requirements	Services support requirements documents including the customer services support requirements documents (CSSRD) in final version
GSS	Completion of ground segment design	D Ground segment baseline definition (GSBD) in final version D Ground segment configuration status report
GSS	Functional and operational requirements engineering of facilities and elements	Ground systems requirements documents (for facilities and elements) in final version
GSS	Preparation of design specifications of facilities and elements	Ground systems specifications (for facilities and elements) in final version
GSS	Definition of interfaces between internal entities and with external entities	ICDs for internal and external entities in final version
GSS	Continuation of mission analysis	Ground segment mission analysis document, including preliminary sequence of events
GSS	D Preparation of ground segment integration D Preparation for ground segment technical verification and validation	D Ground segment integration plan covering verification and validation of ground systems elements and facilities D Technical verification and validation plan
GSS	Functional and operational requirements engineering of tools for simulations, test and training	Test and training tools requirements documents in final version
GSS	Preparation of design specification of tools for simulations, tests and training	Test and training tools specifications
GSS	Preliminary definition of flight control procedures	Draft of flight operations plan
GSS	Definition and initial build-up of operations teams	Defined operations teams, and preliminary teams
GSS	Preparation for training of operations personnel	Draft operations training plan (OTP)
GSS	Operations validation engineering in preparation for ground segment operational validation	Operational validation plan (OVP) for the ground segment DRD ECSS–E–70 Part 2A, annex E
GSS	Logistics support planning, including identification of resources	Logistics support plan including identification of resources (see ECSS–M–70)

Table 4: Activities and products of phase D

Responsible	Activities	Products
GSS	Production engineering or procurement of facilities and elements	Ground segment facilities and elements
GSS	Finalization of mission analysis	Mission analysis reports in final version
GSS	Procurement of initial LS resources	Initial LS resources
GSS	Production engineering or procurement of tools for simulation, test and training	Test and training tools
GSS	Verification and validation of tools for simulation, test and training	D Verification and validation reports for simulation, test and training tools D Validated for simulation, test and training
GSS	Ground segment integration and technical verification and validation	D Ground segment integration and test reports D Technical validation reports
GSS	D Finalization of operations teams D Preparation for training of operations teams D Training of operations teams	D Final operations teams D Operations training plan (OTP) in final version D Training material D Trained operations teams
GSS	D Finalization of the flight operations plan (FOP) D Definition of ground segment operations down to entity level including schedules and procedures D Population of operational databases of ground elements D Validation of mission operations data (procedures and databases)	D Validated flight operation plan (FOP) in final version DRD ECSS–E–70 Part 2A, annex F D Ground segment operation schedule in final version D Validated ground operation plans (GOPs) in final version DRD ECSS–E–70 Part 2A, annex G D Populated and fully validated operational database D Mission operations data validation test plans and reports
GSS	D Operational validation of the ground segment	D Operational validation report D Fully validated ground segment, including personnel and procedures, ready for in-orbit operations and exploitation

Table 5: Activities and products of phase E

Responsible	Activities	Products
GSS	D Early orbit operations D Mission orbit acquisition	D Space segment elements in their final orbits and configured for mission exploitation D LEOP report
GSS	In-orbit calibrations, test and commissioning	D Commissioned space segment D Commissioning report
GSS	D Space segment routine in-orbit operations D Planning and scheduling of space segment utilization and of supporting ground segment entities D Space segment performance and trend analysis D Payload utilization operations D Payload data acquisition and distribution D Control of orbit and attitude D Servicing of space segment D Maintenance of logistics resources D Landing, post-landing and recovery operations as required D Ground facilities operations D Ground facilities maintenance D Ground sustaining engineering and refurbishment	D Mission products D Mission history data archive (e.g. telemetry, telecommand history) D Performance and trend analysis data and associated reports D Mission operations reports covering routine operations (e.g. weekly reports) D Fully operational ground systems including trained ground teams
GSS	Handling of space and ground segments anomalies	Operations anomaly reports (OARs) DRD ECSS–E–70 Part 2A, annex I

Table 6: Activities and products of phase F

Responsible	Activities	Products
GSS	Preparation and execution of mission termination and space segment disposal operations	D Disposed space segment D Space segment disposal report
GSS	Preparation and execution of ground segment disposal	D Disposed ground segment D Ground segment disposal report
GSS	Documentation of mission operations experience	Mission reports including, for example, mission operations experience, summary of spacecraft in-orbit performance, results of end of life tests

Table 7: List of key ground segment documents

Domain	Type	Title	Doc. Id	Life history					
				0/A	B	C	D	E	F
SSYS	REQ	Mission requirements document	MRD	issue					
SSYS	REQ	Customer requirements document	CRD	draft	issue				
SSYS	REQ	EGSE requirements			issue				
SSYS	I/F	Space segment user manual	SUM		draft	issue	maint.		
SSYS	REP	Mission analysis report		draft	issue	maint.	maint.		
SSYS	I/F	Launcher interface control document		draft		issue	maint.		
SSYS	I/F	Space-to-ground interface control document	SGICD	draft	issue	final			
SSYS	REQ	Space segment operability requirements document	SSORD		issue	final			
SSYS	REQ	Customer services support requirements document	CSSRD		issue	maint.	final		
GSEG	SPEC	Ground segment baseline definition	GSBD		issue	maint.	maint.		
GSEG	I/F	ICDs for internal and external entities			draft	issue	maint.		
GSEG	SPEC	Ground segment design definition file	DDF		issue	maint.	maint.		
GSEG	SPEC	Ground segment design justification file	DJF		issue	maint.	maint.		
GSEG	PLAN	Ground segment configuration management plan			draft	issue	maint.		
GSEG	PLAN	Ground segment integration plan				issue	final		
GSEG	PLAN	Technical verification and validation plan				issue	final		
GSEG	REP	Ground segment configuration status report				issue	maint.	maint.	maint.
GSEG	REP	Ground segment integration and test reports					issue		
GSEG	REP	Technical validation reports					issue		
GSEG	REP	Mission operations feasibility study reports		issue					
GSEG	MISC	Ground segment mission analysis document				issue	final		
GSYS	REQ	Ground systems requirements documents				issue	maint.		
GSYS	REQ	Test and training tools requirements documents				issue	maint.		
GSYS	SPEC	Ground systems specifications				issue	maint.		
GSYS	SPEC	Test and training tools specifications				issue	maint.		
LS	MISC	Logistic support concept		draft	issue	maint.	maint.		
LS	PLAN	Logistic support plan	LSP			issue	maint.		
OPS	MISC	Mission operations concept document	MOCD	draft	issue	maint.	maint.		
OPS	PLAN	Operational validation plan	OVP			issue	final		
OPS	PLAN	Operations training plan	OTP			issue	final		
OPS	PLAN	Flight operation plan	FOP			draft	final	maint.	maint.
OPS	PLAN	Ground operations plans	GOP				issue	maint.	maint.
OPS	SCHE	Ground segment operation schedule					issue		
OPS	REP	Operational validation reports					issue		
OPS	REP	LEOP report						issue	
OPS	REP	Commissioning report						issue	
OPS	REP	Performance reports						regular	
OPS	REP	Mission operations reports						regular	
OPS	REP	Operations anomaly report	OARs					occur.	
OPS	REP	Mission report							issue
OPS	REP	Disposal reports							issue

Domain

SSYS: Space system level document
GSEG: Ground segment level document
GSYS: Ground systems level document
LS: Logistics support document
OPS: Operations document

Type

I/F: Interfaces level documents (internal or external)
MISC: Miscellaneous
PLAN: Plan
REP: Report
REQ: Requirements document
SPEC: Design specification
SCHE: Schedule

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6

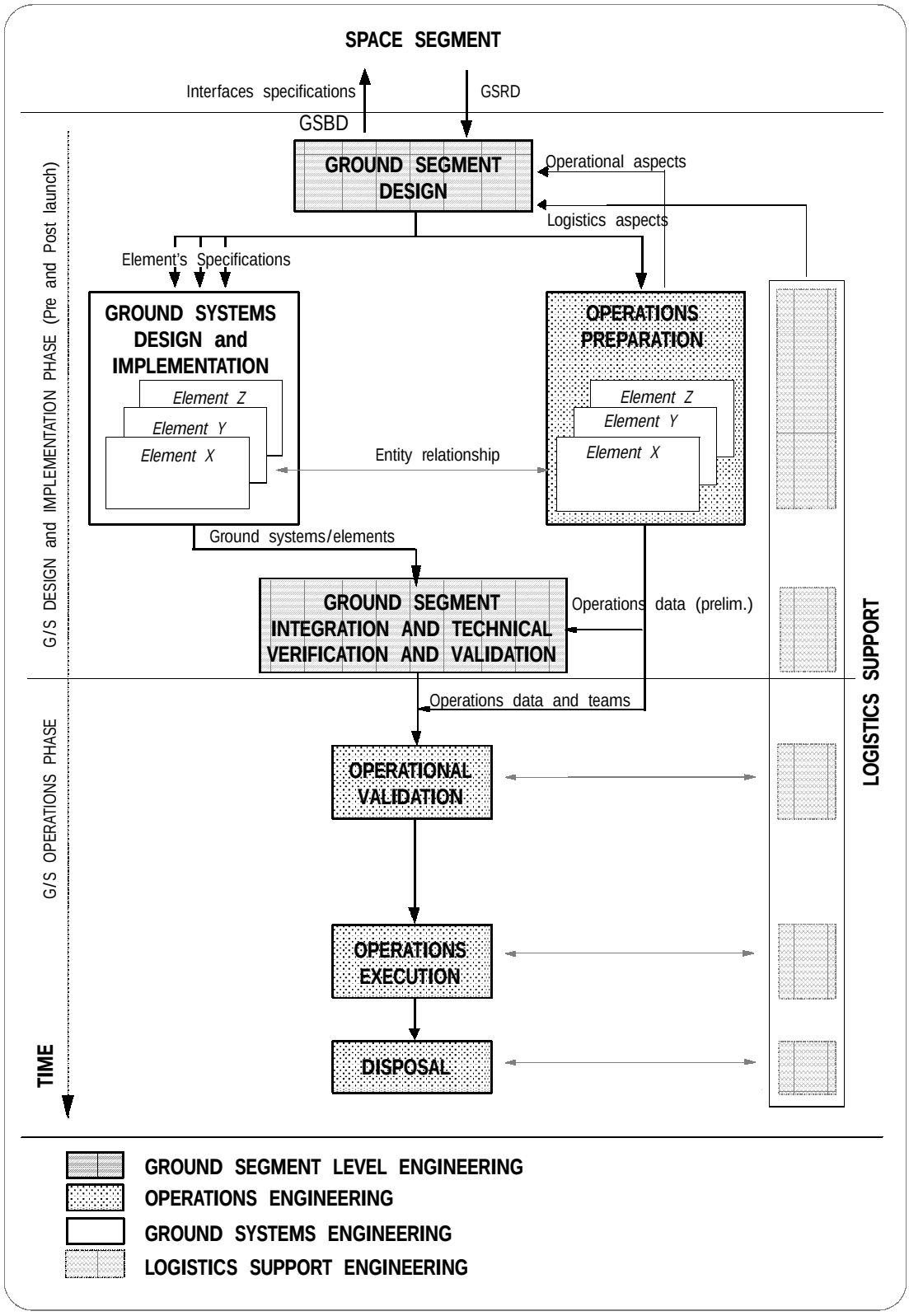
Ground segment engineering

6.1 General

Ground segment engineering encompasses all engineering disciplines and processes required for a space system project as specified in ECSS–E–00 and ECSS–E–10, which shall be applicable to the ground segment domain.

Ground segment engineering may be subdivided into eight main tasks covering the complete life cycle as depicted on Figure 4 and listed below:

- Ground segment design,
- Ground systems design and implementation,
- Operations preparation,
- Ground segment integration and technical verification and validation,
- Operational validation,
- Operations execution,
- Disposal, and
- Logistics support.



NOTE A more detailed timeline of the above tasks with their dependencies during phases 0/A–D of the ground segment project is provided in Figure 5.

Figure 4: Ground segment preparation logic

6.1.1 Ground segment design

This shall cover the design, analysis of the ground segment and specification of its internal and external interfaces including space segment related aspects.

6.1.2 Ground systems design and implementation

This shall cover the design, production and verification of the individual ground systems elements.

6.1.3 Operations preparation

This shall cover the contribution of operations engineering to the space system and ground segment design, production and validation of mission operations data (procedures and databases), and build-up and training of operations teams.

6.1.4 Ground segment integration and technical verification and validation

This shall cover the covering integration and testing of the ground system elements up to the level of the individual ground systems, and the technical verification and validation of the ground systems as a whole.

6.1.5 Operational validation

This shall constitute the ultimate stage of the ground segment validation process where all its elements including operations teams are being exercised to demonstrate readiness for in-orbit operations.

6.1.6 Operations execution

This shall cover all ground segment activities during the period when the space segment is in-orbit.

6.1.7 Disposal

This shall cover all activities to be performed to ensure orderly termination of the mission.

6.1.8 Logistics support

This shall cover all logistics engineering support activities during the complete mission life cycle.

6.1.9 Ground segment engineering - Categories of activities

These tasks listed in 6.1.1 to 6.1.8 may be grouped into four categories of activities according to the type of engineering skills they require and to the logical model of the ground segment domain as shown in Figure 1.

- Ground segment level engineering, ensuring the definition, implementation and verification of a coherent and operational ground segment, and covering design, integration and technical verification and validation of the ground systems into a fully functional ground segment interacting as required with all external elements.
- Ground systems engineering, covering design and implementation of the individual ground systems and of their elements, and their verification.
- Operations engineering, covering all operational activities through all phases of the ground segment life cycle; i.e. operations preparation, operations validation, operation execution and disposal.
- Logistics support, covering all activities aiming at ensuring the maintainability of the ground segment during the whole mission.

For this purpose logistics support aspects shall be taken into account from the start of the ground segment project, and be fully integrated in the design, implementation and operations activities.

6.1.10 Critical areas

In order to ensure mission success in a cost-effective manner, coordination shall be established during all phases of the space system project, between space and ground segment, and between ground segment entities, as these are often under different responsibilities. Critical areas that shall be addressed are:

a. definition of overall mission concepts at space system level with due consideration being given to ground segment and operations aspects;

b. spacecraft teachability, operability and maintainability;

c. adequacy of products delivered by the SSC to the AIT team and to the mission operations teams;

d. end-to-end validation of the complete ground segment and space system;

e. re-use, to the maximum possible extent, of space segment operations data (e.g. telemetry and telecommand list, procedures) between space segment design, AIT and mission operations;

f. commonality between processes and elements of the ground segment such as AIT and mission operations (e.g. commonality between EGSE and MCS).

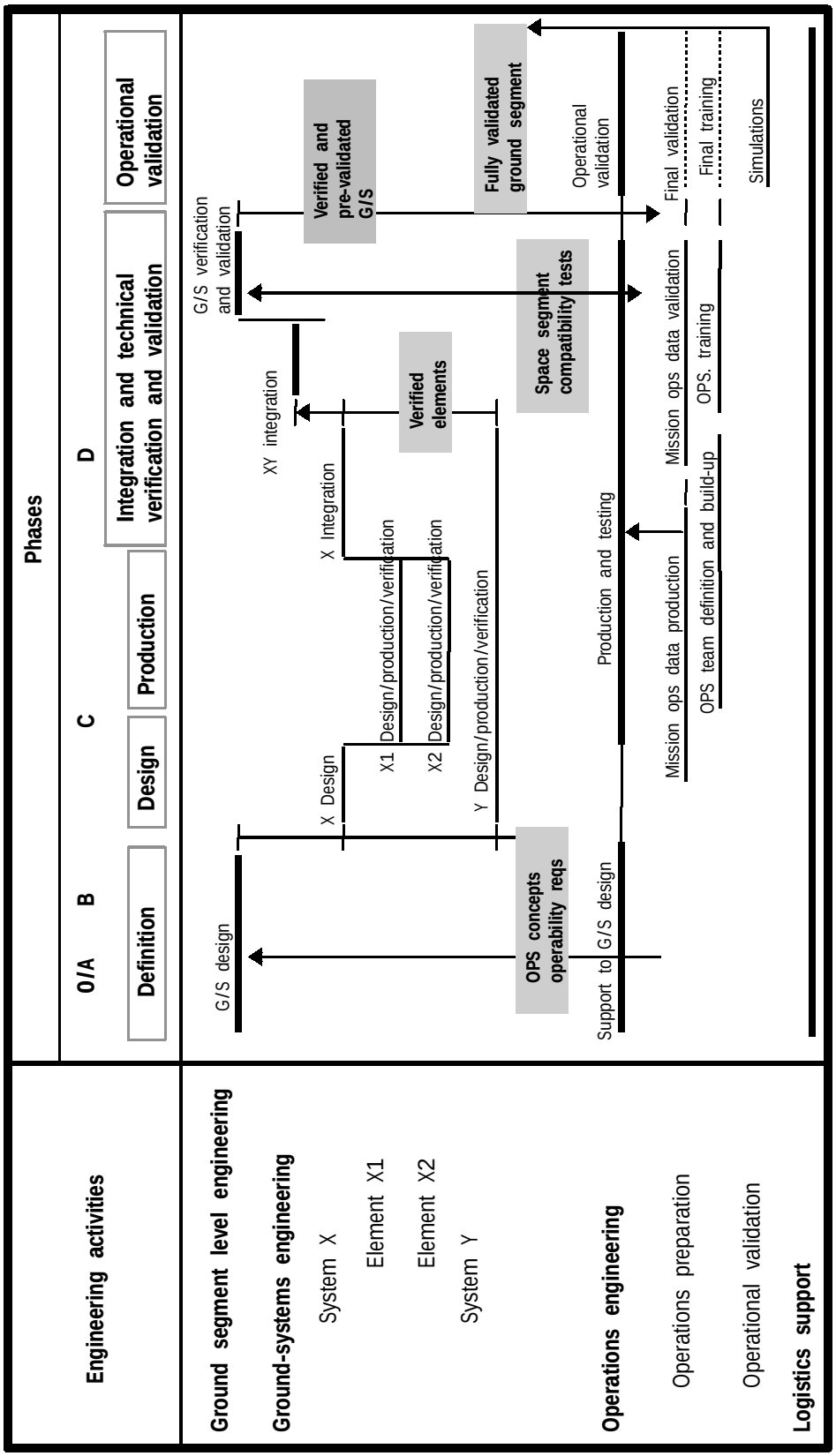


Figure 5: Ground segment preparation process

6.2 Ground segment design

6.2.1 Design general

a. Ground segment design shall be a system level engineering activity and therefore ECSS–E–10 is applicable. It shall be of an iterative nature and comprise the following tasks:

- coordination and management including organization and validation of each iteration;
- requirements engineering (e.g. identification of customer's needs, requirements recording and structuring, requirements database update);
- design engineering (e.g. system entities identification, requirements allocation onto the architecture, design definition file (DDF) production and maintenance);
- verification engineering (e.g. verification strategy definition, requirements, design and analysis traceability and coherence verification, design justification file (DJF) production and maintenance);
- analysis engineering (e.g. functional and data flow analysis, dynamic behaviour and man or system interaction modelling, simulation and analysis, models updates).

b. The main objective of ground segment design shall be to ensure the overall success of the mission by establishing compatibility between the space segment and ground segment design, and within the ground segment, by establishing a coherent and cost effective design of its elements and entities. For this, particular emphasis shall be placed on ensuring that operational and logistics aspects are properly considered at all stages of the design process.

c. The main outputs of the ground segment design shall be:

- An overall ground segment baseline covering both technical aspects in the form of the GSBD and managerial aspects, which together constitute the agreed reference between the SSC and GSS; this baseline also supports the subsequent design and implementation of the ground systems and execution of the operations preparation tasks.
- Definition of interfaces between ground and space segment and with external entities.

d. Operations staff shall be involved in the ground segment design activities from phase 0/A onwards. This shall cover space system and segment level issues, and in particular the definition of the space-to-ground interfaces including:

- the TT&C application level interfaces, the objective of which shall be to define the related application level services and their formats;
- the space segment operability requirements;
- the services and support requirements from the space system customer.

e. Logistics support aspects shall be taken into account in the design of the ground segment from phase 0/A onwards.

6.2.2 Ground segment requirements

6.2.2.1 General ground segment requirements

a. The CRD shall be the initial input of this activity. It shall includes all high level requirements on the ground segment as well as any programmatic and budgetary constraints.

b. The ground segment requirements should cover three types of information (ECSS–E–10):
   - functional requirements;
   - non-functional requirements (e.g. performance and operational requirements) which qualify the functional requirements;
   - additional information necessary to understand these requirements.

6.2.2.2 Requirements engineering

a. The following topics shall be addressed when defining requirements:
   - space segment related functionality, observability and commandability;
   - ground segment related functionality;
   - performance and dependability;
   - operations and logistics support;
   - system interfaces.

b. Requirements addressing the following topics should be included and specified:
   - re-use of generic infrastructure elements (e.g. software systems, ground station equipment);
   - location of main facilities and site diversity aspects;
   - operations autonomy and automation and its apportionment between space and ground segment;
   - failure case operations and recovery and fall back (equipment and communication fault tolerance, automatic or manual recovery);
   - operations centralization and decentralization aspects such as remote monitoring and control;
   - system management (user administration, access authorization, equipment configuration, performance monitoring);
   - network management (stations and communications);
   - commonality between ground facilities, elements and tools.

c. In order to provide a coherent framework, the requirements should identify a data model for the ground segment (data entities or objects and their key attributes, e.g. spacecraft, data sets, products, messages, orders). The data model should identify the key relationships between these entities and should be documented using a standard data modelling method.

6.2.2.3 Definition of space-to-ground segment interfaces

6.2.2.3.1 General

The specification of the interfaces with the space segment are of particular relevance to the ground segment requirements engineering process.

The following subclauses address major aspects.

6.2.2.3.2 RF and TT&C level interfaces

RF and TT&C level interfaces shall be specified in the space-to-ground Interface Control Document (SGICD). This shall cover:

a. RF level interfaces;

b. TT&C transmission level protocols as specified in ECSS–E–50, and its mission specific implementation;

c. TT&C application level interfaces, the objective of which shall be to define the operational services between on-board and associated ground data handling applications and their formats.

d. For a space segment that conforms to the ECSS–E–50 recommendations for packet telemetry and telecommand, the application level telemetry and telecommand interfaces should be specified in accordance with ECSS–E–70–41. From this Standard the requirements applicable to the mission shall be selected and adapted and enhanced with mission specific requirements.

6.2.2.3.3 Operational interfaces

a. Space segment operability requirements shall be established in order to ensure adequate space segment operability, maintainability and testability. They shall include requirements on the space segment functionality being defined taking into account the operations analysis of the main characteristics of the mission as identified in the CRD, and the existing constraints on both the space and ground segments.

b. Space segment operability requirements shall be identified for each mission in order to ensure that the space segment can be operated during all nominal and foreseeable contingency situations, in accordance with the mission requirements and objectives in terms of the quantity, quality and availability of mission products and services.

The resulting requirements shall be compiled in the space segment user manual (SSUM).

NOTE ECSS–E–70–11 defines space segment operability requirements for various classes of space missions. It is used to define operability requirements after being tailored to the needs of the target mission.

6.2.2.3.4 Products from the Space System Customer (SSC)

a. Definition of products (i.e. deliverable items and support services) to be provided by the SSC throughout the ground segment life cycle shall be established for a given space project and documented in the space customer service support requirements document (CSSRD).

b. The products to be delivered by the SSC shall enable a design and configuration of the ground segment that conforms to the mission requirements and thus ensure a successful execution of the mission. These products cover ground segment design and implementation, space segment AIT, and operations preparation and in-orbit execution, and may include:

- space segment documents and information required for the implementation of the ground segment and subsequent mission operations (e.g. SSUM, space segment operations database);
- support to, or supply of, the space segment simulator (real-time behavioural model of the space segment, implemented in software or as a combination of software and hardware) and other test and training tools required for the validation of the ground segment;
- provision of representative space segment TM data samples;
- provision of RF suitcase for testing compatibility between space segment TT&C and ground stations;
- access to the space segment when on ground, for the validation of the compatibility between the ground and space segments;
- provision of space segment engineering support for the ground segment design phases (in particular testing) and during phases E and F;

- provision of tools, document and engineering support required for the maintenance of the space segment software during operations execution; this involves code in source and object form, software engineering tools and software validation tools;
- provision of space segment engineering support for the in-orbit control of the mission during critical phases, and for in-orbit commissioning.

c. The database to be provided by the SSC shall include all space segment characteristics data required for space segment data processing. It shall be delivered in accordance with an agreed interface control document.

6.2.2.4 Definition of interfaces between ground entities

Ground segment design shall include specification of the interfaces with external entities and between the ground segment entities. This typically comprises: the launcher segment, space segment AIT site, ground stations, mission control centre.

6.2.3 Analysis

6.2.3.1 System analysis

a. System analysis shall be performed during all phases of the ground segment project life cycle and shall include mission analysis, requirements analysis, functional analysis, operational analysis and performance analysis. ECSS–E–10 fully addresses requirements, functional and performance analyses.

b. For the ground segment this analysis shall also include the identification of the critical elements of the ground segment in terms of mission success and of the associated RAMS requirements. This task shall be performed in accordance with ECSS–Q–30 and ECSS–Q–40.

6.2.3.2 Mission analysis

a. At the beginning of Phase 0/A, the space system customer shall provide the current version of the mission analysis for in-orbit operations. This version shall take into account the assumptions made for the ground segment together with launch vehicle and spacecraft constraints, so as to establish the feasibility of the proposed operational sequences.

b. The mission analysis shall be further refined by the ground segment team prior to the operational validation down to the level required to produce detailed operations schedules for individual ground segment entities. This team shall be responsible for the delivery of the final mission analysis to be accepted by the customer after the operational validation (at ORR).

c. The mission analysis shall be based on the following typical input:
- launcher related constraints;
- LEOP ground stations characteristics;
- station keeping ground stations specifications;
- spacecraft related constraints;
- specific mission-related constraints (station keeping window for geostationary spacecraft, orbit phasing for LEO spacecraft);
- payload-related constraints.

d. The mission analysis shall supply the following information:
- launch window prediction;
- spacecraft and launch vehicle separation sequence;
- positioning strategy;

- required accuracy for attitude and orbit determination;
- schedule of operational events (covering both nominal scenarios and planned contingencies), from which the detailed operations schedules used to execute the mission (e.g. flight operations schedule) are derived;
- ground stations visibility;
- detailed analysis of high risk sequences;
- risk of interference with spacecraft already in operation;
- fuel budget;
- impact of space environment on operational sequences (e.g. sensor blinding, eclipses);
- payload operations strategy.

6.2.3.3 Operational analysis

a. Although this activity can be seen, due to the specific expertise it requires, as belonging to operations engineering, it shall be carried out as part of the ground segment design tasks.

b. Operational analysis shall consist of the analysis of the main characteristics of the mission from an operational point of view with the following tasks:

- assess the operational feasibility of the mission;
- identify the main drivers for the ground segment;
- define the overall operations concept and requirements for the mission and its supporting ground segment;
- contribute to the definition of the ground segment internal and external interfaces.

c. The main output of these tasks shall consist of an input to the GSBD and to the mission operations concept document (MOCD).

d. The contents of the mission operations concept shall conform to DRD ECSS–E–70 Part 2A, annex C.

6.2.4 Ground segment system design

a. According to ECSS–E–10, the purpose of the ground segment system design shall be to derive a physical architecture and design from the ground segment requirements definition and analysis. This derivation shall be conducted interactively with system analysis and verification in order to check which design conforms closest to the requirements.

b. One essential output of this activity shall be the GSBD.

In addition the following requirements shall apply.

c. The ground segment design team shall define:

- the ground segment system architecture (down to entity level, including reuse of existing components);
- the requirements specification of each entity identified in the design process (starting with the mapping of the ground segment requirements base onto the various entities);
- the internal interfaces (between the various entities).

d. The design team shall maintain the ground segment design definition and design justification files.

e. The contents of the GSBD shall conform to DRD ECSS–E–70 Part 2A, annex B.

6.3 Ground systems design and implementation

6.3.1 General

a. The ground segment baseline definition (GSBD) and related documents produced by the ground segment design task are the input to this activity, which covers design, implementation and verification of ground segment elements and systems. The following ECSS Standards shall be applicable:

NOTE The GSBD covers design, production and procurement of hardware, software and also basic infrastructure elements such as rooms, furniture and consumables.

- ECSS–E–10 and level 3 standards;
- ECSS–E–40;
- ECSS–E–50 and level 3 standards.

b. The related activities are at the level of each ground system and element covering all steps of the system engineering discipline as defined in ECSS–E–10. The requirements are first established based on the inputs from the higher level including contributions from the operations engineering teams. As for ground systems design, it is essential that the unit responsible for the design and production, verification of a system and element works in close relationship with the corresponding operational organization.

c. The ground systems shall not only cover the elements directly involved in controlling the mission, but also support tools for testing and maintenance of elements, and training of personnel.

d. Representatives of the operations organization shall be involved in the following aspects of the design, production and validation of the ground systems and elements:

- definition of the requirements;
- design and implementation process;
- verification and validation of the systems and elements.

e. Representatives of the operations and logistics organizations shall be involved in the following aspects of the design, production and validation of ground segment test and training tools:

- definition of the requirements;
- design and implementation process;
- verification and validation of the tools.

6.3.2 Common aspects

6.3.2.1 General

In order to achieve a cost-effective design and implementation of the ground segment commonality aspects between ground segment elements shall be taken into account.

The following aspects should be considered:

- software elements in terms of design and implementation and functionality;
- space link interface elements;
- mission operations data.

6.3.2.2 Software

a. Software products are essential elements of the ground facilities. They often constitute critical elements of the ground segment in terms of cost, schedule and technical risk. Therefore special attention shall be paid to their design,

implementation, and maintenance. A particular aspect for consideration shall be to maximize the re-use of functionality across missions, since in most of the cases only a small part (typically 30 %) of the total system is modified to accommodate the mission specific characteristics.

b. The main software elements to be considered shall be:
   - the mission control system (MCS) including its logical components that are the OCS, PCS and MES;
   - the EGSE system;
   - the GSTS monitoring and control (GSTS-M&C), and data storage and distribution functions;
   - simulation, test and training tools which include real-time behavioural software models of the space segment or some of its elements.

c. The design, implementation, testing, maintenance and documentation of ground software shall follow ECSS–E–40 tailored for ground software development.

d. The following aspects should be considered to ensure a cost-effective design, implementation and maintenance of ground software systems:
   - Configurability: in terms of functionality (e.g. to be modular and parameter driven) to accommodate evolution and to enable re-use across missions.
   - Vendor independence: with respect to computer platform and vendor.
   - Scalability: to facilitate expansion of the hardware or software configuration of the system without major redesign; e.g. in the case of the MCS, it should be possible to add workstations that perform MCS functionality without degradation of performance.
   - Portability: to reduce the cost of migrating the system to a new computer platform or operating system in order to cope with the obsolescence of hardware or software (e.g. in case of long duration missions).
   - Openness: to facilitate both the integration of new functionality or interfacing with other systems without major redesigns.
   - Re-usability: to permit re-usability across missions, i.e. mission customisation should not involve massive modifications.
   - Standards: i.e. wherever possible, widely used (including de-facto) standards should be utilized.
   - COTS products: i.e. wherever effective, commercial-off- the-shelf products (COTS) should be used.

e. Re-usability aspect shall be considered for the MCS, EGSE and GSTS-M&C software systems. Maximizing re-use of core functions in this area can provide an additional cost benefit and can further reduce the criticality for a given mission of the development of these software systems.

   The main functional elements subjected to commonality and thus re-usability shall include
   - monitoring,
   - commanding,
   - generation and execution of control procedures,
   - operational database management,
   - data archiving and distribution,
   - performance evaluation,
   - on-board software management and maintenance (both software and hardware), and

- Human-computer interactions (HCI).

f. These issues are detailed in subclauses 6.3.3, 6.3.4 and 6.3.5, where the functionality of these systems is described in more details.

6.3.2.3 Spacelink interfaces

The EGSE used during ground tests and the GSTS both have interfaces to the space segment via the space link. Even though these interfaces usually differ at physical interface layer, a significant part of the interface functions are common.

Commonality between EGSE and GSTS for the following space link interface functions shall be considered:

a. downlink signal reception;

b. uplink signal radiation;

c. downlink data processing;

d. uplink data processing.

6.3.2.4 Mission operations data

a. The EGSE and MCS share a significant subset of the mission operations data (e.g. telemetry, telecommand data, control procedures, displays) which originate from the space segment domain. For both technical and economic reasons data re-usability shall be taken into account.

b. The MCS and the EGSE shall be compatible in terms of operational database, so that the space segment related data can be fully re-used across domains.

6.3.3 Mission control system

6.3.3.1 MCS logical model

The high level logical model of the mission control system (MCS) is presented in Figure 2 where three main elements are identified: the operations control system (OCS), the payload control system (PCS) and the mission exploitation system (MES). The definition of these elements is provided below, by specifying the relevant functionality. Depending upon the mission complexity and its operational concept, some of these MCS elements can have reduced functionality or not exist at all. Similarly, two or more MCS elements may be physically merged. A typical split of functionality is presented in Table 8.

Table 8: High level logical model of the mission control system (MCS)

Functionality	OCS	PCS	MES
Monitoring	n	n	
Commanding	n	n	
Control procedure execution	n	n	
Performance evaluation	n	n	
Mission planning and scheduling	n	n	n
On-board software management	n	n	
On-board software maintenance	n	n	
Flight dynamics	n		
Products generation			n
Data distribution	n	n	n
Data archive	n	n	n
Operational database management	n	n	
Control procedure generation	n	n	
Human-computer interaction (HCI)	n	n	n

The OCS and PCS functions are very similar, the difference being that the OCS acts on the platform data while PCS acts on the payload data. Both OCS and PCS can also act on ground segment data (e.g. monitoring and controlling of ground station equipment or network links). On the other hand, the MES mainly provides functionality that is related to the end users of the space mission (e.g. scientific community).

a. Monitoring (platform, payload and ground segment):
Covering all monitoring functions in which all data, regardless of source, can be extracted, calibrated, subjected to a range of monitoring checks, and displayed. Monitoring also provides the functionality associated with data or telemetry processing required by other control system elements (e.g. commanding and on-board software management).

b. Commanding (platform, payload and ground segment):
Covers all functions in which control messages (commands) are prepared, validated, sent for transmission, verified and logged. As for monitoring, this applies to any commandable entity (e.g. spacecraft element, ground station element) for which command messages can be defined.

c. Control procedure execution (platform, payload and ground segment):
Includes the functionality required to automate the execution of flight control procedures, thereby enabling the control of the space segment in-orbit and of the supporting ground segment elements.

d. Performance evaluation:
Provides the functionality required to evaluate spacecraft performance, including trend analysis, during operations and to prepare test or operations reports. It can be performed on platform (OCS) or on payload (PCS) data.

e. Mission planning and scheduling:
Provides the functionality required to prepare operations schedules derived from end user requests whilst accounting for spacecraft and ground system constraints (including resources), scheduling rules and optimization goals. The output should be defined in two stages: the first stage should provide a constraint-free schedule of activities annotated with all necessary control information whilst the second stage should convert the schedule into actual executable items (e.g. commands, procedures) that are submitted to the commanding functionality for execution.

f. On-board software management:
Provides the functionality required to manage the products generated by external (e.g. prime contractor or experimenter provided) on-board software maintenance and validation systems, to prepare command to load and to process on-board memory dump data. On-board software management is performed on the platform software in the OCS and on the payload software in PCS.

g. On-board software maintenance:
Covers the functions needed to maintain the space segment on-board software platform and payload sides. It should include a software development environment (SDE) which replicates the environment in which the on-board software was originally developed plus a software validation facility (SVF) which reproduces with maximum fidelity (including original hardware wherever possible) the physical and logical environment in which the on-board software operates. It should also include the functionality for software configuration management.

h. Flight dynamics:
Provides the functionality required to calculate the spacecraft orbit and attitude, GSTS antenna pointing and spacecraft manoeuvres. It is a major functional subsystem of the MCS, which should include

- orbit and trajectory determination and prediction,

- orbit and trajectory manoeuvre calculation and evaluation,
- attitude determination and prediction,
- attitude manoeuvre calculation and evaluation,
- prediction of orbital events of operational significance, and
- prediction of ground station antenna pointing data.

i. Products generation:
Provides the functionality required to prepare the mission products, which usually include the data, downlinked from the spacecraft and auxiliary data generated on the ground that allows its meaningful interpretation.

j. Data distribution:
Provides the functionality required to service external requests for data being distributed on-line or off-line.

k. Data archive:
Provides the functionality required to create, manage and maintain the mission archive, for access internally by other control system elements or for external access through data distribution.

l. Operational database management:
Covers the functionality required to acquire external inputs to the operational database, and to generate and maintain the operational databases needed within the executable environment of the control system (e.g. for monitoring and commanding).
The operational database is a repository for all data (spacecraft, ground segment) defining the characteristics of the elements subjected to the MCS processing functions.

m. Control procedure generation:
Provides the functionality required to prepare control procedures in different forms, including simple command sequences to executable flight control procedures. Control procedures relating to the platform should be generated in the context of the OCS whilst those relating to the payload, in PCS.

n. Human-computer interaction (HCI):
Provides the functionality required for users to interact with the control system in a systematic and consistent manner. It covers the system “look and feel”, for general HCI principles and techniques and for use of HCI devices.

6.3.3.2 Requirements for MCS design, implementation, testing and maintenance

The following requirements relate to the design, implementation, testing and maintenance of the MCS.

a. The functionality of the MCS shall be so that the mission can be operated under all nominal and expected contingency conditions with the required level of performance, quality, and reliability.

b. Representatives of the operations engineering, space segment AIT engineering and final user teams shall be involved in the design of the MCS.

c. All internal and external interfaces shall be identified and defined before the start of the implementation of the interfacing elements.

d. The telemetry and telecommand processing layer of the monitoring and commanding functionality shall be in conformance to the ECSS–E–50 standards on spacelink services and with the spacelink services characteristics of the mission.

e. The HCI functionality shall be highly intuitive, consistent and possess an adequate level of ergonomy.

f. The MCS shall undergo verification and validation in accordance with the standard methodology (ECSS–E–10–02 and ECSS–E–10–03).

g. The MCS maintenance during mission operations shall not affect the operational system.

6.3.4 EGSE system

6.3.4.1 EGSE description

All space projects require ground support equipment for the handling and testing of space segment elements. A significant part is the electrical ground support equipment (EGSE).

a. The EGSE shall comprise all transportable test facilities required for functional testing of space segment elements at all levels of integration and during maintenance and storage.

b. The complexity of the systems which provides this functionality increases as the level of space segment integration progresses. This standard details only the EGSE for system-level testing, however, the concepts and solutions should be applied at all levels.

c. A large part of the EGSE provision is concerned with re-use of existing facilities or procurement of off the shelf equipment. The full engineering process shall only apply to those elements which are developed and should be limited to those items which interface directly with, and are special to, the space segment.

d. The life cycle of the EGSE engineering process shall be shifted in time with respect to the remainder of the ground segment, due to its role in the spacecraft assembly, integration and verification process. To have EGSE in a usable state in preparation for the test activities often leads to development starting in advance of the normal space segment project phasing. This need shall be assessed in the planning process.

6.3.4.2 EGSE functional requirements

The EGSE shall provide the following functionality:

a. Data interfacing:
The major input interfaces are telemetry data and test point measurement data; major output data are telecommands and stimulation data. Stimulation should be achieved using separate computerized systems referred to as special check-out equipment (SCOE) whilst telemetry and telecommand require similar facilities to those used in a spacecraft ground station.

b. Monitoring:
Provides data extraction for a range of input sources, calibration into engineering units, validity checking, limit checking, automatic control actions on limit violation and visualization of error reports.

c. Commanding:
Provides the capability to send data to the test object for control and data loading purposes both from user terminals and from other software. It covers preparation of control messages, validation, release and verification thereof. The same protocol data units used in the operational space-ground data links are used for telecommanding.

d. Test procedures execution:
Provides the capability to automate, using a domain specific language, the procedures required to be followed in order to execute the required tests.

e. Performance evaluation:
Provides the functionality required to evaluate the test results and in particular the performance of the tested space segment elements.

f. On-board software management:
Provides the means to store, uplink, downlink and compare images of on-

board software. Uplink is performed using the telecommand channel and via fast-access test points (for high speed loading).

g. Database management:
The database is the repository of descriptions of all data used in the test system. It includes data defining all monitoring parameters, telecommands and associated parameters and defining their extraction, interpretation, validity and verification conditions. It also includes the definition of the test procedures. Consistency of data shall be maintained. The database is exported to the flight operations domain for use in the mission control systems.

h. Test procedures generation:
Provides the functionality required to prepare test procedures. The language provides both algorithmic (i.e. procedural programming) and functional capabilities.

i. Data archiving:
Provides means to record all incoming and outgoing data in a form suitable for replaying or further processing, along with a means to record all processed data and results of the tests performed.

j. Data distribution:
Provides a real-time data stream for telemetry towards all connected SCOE equipment (local or remote from the test site) to support subsystem and experiment tests at system level.

k. Human-computer interaction (HCI):
Provides the means to utilize the EGSE for testing purposes. The main interfaces are for telemetry and data display, monitoring reports, procedure execution control and graphical and synoptic displays of test object status.

As indicated in subclause 6.3.2, EGSE and MCS have a large degree of commonality with respect to their interface vis-à-vis the space system and with respect to their functionality. Therefore they shall be subjected to common standards for functional requirements and interfaces.

6.3.4.3 EGSE design, implementation, testing and maintenance requirements

a. EGSE shall be produced for space system elements at each level of decomposition, to support testing at each level, in line with the project model philosophy. It shall comprise at least:
   - equipment level test equipment;
   - subsystem level test equipment (including instruments or payloads);
   - system level test equipment.

b. The RF and TT&C level interfaces of the EGSE shall be designed in accordance with the space-to-ground interface control document (SGICD).

c. EGSE shall be engineered in accordance with the practices of the countries in which it shall be used.

d. All EGSE components which affect space system equipment shall be engineered in accordance with the standards applied to the space hardware itself.

e. EGSE shall be engineered in a manner which protects the space hardware from being damaged by the EGSE.

f. Requirement engineering, design engineering and analysis of EGSE shall be prepared in phase B of the space segment life cycle.

g. Production and verification engineering shall be performed in phase C of the space segment life cycle.

h. Development, testing and preliminary validation of EGSE elements shall be performed according to a schedule driven by the project AIT planning. Final

validation shall normally be granted after a successful engineering model test campaign of the item to be tested.

6.3.5 Ground station system

6.3.5.1 GSTS logical model

The high level logical model of the ground station system (GSTS) is presented in Table 9. Two main GSTS elements shall be considered in accordance with the logical ground segment decomposition of clause 4:

- GSTS-SSC: for the ground station system(s) in support of space segment control for both the platform and the payload.
- GSTS-ME: for the ground station system(s) in support of mission exploitation.

The definition of these elements is provided below in terms of the relevant functionality. Clearly, depending on the mission complexity, some of the ground station elements can have reduced functionality or not exist at all. Similarly, two or more GSTS elements may be physically merged. A typical split of the main functionality is presented in the table below.

Table 9: High level logical model of the ground station system (GSTS)

Functionality	GSTS-SSC	GSTS-ME
Downlink signal reception	n	n
Downlink data processing	n	n
Uplink signal radiation	n	n
Uplink data processing	n	n
Ranging	n	
Tracking	n	(n)optional
Time calibration	n	n
Monitoring and control (M&C)	n	n
Data storage	n	n
Data distribution	n	n

All GSTS-SSC functionalities are also provided by the GSTS-ME, the essential difference being that the former shall control the space segment while the latter shall support mission exploitation.

6.3.5.2 GSTS functional requirement

The GSTS shall provide the functionality itemized below:

a. Downlink signal reception:
Performs acquisition, down conversion and demodulation of the radio frequency (RF) signal.

b. Downlink data processing (for digital signal):
Performs signal synchronization, decoding, extraction and annotation to produce the data in the form required by the user. This includes production of data units (e.g. frame or packets in the case of telemetry) ready for transmission to the MCC or MEC.

c. Uplink signal radiation:
Provides the capabilities to accept the source uplink signal, and converts it (e.g. by modulation) into the RF uplink signal to be radiated to a spacecraft. It also supports carrier acquisition.

d. Uplink data processing (for digital signal):
Receives the incoming source signal (e.g. telecommand frames or packets), codes it into the final format for uplink and makes it available to the uplink

signal radiation function for transmission to the spacecraft. It may also support the management of the communications protocol between space and ground.

e. Ranging:
Provides the means to measure the range and range rate, or Doppler of the spacecraft.

f. Tracking:
Supports pointing of the GSTS antenna towards a spacecraft and acquisition of the antenna angular measurements.

g. Time calibration:
Provides timing and frequency information for all the GSTS elements (e.g. for command radiation, annotation of telemetry and radiometric data). It also provides the user (MCC or MEC) with the time calibration information for accurate timing of space segment on-board events.

h. Monitoring and control (GSTS-M&C):
Provides monitoring and control of all GSTS equipment. It provides therefore functionality similar to the corresponding MCS functions (see 6.3.2).

i. Data storage:
Provides the functionality required to create, manage and maintain the storage of the downlink data and signal, for access internally by other control system elements or for external access through data distribution. The data storage can be considered as one logical entity, which may be split in constituent parts.

j. Data distribution:
Provides the functionality required to provide downlink data and signal to external users in the required format (e.g. telemetry frame or packet) in either on-line mode (i.e. data dispatched as soon as processed) or in off-line mode from the data storage.

6.3.5.3 GSTS design, implementation, testing and maintenance requirements.

The following requirements relate to the design, implementation, testing and maintenance of the GSTS:

a. The GSTS downlink and uplink functions shall conform to the space link part of ECSS–E–50.

b. The GSTS-SSC shall provide external interfaces (e.g. with the MCC) conforming to the space link extension services defined by ECSS–E–50.

c. The design, implementation, testing, maintenance and documentation of the software elements of the GSTS shall follow ECSS–E–40.

d. All internal and external interfaces shall be identified and defined before the start of the implementation of the interfacing elements.

e. The GSTS shall undergo verification and validation in accordance the standard methodology (E–10–02 and E–10–03).

f. The GSTS maintenance during mission operations shall not affect the operational capability of the system.

6.3.6 Ground communications subnet

6.3.6.1 General

a. The ground communications subnet (GCS) shall connect the various entities that compose the ground segment and the external entities involved in the mission. As far as the communications engineering aspects are concerned, the ground segment related parts of ECSS–E–50 and associated level-3 Standards are applicable.

b. In addition to the mission operations and exploitation support services, ground communications shall be provided during testing of interfaces between ground segment entities and for space segment compatibility tests, and during operational validation. Moreover communications shall be provided during ground segment preparation for exchanging mission operations data, However this is often achieved by using office type communications and is not addressed in this subclause.

c. The characteristics of these application level services drive the requirements for the underlying communications services in terms of data quality, quantity, latency, and availability. For this they shall be categorized depending on their significance to the mission.

6.3.6.2 GCS functional requirements

a. The GCS shall provide the following main services in support of mission operations and mission exploitation:

- data communications;
- voice communications;
- video;
- management of the above services.

b. The following aspects should be considered in the definition of the communications requirements.

- Mission impact, caused by the degradation of the communications service in terms of safety and productivity; this influences the reliability and availability requirements on the communications service.
- Timing characteristics of the service, differentiating between on-line services, requiring near real-time communications (usually related to mission critical functions) and off-line services for communications that are not of a near real-time nature (often of a lower criticality).

Table 10 gives an indicative assessment of the requirement on communications depending on mission impact level and timing characteristics.

c. In addition to the communications services capabilities, communications engineering shall also cover security aspects. This is often achieved by using closed communications systems. When it is not possible to use a closed communications system (e.g. access to operations facilities have to be granted to external users connected to the facilities through un-secure networks such as the internet), then special security measures (e.g. use of firewalls to isolate internal networks from external access points) shall be taken to ensure that “un-trusted” connections do not put the mission and its products under unacceptable risk.

Table 10: Communications service requirements (indicative)

Mission impact level		Timing	
		Real-time	**Off-line**
High (Safety)	*Quality and completeness*:	Very high (i.e. no loss of data)	Very high (i.e. no loss of data)
	Delay:	High (stringent delay requirements)	Low (high delays acceptable)
	Availability:	Very high (e.g. redundancy with route diversity)	Very high (e.g. redundancy with route diversity)
Medium (Productivity)	*Quality and completeness*:	Depending on user requirements (e.g. high levels for commercial mission products)	Depending on user requirements (e.g. high levels for commercial mission products)
	Delay:	High (stringent delay requirements)	Low (high delays acceptable)
	Availability:	High	High
Low	*Quality and completeness*:	Low (losses are acceptable)	Low (losses are acceptable)
	Delay:	Low (delays acceptable).	Low (no latency requirements)
	Availability:	Low	Low

6.3.6.3 Requirements for GCS design, implementation, testing and maintenance

a. The GCS shall be designed so that the interface to the interconnected ground systems is independent of the underlying communications technology.

b. For a given mission a cost trade-off shall be performed between the various ground communications services (e.g. ISDN versus leased lines).

c. The GCS design shall provide the required bandwidth guarantee and availability on a per application data-path (e.g. telemetry transfer from GSTS to MCS) basis.

d. The GCS design shall allow for modifications to accommodate changes to the mission profile.

e. The GCS shall undergo verification and validation in accordance with the standard methodology (ECSS–E–10–02 and ECSS–E–10–03) and further elaborated in subclauses 6.4 and 6.5.

f. The GCS maintenance during mission operations shall not affect the operational system.

g. Whenever relevant, adequate security measures shall be taken to ensure that external connections do not put the mission and its products under unacceptable risk.

h. The communications system shall support, wherever possible, widely used standard communication protocols.

6.4 Operations preparation

6.4.1 General

This task, which belongs to operations engineering, shall cover two main areas:

- flight operations: dedicated to the control of the space segment, and
- ground operations: dedicated to the control of the supporting ground facilities such as ground stations, ground subnets.

The operations preparation activities shall cover

a. contribution to ground segment and ground systems engineering activities,

b. production of mission operations data; i.e. plans, procedures and databases, which are required to control the space segment in-orbit and to operate and maintain the supporting ground elements,

c. technical validation thereof by verifying their correctness and compatibility with the space segment, and

d. build-up and training of the operations teams.

6.4.2 Operations Design

Representatives of the operations engineering and space segment AIT teams shall be involved in the following aspects of the design of the ground segment and of its constituent facilities and elements:

a. elaboration of the operations concepts down to the level of its main constituent elements;

b. definition of the operational and functional requirements, for the ground facilities and elements, for supporting tools (e.g. test tools), and of their interfaces (both internal and external);

c. definition of teams and associated requirements in terms of team structure, manning, skills, training and maintenance;

d. involvement in the subsequent development and technical verification and validation (including in particular validation testing) of the above ground segment elements in order to ensure their conformance to the operational needs.

Some of the above aspects imply an involvement in the overall design of the space system, and are thus covered in more detail in subclause 6.2 and 6.5.

6.4.3 Mission operations data production

6.4.3.1 General

a. These tasks shall cover both the operations of the space segment (i.e. flight operations) and of the supporting ground facilities (i.e. ground operations). They shall consist of

   - producing all documentation required for in-orbit control of the space segment and of the supporting ground facilities, and
   - populating the databases of the ground facilities with the mission specific characteristics data; e.g. telemetry and telecommand characteristics data used to drive their ground processing at MCS level, uplink and downlink characteristics for ground station.

   While often composed of physically distinct data sets that are residing on different media (e.g. computer or even paper), the above mission characteristics data should be seen as constituting conceptually a unique set of data, the mission operations data.

b. A dedicated management system (e.g. supported by software tools) shall be established to ensure a controlled management of the data and to guarantee consistency, coherency and quality of the data.

c. The main sources for mission operations data production are the SSUM, and the space segment database to be provided by the SSC.

d. The SSC shall provide the GSS with a timely delivery of all information required for the implementation of the ground segment and for the in-orbit operations of the space segment, in accordance with the requirements of the space segment customer service support requirements document (CSSRD). Its main components are

- the SSUM, and
- the space segment database (containing all space segment characteristics data required for ground processing) and space segment control procedures, in an electronic form.

e. Before formal delivery to the GSS the inputs to be provided by the SSC shall have undergone verification against representative models of space segment. This verification shall at least include

- the space segment database, and
- the space segment procedures contained in the SSUM.

6.4.3.2 Flight operations

a. All information required for in-orbit control of the space segment (e.g. procedures, rules, plans, schedules) shall be formally documented.

b. One major element of the mission operations data is the flight operations plan (FOP) which shall contain all information required to execute the operations of the space segment when in-orbit, including space segment disposal; it includes all flight control procedures (FCPs). These shall be established by enhancing the procedures provided by the SSC in the SSUM to include ground segment specific aspects.

c. The contents of the FOP shall conform to DRD ECSS–E–70 Part 2A, annex F. It shall include the following information:

- definition of the operation organization and responsibilities, of the decision making process, and of the major mission rules;
- sequence of main mission events for all critical mission phases, including identification of major space segment operations, ground stations visibility;
- flight operations schedule for all mission critical phases (e.g. LEOP), defining for each operational position the timed sequence of operational activities to be executed, the interfaces with other team members, the interfaces with external entities (including for ground entities identification of required configuration), and the associated constraints and dependencies with respect to external events;
- flight control procedures (FCPs) covering all nominal operations of the space segment and all major contingencies as defined in the SSUM.

d. The criteria for implementing (or not) contingency procedures shall be based on economic aspects trading-off the impact of the contingency to the mission against the cost for producing, testing and maintaining the related procedures. The decision process shall be based on:

- impact on the mission, distinguishing potential damages to the space segment from contingencies that only affect mission productivity;
- required recovery time (i.e. maximum acceptable outage of the impacted ground function);
- probability of occurrence.

e. The FOP and the FCPs shall be placed under configuration control.

f. Each FCP shall include the identification of the authorization required for performing the procedure, its applicability and execution conditions and constraints (pre, during and post execution), and the elementary actions.

g. In addition to the production of the FOP, the flight operations team also populates and maintains the MCS database with the relevant part of the mission operations data. This shall include all telemetry and telecommand-processing data (such as decoding and encoding, interpretation, checking data) as obtained from the SSC and enhanced by flight operations.

h. The flight operations database shall be placed under configuration control. This control shall apply to both the preparation and in-orbit utilization phases.

6.4.3.3 Ground operations

a. All information required for the operations of the ground facilities in support of in-orbit control of the space segment (including ground segment disposal) shall be formally documented.

b. The above information shall be compiled for each entity in a corresponding ground operations plan (GOP), the contents of which shall conform to DRD ECSS–E–70 Part 2A, annex G.

c. The GOP shall include the following information:

- definition of operation organization and responsibilities, of decision making process, and of major mission rules;
- sequence of major space segment operations events of relevance to the ground entity;
- schedule of entity operations for all mission critical phases (e.g. LEOP) defining for each element of the entity, the timed sequence of operational support activities to be carried out, the interfaces with other elements, the interfaces with external entities and the associated constraints and dependencies with respect to related events (e.g. space segment operations);
- ground control procedures covering all nominal operations of the entity and its main elements, and major contingencies.

d. The decision to produce procedures to handle ground entity level contingencies shall be based on the following characteristics of a contingency:

- impact on the mission (i.e. does it have severe or irreversible effects?);
- required recovery time (i.e. maximum acceptable outage of the impacted ground function);
- probability of occurrence.

e. The GOP and each individual procedure and item required for control shall be placed under configuration control.

f. Ground operations databases shall be placed under configuration control. These databases shall include the part of the mission operations data that are required for the configuration of the ground entities such as RF and TM/TC layer characteristics for ground stations.

6.4.4 Mission operations data validation

a. The validation of the mission operations data shall demonstrate the technical correctness of the data and their compatibility with the space segment.

b. Validation of the mission operations data should proceed in parallel with the ground segment integration and technical verification and validation.

c. Validation should be achieved by exercising procedures and databases against test tools that shall be representative of the space segment design; usually the primary tool is a space segment simulator (software or hybrid

simulator). This also includes complementary tests involving access to space segment elements while on ground. These tests shall be part of the space segment compatibility tests, which shall also be used for the technical validation of the ground facilities, and are further addressed in subclause 6.5.

d. Technical validation of the mission operations data is not sufficient to achieve a full validation of the data, which is only feasible by using the data in a fully realistic operational context as performed during the operational validation.

e. The choice of the verification approach shall be mission specific,taking into account the significance to the mission of a potential data error in relation to the cost of the test. Validation shall be carried out for time critical contingencies that can affect mission safety (mandatory), whilst for contingencies impacting mission productivity, the validation can depend on the mission and product characteristics. Two main aspects should be considered:

- mission impact, differentiating between contingencies that can affect mission safety and those affecting only mission product delivery (e.g. quality, availability);
- time criticality, taking into account the requirements on ground reaction time to isolate the contingency.

f. All mission operations data of operational significance shall be formally validated. For data of a lower significance (i.e. at least not impacting on the safety of the mission) verification by inspection may suffice.

g. Flight operations data validation shall include testing with tools that are representative of their operational environment. For the flight operations data this shall involve use of spacecraft simulator and access to the maximum possible extent to space segment elements while on ground.

h. Space segment compatibility tests shall address the following issues (subject to the limitations placed on the spacecraft operations whilst on the ground):

- all flight control procedures and telecommands;
- all operational modes of the spacecraft (including non-nominal modes);
- all spacecraft redundancies and subsequent re-configuration to nominal state.

i. The test activities shall cover test preparation to identify test strategies, methods, scenarios and resources, as well as post test activities (e.g. reporting, handling of nonconformances).

j. For all major test activities, requirements for execution of the tests (either technical or managerial) as well as, for example, the proposed test strategy, methods, scenarios, and tests pass or fail criteria, shall be formally documented in test plans, to be subject to formal review before execution of the tests.

k. Results of validation tests and status of validation of each data item shall be formally reported and recorded.

l. All major tests (i.e. at least those involving multiple elements and costly resources) shall be preceded and followed by formal reviews (i.e. test readiness review and test results review) to assess

- whether all conditions required for successful execution of the test are met, and
- the results of the tests and implementation of any necessary actions (e.g. corrections to the space segment design or impacts on subsequent activities such as the repetition of tests).

6.4.5 Operations teams build-up and training

a. The operations of the mission and of the supporting ground segment shall be carried out by different operations and support teams, each being in charge of a specific entity. Although the organization of the teams is highly coupled

with the organizational structure of the ground segment project, the following team activities shall be addressed by the overall team structures:

- Operations teams:
  - Flight control team, in charge of the overall control of the mission and of its space segment. In accordance with the logical model of Figure 2 and depending on the ground segment context, this team can be subdivided during the routine phase of a mission into a platform and a payload operations team.
  - Flight dynamics team, providing support to flight control team for orbit determination, prediction of orbit and orbital events, preparation of orbital and attitude manoeuvres.
  - Ground operations teams, in charge of the operations and maintenance of the supporting facilities (e.g. ground stations, ground communications subnet, mission control centre).
  - Mission exploitation team, in charge of the operations and maintenance of the MES.

  This team is normally only active during the routine phase of a mission.
- Support teams:
  - Ground support teams, composed of experts from the ground systems and elements engineering teams providing support to the ground operations teams.
  - Project support team, composed of experts from space segment manufacturing teams providing support to flight control team.

b. The operations and support teams, are complemented by operations management positions representing both the GSS and the SSC.

c. Build-up and training of the operations teams shall be a progressive activity which proceeds in parallel with the rest of the operations preparation activities. It shall finish when the teams have been fully constituted.

d. The members of the operations and support teams shall be nominated and in place before the start of the operational validation and the composition of these teams shall be placed under configuration control.

e. The members of the operations and support teams shall undergo thorough training in accordance with the respective duty of the team so that they are fully familiar with the mission and the supporting facilities at the start of the operational validation.

f. The corresponding training programme shall be documented in the operations training plan (OTP).

g. In accordance with the operations training plan, each member of the operations teams shall undergo formal training before being allowed to take up operational duties. Training comprises theoretical and practical training and include realistic simulations or rehearsals of operational scenario. For LEOP, the latter shall be achieved during operational validation.

6.5 Ground segment integration and technical verification and validation

6.5.1 General

a. Integration, verification and validation of the ground segment shall be performed (ECSS–E–10–02 and ECSS–E–10–03). Ground segment specific aspects are addressed in this subclause.

b. The ground segment integration and technical verification and validation constitutes the logical completion of the implementation of the ground systems. It shall be composed of the two steps as follows:

1. Ground segment integration: This activity shall be performed using a preliminary set of mission operations data. It shall be carried out in an incremental manner, starting from the low level elements up to facility level, including at each stage of the process
   - a verification test, to demonstrate the conformance of the element with its design specification and interfaces to other ground segment elements, and
   - a validation test, to demonstrate that the element fulfils its requirements specification and to provide a preliminary confirmation that it is fit for use.
2. Technical verification and validation: This activity shall follow the ground segment integration. It addresses the ground segment systems as a whole. It shall result in
   - demonstrating the conformance of the ground segment to the requirements and design specifications,
   - verifying the functional coherence of the ground systems and their compatibility,
   - verifying the technical compatibility of the ground segment with the space segment,
   - verifying the technical compatibility of the ground segment with the external ground entities, by carrying out a series of end-to-end tests which involve all external interfaces of the ground systems, and
   - providing a preliminary confirmation of the conformity of the ground segment systems as a whole with their intended use, by exposing them to realistic operational conditions.

c. The ground segment integration and technical verification and validation shall provide a preliminary validation of the ground segment facilities. Further testing (termed operational validation described in subclause 6.5) shall be performed to achieve a full validation of the ground segment.

d. Any subsequent significant modifications to the ground systems shall necessitate regression testing during which the ground segment shall undergo a similar validation process.

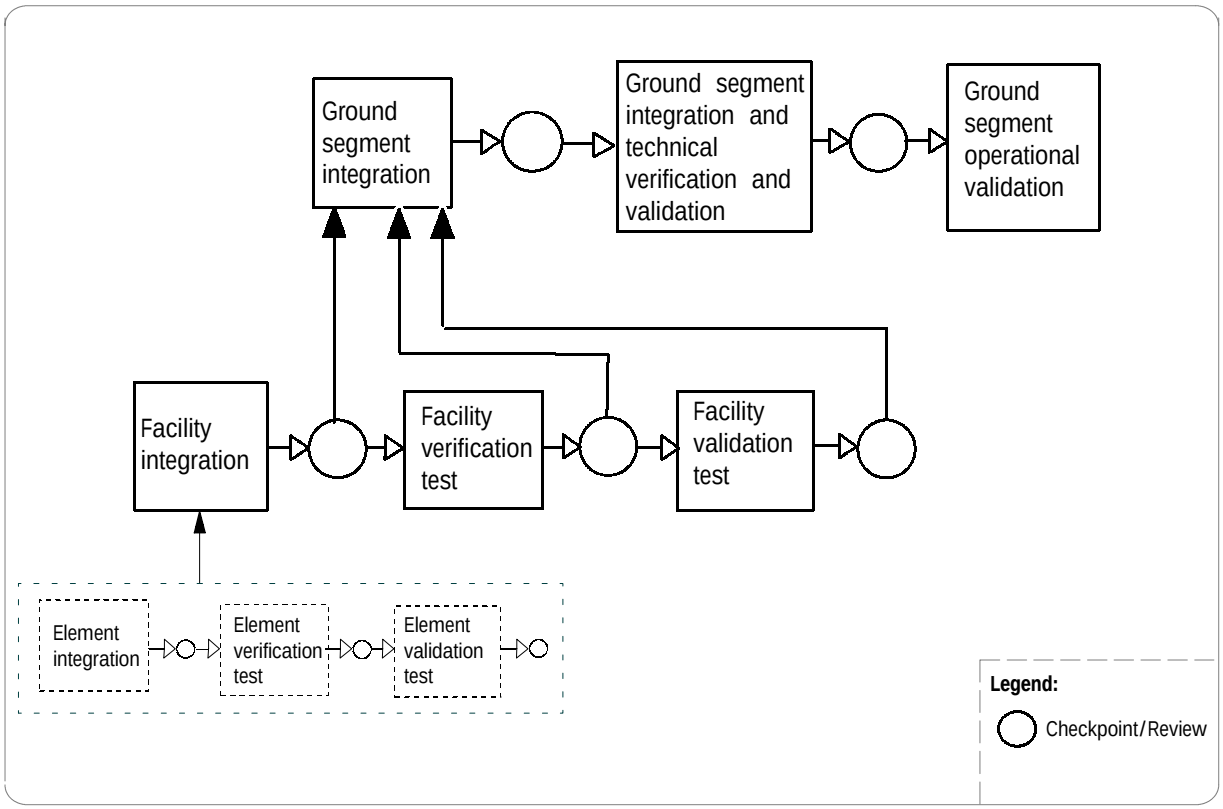


Figure 6: Ground segment validation

6.5.2 Ground segment integration

The following requirements apply:

a. Integration shall be carried out in a formal manner. It shall be documented in the ground segment integration plan, by a set of test procedures and in reports covering all stages of the process.

b. The ground segment integration plan shall include all the steps from the receipt of the first integration release to the completion of integration, and shall cover the following aspects:

- execution of each of the tests covered by the test specifications and production of the associated test documentation;
- the sequence in which the individual facilities are integrated;
- the availability of any test systems or simulators required;
- integration with individual external elements;
- the relationship between these tests and planned pre-releases of the facility for ground segment integration purposes.

c. Ground segment integration shall be carried out in an incremental manner starting from low level elements, in parallel with their integration. Integration of level n+1 shall only be started after successful completion of testing at level n including validation of interfaces between level n elements (see Figure 6).

d. The results of the tests performed during ground segment integration shall be assessed through a formal review process (i.e. test review board).

6.5.3 Technical verification and validation

The following requirements apply.

a. Technical verification and validation shall cover:

- conformance of the ground segment and of its elements to its design requirements and specifications,
- functional coherence and compatibility with the space segment and with the external ground entities, and
- preliminary verification of its operational adequacy.

b. Representatives of the end-users of the ground systems shall participate to their technical verification and validation. Their involvement shall include:
   - definition of the verification and validation approach, and of the required supporting tools and resources,
   - identification and definition of the operational and functional requirements for the required tests tools, and
   - execution of the corresponding validation tests and production of associated reports.

c. Technical verification and validation shall start after a test readiness review, which shall ensure that all prerequisites for the start of the tests are satisfied.

d. The results of the tests performed during technical verification and validation shall be assessed through a formal review process (i.e. GSTVVR).

e. Technical verification and validation of the ground segment shall include an extensive verification of its compatibility with the space segment. This shall include the use of the following test resources:
   - RF suitcase representative of spacecraft hardware and software equipment for testing RF and telemetry and telecommand protocols and format compatibility between space segment and GSTS;
   - space segment simulator including realistic software models of the space segment elements (e.g. emulators for complex software elements) and in some cases real spacecraft components (hybrid simulator);
   - representative space segment TM data samples;
   - access to the spacecraft on ground during AIT activities and at launch site, involving as far as is technically feasible, tests of all ground systems, elements and functions.

   These tests, called space-to-ground segment compatibility tests later in this document, should also be used for validating the mission operations data. In this case, they should include verification of telecommands and telemetry messages and parameters (i.e. mission operations database), of nominal procedures, of parts of contingency recovery procedures, and should also include initiation of and recovery from major modes of the on-board fault management system(s).

f. Access to the spacecraft on ground shall be provided for at least two periods of a duration that is commensurate with the complexity of the space segment and with an interval allowing correction of potential ground segment problems found during previous tests.

g. The space-to-ground segment compatibility tests, shall include the MCS and mission operations data, which constitute the emphasis of the tests, and a maximum set of additional ground systems elements (e.g. ground station equipment).

6.6 Operational validation

a. Operational validation may start after successful completion of the
   - integration and technical validation of the ground systems,
   - validation (technical) of the mission operations data, and
   - training of the operations teams;

   i.e. after all ground segment elements are ready to be exercised as a whole.

b. This phase shall demonstrate that all ground segment elements (including operational teams) work as a coherent whole and are able to support all anticipated mission operations.

c. To achieve this, the complete ground segment shall be exercised in a fully realistic operational context (i.e. through realistic system level operations scenarios), thereby providing a final demonstration of the
   - proper functioning and set-up of all ground segment facilities,
   - correctness and adequacy of all mission operations data,
   - proper qualification of all operations and maintenance personnel, and
   - adequacy of the entire ground segment to support the mission.

d. Operational validation shall constitute the formal operational qualification of the ground segment.

e. Operational validation shall start with a formal review (OVR), that shall verify that all pre-conditions for this phase are met and shall end with a formal review (ORR), that shall confirm the readiness of the ground segment to support in-orbit operations (phase E).

f. Operational validation shall involve all operations entities (internal and external), i.e. including all operations teams as identified in 6.4.5.

g. Operational validation shall exercise the complete ground segment through an extensive series of simulations and rehearsals
   - using realistic tests tools (mainly space segment simulator),
   - involving all operations teams, and
   - through all nominal operations and exercising all critical mission contingencies.

h. Operational validation shall be formally documented in terms of
   - plans (OVP) defining the simulations and rehearsal programme, including involvement of ground segment elements and entities, and
   - reports addressing the results of the activities and in particular the simulations and rehearsal tests, covering nonconformances.

i. In parallel with the simulation and rehearsal programme, further tests (mission readiness tests) to demonstrate that ground segment facilities are fully functional and to maintain proficiency of ground operations personnel shall be carried out on a regular basis. This shall cover ground station facilities and ground communications subnet and include data flow tests.

6.7 Operations execution

6.7.1 General

a. Operations execution shall cover all operations of the space segment and operations and maintenance of the supporting ground segment entities to be carried out during phases E and F of a space mission.

b. Operations execution may be split into different phases depending on their criticality for the mission and their duration as follows:

- Phase 1 (critical phase), covering all operations following the launch up to the start of mission exploitation, and including launch and early operations phase (LEOP), in-orbit commissioning and validation of the space segment.
- Phase 2 (routine phase), during which usually the mission exploitation takes place.

c. The LEOP phase shall be completed, as indicated in clause 5, by a formal review, the IOQR.

d. In some cases (e.g. science deep-space or experiment retrieval missions) several mission critical phases are planned. These phases shall be performed in a similar operational organization as that required for LEOP.

e. During the routine phase(s), operations execution shall involve the following major tasks, which are carried out as an iterative process.

- Preparation:
  covering planning of future operations (and maintenance activities) and production of the related detailed schedules, based for the space segment on user request as coordinated by the MEC and on the outcome of the preceding performance evaluation.
- Execution:
  covering implementation of the above scheduled operations and maintenance activities, and execution of regular health monitoring (either permanent or periodical depending on the characteristics of the mission) of the space and ground segment elements, including in case of anomalies execution of necessary corrective actions.
- Evaluation:
  covering evaluation of the performance of the space and ground segment elements during operations, including trend analysis, in support of the preparation of future operations and maintenance (preventive) activities.

6.7.2 Operations execution

Operations affecting the space segment shall be executed in a fully controlled manner and in accordance with predefined procedures, rules, plans and schedules. Deviations should only be introduced in exceptional cases and should undergo formal design and implementation, verification and approval process before any modified element is declared operational.

The following operations execution requirements shall apply:

a. All space segment control activities shall be executed in accordance with the formal plans and procedures as documented in the FOP. In addition routine operations shall be executed in accordance with agreed mission schedules.

b. In case of a mission contingency not covered by the FOP, a new plan and procedure(s) shall be produced and verified (preferably by testing) and approved by the responsible authority before being implemented.

c. All ground systems and elements operations (including maintenance activities) shall be executed in accordance with the GOP. In addition routine operations shall be executed in accordance with the mission operations schedules.

6.7.3 Reporting and reviews

The following reporting and review requirements shall apply:

a. Operations status reports shall be produced on a periodic basis (e.g. weekly) by all ground segment entities. These reports shall identify the operations and maintenance activities carried out during the reporting period, and the performance of the service rendered, including anomalies.

b. In addition to the operations status reports, the performance of the space segment (including trend analysis) shall be assessed at appropriate intervals. The main outcome of these performance evaluation activities should also be reported.

c. All space segment and ground segment anomalies shall be formally reported and documented in the form of an OAR in accordance with DRD ECSS–E–70 Part 2A, annex H. OAR items shall be maintained for the entire life of the mission and followed until closure.

d. During routine phase(s), regular operations reviews (IOORs) shall be held to assess the performance of mission operations.

6.7.4 Operational configuration

For the success of the mission the ground segment (i.e. facilities, mission operations data, and key operations personnel) shall be maintained in a functional state and remains under configuration control for the duration of the operations execution phase. In case of changes, the same processes as applied during phases CD shall be applied even if in a reduced form.

The following operational configuration requirements shall apply:

a. Modifications to ground segment systems and elements that are in direct support of mission operations shall be carried out in a controlled manner, i.e. including
   - definition of changes (requirements and specification), and
   - implementation, technical verification and validation, operational validation and formal authorization for use.

b. Modifications to operations procedures and databases in direct support of mission operations shall be carried out under configuration control, and shall include
   - definition of changes (requirements and specification), and
   - implementation, technical and operational validation, and formal authorisation.

c. During the whole of phase E, the operations teams shall be maintained in terms of human resources and skills in a fully operational state. In case of replacement of staff, the new members of the operations teams shall undergo formal training and operational tests before working autonomously.

6.8 Disposal

6.8.1 General considerations

a. As defined in ECSS–E–00, disposal constitutes the tasks, actions, and activities to be performed, and the system elements required, to ensure mission termination without degradation to the environment.

b. The disposal engineering process shall include
   - disposal analyses,
   - development of products and processes for disposal,
   - processes validation,
   - final de-orbiting or re-entry operations, and
   - disposal or recycling of ground facilities or of retrieved space segment elements.

c. Disposal analysis shall cover methods for storage, dismantling, reusing, recycling and destruction of the relevant parts of the space segment and of the ground segment.

d. Cost and organizational aspects and applicable international rules shall be taken into account in the disposal analysis.

e. All products and processes dedicated to disposal activities shall be developed according to ECSS engineering standards.

f. All disposal operations (for both the space and ground segment) shall be documented in appropriate disposal plans. These plans shall be covered as part of the FOP and GOP.

6.8.2 Space segment disposal

For the space segment several cases of disposal can be distinguished as follows:

- manoeuvre into graveyard orbit, typically for geostationary missions;
- destructive re-entry, for low Earth orbiting missions;
- ground disposal for retrievable missions.

The following requirements shall apply:

a. At the end of the mission, the space segment shall be withdrawn from service during what constitutes the disposal phase.

b. Disposal of the space segment shall be performed according to the rules defined in ECSS–Q–40.

c. The space segment shall be designed to include adequate design features and resource margins to enable a predicted and controlled disposal after the planned mission lifetime.

d. Graveyard disposal shall ensure a final orbit and a state of the spacecraft that minimizes impacts to other space missions. This shall include

   - RF emission switched off,
   - discharge of batteries,
   - emptying of any propellant tanks, and
   - disposal of potential hazardous material.

e. Re-entry disposal shall be performed in a controlled manner to minimize risk to inhabited areas.

f. For retrievable missions, disposal shall be preceded by tests of the space segment elements in order to assess the impacts of the space environment. Disposal shall be performed according to disposal procedures for ground system elements.

6.8.3 Ground segment disposal

After phase E, ground segment elements may either be maintained for later reuse, or may be dismantled. The following requirements shall apply:

a. Dismantling shall be performed in an environmentally acceptable manner.

b. In order to provide feedback to the engineering of future space missions, mission reports including mission operations experience and lessons learned, and spacecraft in-orbit performance shall be produced.

c. Mission data shall remain accessible for a duration that conforms to relevant regulations and with mission requirements.

6.9 Logistics support

6.9.1 General considerations

Management aspects of logistics support (LS) are covered by ECSS–M–70, which as far as logistics support is concerned defines how the LS activities and the associated products are supported and merged in the general management tasks.

This Standard is complemented in this subclause by describing the aspects of logistics support management that are specific to the ground segment domain and to cover all the technical aspects related to the integrated engineering of the logistics support functionality.

a. The engineering of the logistics support functionality shall be based on the following analysis and tasks:
   - reliability centred maintenance analysis (RCMA);
   - maintenance tasks analysis (MTA);
   - level of repair analysis (LORA);
   - resources analysis;
   - definition of technical manuals and documentation;
   - definition of logistics facilities;
   - definition of inventory management tools.

b. Logistics support engineering shall be performed to establish (in parallel with the ground segment implementation) a suitable logistics support entity comprising all elements (staff, equipment, tools, information) capable of providing the services necessary for the maintenance of the ground segment and its constituent entities, during operations execution. Logistics support engineering shall
   - identify ground logistics support needs,
   - select and establish an logistics support solution (after performance of the necessary trade-off analyses), and
   - ensure that the ground segment design incorporates the ground logistics support requirements.

c. Each entity of the ground segment shall implement its own logistics support functions.

6.9.2 Phasing

a. The logistics support engineering activities shall be phased with the rest of the ground segment engineering processes as identified in clause 5.

b. The logistics support concept shall be produced along phases A and formalized in phase B. The logistics support plan including the identification of resources necessary for logistics support functions shall be produced during phase C.

c. During the production phase, the logistics support activities shall be finalized to ensure the satisfaction of the needs in terms of logistics products that shall be used during the operational phase. These activities should include
   - preparation of the maintenance plans at the entity level,
   - procurement of spares and consumable,
   - generation of the documentation (e.g. technical manuals, operation procedures),
   - manufacturing of maintenance support equipment (e.g. test equipment, tools),
   - procurement of products for the maintenance of the on-board software and ground software, including the capability for validating new software releases before their activation for operational use,
   - identification of required skill profiles and manpower resources,
   - preparation and holding of training courses for the personnel, and production of the related training material,
   - building or refurbishing of logistics facilities,
   - procurement of software products for inventory management, and

- procurement of PHST products (packaging, handling, storage and transport).

d. Before the beginning of technical validation initial logistics support (as defined in ECSS–M–70) shall be in place.

e. During the operations execution and disposal phases, the logistics support organization should become an integral part of the corresponding ground operations organization.

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Annex A (informative)

DRD list

The following table identifies the list of the document requirements documents (DRDs) associated to this Standard.

Table A-1: ECSS-E-70 DRD list

DRD Id	DRD title	DRD summary content	Applicable to (phase)	Delivered (phase)	Remarks
ECSS-E-70 Part 2A, annex A	Customer requirements document (CRD)	Formally defines the requirements from the Customer on the ground segment. Covers design, implementation and operations as well as cost and programmatic issues.	B	B	
ECSS-E-70 Part 2A, annex B	Ground segment baseline Definition (GSBD)	Formal response to CRD. Constitutes the ground segment technical baseline for the its design, implementation of the ground segment and for the operations of the mission. It includes conformance to CRD requirements, identifies derived requirements and major constraints and assumptions.	C to F	B	
ECSS-E-70 Part 2A, annex C	Mission operations concept document (MOCD)	Defines the overall mission operations concept at the level of major ground segment entities.	A, B	A*/B	
ECSS-E-70 Part 2A, annex D	Space segment user manual (SSUM)	Provides all information required to implement the ground segment and to operate the space segment, i.e.: D space segment design characteristics of operational relevance (e.g. operational modes, constraints); D telemetry and telecommand lists (i.e. all information items required for ground processing of TM and TC); D nominal and contingency recovery procedures (only covering space segment aspect).	C to F	C*/D	Used in phases C/D for design of G/S and maintenance in phase F
ECSS-E-70 Part 2A, annex E	Operational validation plan (OVP)	Provides all information required to execute the operational validation of the ground segment, i.e.: D definition of simulations and rehearsal activities; D timeline of above activities; D related organizational aspects and required re-sources and participation.	D	D	

* Delivery phase marked with an asterisk indicates a preliminary (draft) delivery

Table A-1: ECSS-E-70 DRD list *(continued)*

DRD Id	DRD title	DRD summary content	Applicable to (phase)	Delivered (phase)	Remarks
ECSS-E-70 Part 2A, annex F	Flight operations plan (FOP)	Defines information required to operate the space segment during all applicable in-orbit phases of the mission, i.e.: D general operation organization and decision making process and major mission rules; D detailed schedule of flight operations; D Flight control procedures (FCP see below) for both nominal operations and major contingencies.	D	E, F	To contain also space segment disposal procedures
ECSS-E-70 Part 2A, annex G	Ground operations plan (GOP)	Defines all information required to operate the corresponding ground facility and its constituent elements in order to support the mission, i.e.: D operations management and organizational aspects; D detailed schedule of activities for the entity in relation to mission events; D elementary entity operation procedures.	D	E, F	To contain also ground segment disposal procedures

* Delivery phase marked with an asterisk indicates a preliminary (draft) delivery

Table A-1: ECSS-E-70 DRD list *(continued)*

DRD Id	DRD title	DRD summary content	Applicable to (phase)	Delivered (phase)	Remarks
ECSS-E-70 Part 2A, annex H	Operations anomaly report (OAR)	Documents a departure from the expected performance of an item during its operation. Includes: D date and time of anomaly occurrence and unique identifier for the anomaly; D summary description of the symptoms and impacts; D corrective actions and recommendations.	E	E	
ECSS-E-70 Part 2A, annex I	Flight control procedure (FCP)	Elementary constituent of the FOP. D Defines all actions to be performed to ensure adequate configuration of the space segment to achieve a given mission goal. D Addresses operational responsibilities, system prerequisites and post execution verification conditions. Two types of FCPs can be distinguished, for nominal and routine operations, and contingency operations respectively.	D	E, F	To contain also space segment disposal procedures

* Delivery phase marked with an asterisk indicates a preliminary (draft) delivery

Annex B (informative)

Ground segment reviews

The following table provides a summary of the major ground segments reviews.

Table B-1: Ground segment reviews

Review Id	Review title	Review objective	Date	Level
GSRR	Ground segment requirement review	To select a ground segment baseline	End of phase 0/A	Space system customer level
GSPDR	Ground segment preliminary design review	To approve the ground segment design baseline, and to select the ground segment main supplier	End of phase B	Space system customer level
GSCDR	Ground segment critical design review	To establish acceptance by the customer of the ground segment design	End of phase C	Space system customer level
GSTVVRR	Ground segment technical verification and validation readiness review	To ensure the readiness of ground systems and elements and personnel for technical verification and validation activities	In phase D, before technical verification and validation	Ground segment supplier level
GSTVVR	Ground segment technical verification and validation review	To ensure that the ground segment conforms to its specifications, with its technical requirements and that all conditions are met for proceeding with the operational validation activities	In phase D, at the end of technical verification and validation	Ground segment supplier level
OVRR	Operational validation readiness review	To ensure the readiness of ground systems and elements and personnel for operational validation activities	In phase D, prior to start of operational validation	Ground segment supplier level
ORR	Operational readiness review	To ensure full readiness of the ground segment for in orbit operations, and to authorize its utilization for space segment in orbit operations	End of phase D (after operational validation)	Space system customer level
IOQR	In-orbit qualification review	To assess the performance of the space segment after in-orbit commissioning and to declare its readiness for in-orbit exploitation	In phase E at the end of the commissioning activities	Space system customer level
IOORs	In-orbit operations reviews	To carry-out a regular assessment of the performance of the space system; i.e. both space segment and ground segment	In phase E on a periodical basis (e.g. yearly)	Space system customer level
MCOR	Mission close-out review	To ensure that all mission disposal activities have been adequately completed	End of phase F	Space system customer level

ECSS Document Improvement Proposal

1. Document I.D.	2. Document date	3. Document title
ECSS–E–70 Part 1A	25 April 2000	Ground systems and operations — Part 1: Principles and requirements

4. Recommended improvement (identify clauses, subclauses and include modified text or graphic, attach pages as necessary)

5. Reason for recommendation

6. Originator of recommendation

Name:	Organization:	
Address:	Phone: Fax: e-mail:	**7. Date of submission:**

8. Send to ECSS Secretariat

Name:	Address:	Phone: +31–71–565–3952
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Note: The originator of the submission should complete items 4, 5, 6 and 7.

This form is available as a Word and Wordperfect–Template on internet under
http://www.estec.esa.nl/ecss/improve/

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