ECSS-E-ST-10C
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EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space engineering

System engineering general requirements

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

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.

This Standard has been prepared by the ECSS-E-ST-10C Working Group, reviewed by the ECSS Executive Secretariat and approved by the ECSS Technical Authority.

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Change log

ECSS-E-10A 19 April 1996	First issue
ECSS-E-10 Part 1B 18 November 2004	Second issue
ECSS-E-ST-10C 6 March 2009	Third issue The main driver for the changes in this issue of the standard comes from the intention to include in this document only requirements and moving to an ECSS Handbook (ECSS-E-HB-10) all the informative material related to the process, in line with the ECSS Task Force #2 recommendations. Consequently, the former clause 5 "System engineering process", which contained a thorough description of a reference space system development process has been replaced by a brief overview of the project phases and related system engineering tasks in the current clause 6 "Overview of system engineering tasks per project phase". Former Clause 4 has now been split into an introductory clause 4 "Overview of Systems engineering" and clause 5 "General Requirements". The remaining requirements have been reworded for readability and consistency. Repetition of requirements included in other related standards have been eliminated. Regarding the documentation model, the only significant modification originates in the simplification of the concept of Functional Specification and Technical Specification, established in the previous issue of ECSS-E-10-06. In the new issue of ECSS-E-ST-10-06 only one specification, the technical requirements specification (customer specification), is considered. This is reflected in this standard, as explained in clause 5.2.3.1 Other changes are explained below: • Clause 2: Normative references Extended and completed • Clause 3: Terms, definitions and abbreviated terms Includes additional definitions and abbreviated terms. In particular definition of the Technology Readiness Levels (TRL) has been added.

	• Clause 4: Overview of system engineering Includes the first clause of former clause four "The system engineering discipline". A brief characterisation of the System engineering process has been added to this introductory clause. • Clause 5: General requirements The set of requirements initially contained in clause 4 of previous issue have been considerably restructured. Non mandatory requirements contained in previous issue have been eliminated, leaving only "mandatory requirements" or "shall" requirements. Descriptive text has been eliminated and it will be included in the System engineering handbook (to be published). The use of technology readiness level (TRL) is introduced in clause 5.6.7. • Clause 6: Overview of system engineering tasks per project phase This new issue contains high level requirements on the system engineering tasks to be complied with for each of the project phases. • Annex A: System engineering documents delivery per review This annex replaces and expands old annex B. It includes the listing of the main documents per phase of the project development indicating when the document needs to be available. • Annexe B to Q: Document Requirements Descriptions (DRD) This annexes include all the project documents pertinent to this standard. In the previous issue of the standard the DRDs were not included. • Annex R: Mapping of typical DDP to ECSS documents This is an addition with respect to the previous issue. It presents where specific subjects contained in the previously used Design and Development Plan are located in the new set of ECSS documents.

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1 Scope

This standard specifies the system engineering implementation requirements for space systems and space products development.

Specific objectives of this standard are:

- to implement the system engineering requirements to ensure a firm technical basis and to minimize technical risk and cost for space systems and space products development;
- to specify the essential system engineering tasks, their objectives and outputs;
- to implement integration and control of engineering disciplines and lower level system engineering work;
- to implement the "customer-system-supplier model" through the development of systems and products for space applications.

This Standard is intended to apply to all space systems and product, at any level of the system decomposition, including hardware, software, procedures, man-in-the-loop, facilities and services. Through the document and its annexes the requirements however apply as they are to complex systems only; for lower level elements tailoring is necessary.

Specific requirements related to system engineering, like technical specification, verification, and testing are specified in dedicated documents and standards within the set of ECSS system engineering standards ECSS-E-ST-10-XX.

Discipline or element specific engineering implementation requirements are covered in dedicated ECSS standards. These standards are based on the same principles, process and documentation model. The applicability of each these standards can therefore not be considered in isolation from the others.

ECSS-E-HB-10 "System engineering guidelines" contains guidelines related to this standard, including a description of the reference system engineering process for a space system and its products.

NOTE 1 The term "Discipline" is defined in ECSS-M-ST-10, as "a specific area of expertise within a general subject". The name of the discipline normally indicates the type of expertise, e.g. in the ECSS system mechanical engineering, software and communications are disciplines within the engineering domain.

NOTE 2 The requirements on the system engineering process are gathered in this standard; specific aspects of the SE process are further elaborated in dedicated standards.

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

2
Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this ECSS Standard. For dated references, subsequent amendments to, or revision 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 more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00-01	ECSS system - Glossary of terms
ECSS-E-ST-10-02	Space engineering – Verification
ECSS-E-ST-10-06	Space engineering – Technical requirements specification
ECSS-E-ST-10-09	Space engineering – Reference coordinate system
ECSS-E-ST-10-24 [1)]	Space engineering – Interface control
ECSS-M-ST-10	Space project management – Project planning and implementation
ECSS-M-ST-40	Space project management – Configuration and information management
ECSS-Q-ST-20-10 [1)]	Off-the-shelf items utilization in space systems

[1] To be published.

3
Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:

acceptance

approval

configuration baseline

design

development

equipment

inspection

integration

need

performance (see also ECSS-E-ST-10-06)

product tree

requirement

specification

subsystem

system

test

verification

3.2 Terms specific to the present standard

3.2.1 agreement

act of an authorized representative of an organization by which it confirms satisfactory performance of specific services

3.2.2 critical

characteristic of a process, process condition, parameter, requirement or item that deserves control and special attention in order to meet the objectives (e.g. of a mission) within given constraints

3.2.3 design to cost

method of managing a project, which enables the project to be controlled from its inception in order to meet defined performances within pre-established objectives of cost and time

3.2.4 integration

process of physically and functionally combining lower level products (hardware or software) to obtain a particular functional configuration

3.2.5 mission statement

document expressing the set of collected needs

NOTE The mission statement is a document established by the customer, which reflects the users needs, and is used as input to Phase 0 of a space system project.

3.2.6 requirement traceability

requirement attribute that links each single requirement to its higher level requirements inside the requirement set

NOTE This enables the derivation of a requirement tree, which demonstrates the coherent flow-down of the requirements.

3.2.7 recurring product

product which conforms to a qualified design and is produced according to the corresponding production master file

3.2.8 system engineering

interdisciplinary approach governing the total technical effort required to transform a requirement into a system solution

NOTE From IEEE P1220.

3.2.9 system engineering organisation

entity within a project team of a supplier which performs the system engineering activities of the project

NOTE For further details see clause 4.2.

3.2.10 system engineering process

set of inter-related or interacting activities, each transforming inputs into outputs, to implement system engineering

3.2.11 technical requirement

required technical capability of the product in terms of performances, interfaces and operations

NOTE These are requirements related to a product and not those related to the process or management of the project or business agreement.

3.2.12 technology readiness level

achieved status of development of a technology

NOTE TRL levels 1 to 9 are defined as follows:

TRL1 Basic principles observed and reported

TRL2 Technology concept and/or application formulated

TRL3 Analytical and experimental critical function and/or characteristic proof-of-concept performed

TRL4 Component and/or breadboard validated in the laboratory environment

TRL5 Component and/or breadboard validated in the relevant environment

TRL6 System/subsystem model or prototype demonstrated in the relevant environment (ground or space)

TRL7 System prototype demonstrated in a space environment

TRL8 Actual system completed and flight-qualified through test and demonstrated (ground or flight)

TRL9 Actual system “flight-proven” through successful mission operations.

3.2.13 verification matrix

initial issue of the VCD which contains for each requirement to be verified the methods, levels and stages of product verification

NOTE See ECSS-E-ST-10-02 for a more detailed definition of the VCD.

3.3 Abbreviated terms

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

Abbreviation	Meaning
AIT	assembly, integration and test
AIV plan	assembly, integration and verification plan
AOCS	attitude and orbit control sub-system
AR	acceptance review
CDR	critical design review
COTS	commercial off-the-shelf
CRR	commissioning results review NOTE For space vehicles (e.g. launcher, transfer vehicle, crew transport vehicle) the CRR can be replaced or complemented by a flight qualification review (FQR).
DDF	design definition file
DDP	design development plan
DJF	design justification file
DRD	document requirements definition
ECSS	European Cooperation for Space Standardization
ELR	end-of-life review
FDIR	failure, detection, isolation, recovery
FM	flight model
FMECA	failure modes, effects, and criticality analysis
FRR	flight readiness review
FTA	fault tree analysis
GSE	ground support equipment
ICD	interface control document
ILS	integrated logistic support
IRD	interface requirement document
LRR	launch readiness review
MCR	mission closed-out review
MDD	mission description document
MDR	mission definition review
MOP	mission operations plan
MS	mission statement
ORR	operational readiness review

PDR	preliminary design review
PMP	project management plan
PRR	preliminary requirement review
PUM	product user manual
QR	qualification review
RAMS	reliability, availability, maintainability, safety
RF	radio frequency
RJF	requirement justification file
ROD	review of design
ROM/RAM	read only memory / random access memory
RTM	requirement traceability matrix
R&D	research and development
SE	system engineering
SEP	system engineering plan
SFT	system functional test
SRR	system requirement review
SVT	system validation test
TP	technology plan
TRL	technology readiness level
TS	technical requirements specification
UM	user manual
VCD	verification control document
VP	verification plan
w.r.t.	with respect to

4
Overview of system engineering

4.1 The system engineering discipline

System engineering is defined as an interdisciplinary approach governing the total technical effort to transform requirements into a system solution.

A system is defined as an integrated set of elements to accomplish a defined objective. These elements include hardware, software, firmware, human resources, information, techniques, facilities services, and other support elements.

In this standard the concept of "system" is used in a wide sense. The highest level, often called "mission level" or "space system", consists usually of one (or more) space segment(s), of a ground segment, and of a user segment. Elements of system decomposition are also considered a system. For the purpose of this standard the system can be any element at any level of decomposition as defined by the function tree (see Annex H) or the product tree (see ECSS-M-ST-10 Annex B). The scope of an element can include hardware, software, procedures, man-in-the-loop, facilities and services.

From the perspective of the considered system, requirements originate from the next upper level (the customer) and elements are procured from the next lower level (the suppliers).

NOTE 1 The customer-supplier model is described in ECSS-S-ST-00.

NOTE 2 Through this standard the notion of customer refers to several actors ,in relation to the project phase. In fact a customer can be e.g. a scientific community in phase 0, a commercial user in phase A or an Agency in phase B. A supplier can on the other hand be an Agency in both phase 0 and phase A.

Figure 4-1 shows the boundaries of the system engineering discipline, its relationship with production, operations, product assurance and management disciplines and its internal partition into the following functions:

- requirement engineering, which consist on requirement analysis and validation, requirement allocation, and requirement maintenance;
- analysis, which is performed for the purpose of resolving requirements conflicts, decomposing and allocating requirements during functional analysis, assessing system effectiveness (including analysing risk factors);

and complementing testing evaluation and providing trade studies for assessing effectiveness, risk, cost and planning;

- design and configuration which results in a physical architecture, and its complete system functional, physical and software characteristics;
- verification, which objective is to demonstrate that the deliverables conform to the specified requirements, including qualification and acceptance;
- system engineering integration and control, which ensures the integration of the various engineering disciplines and participants throughout all the project phases.

Figure 4-2 shows system engineering functions, their relationships and their main activities during the system engineering process.

System engineering functions are applied in an iterative mode during implementation of the system engineering process described in clause 4.2.

Within the frame of a project, the system engineering functions are implemented by a system engineering organisation of the supplier which is in charge of transforming the requirements of the customer into a system solution delivered by the supplier.

NOTE With respect to the next lower level, the supplier plays the role of the customer.

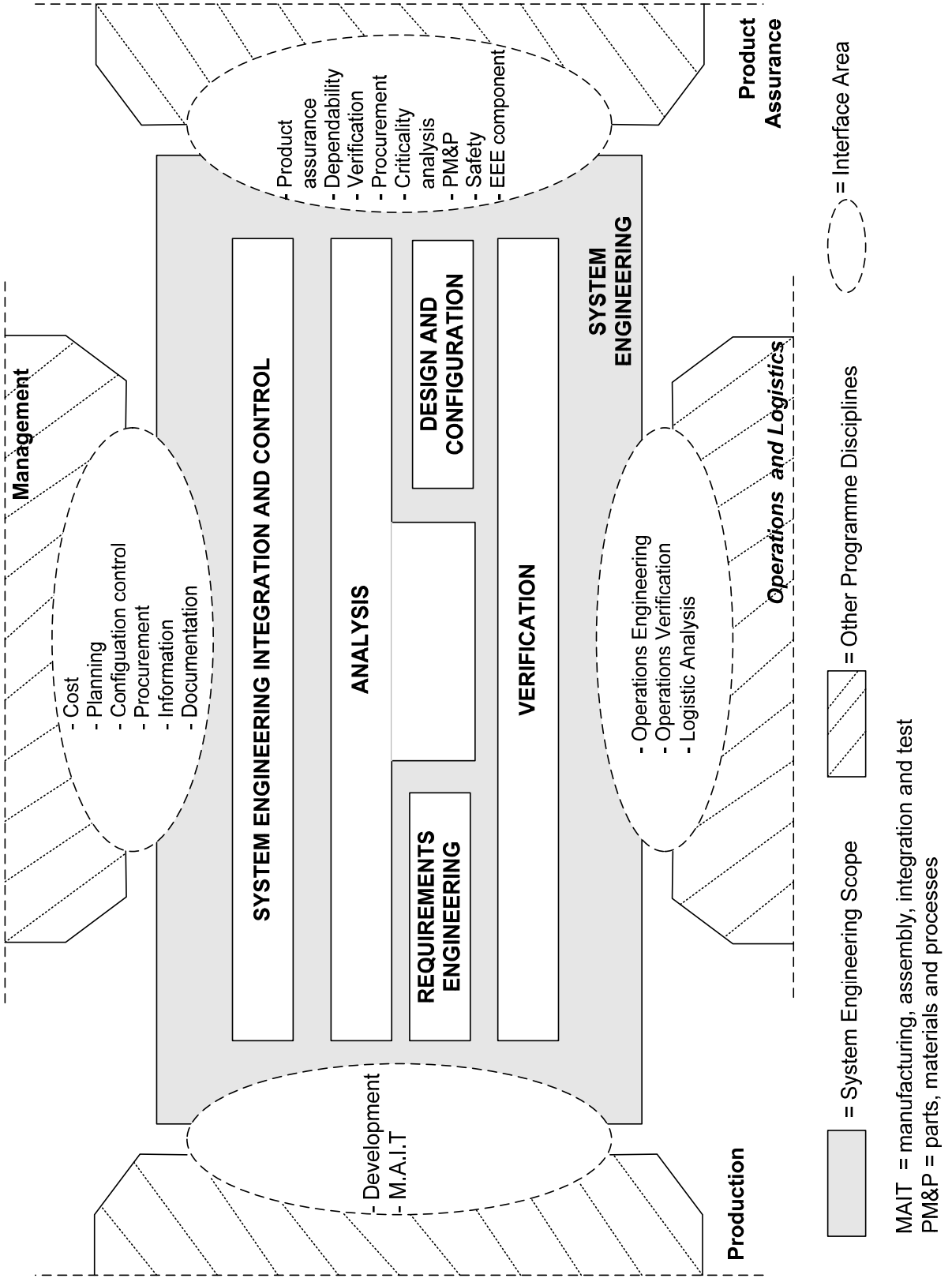

Figure 4-1: System engineering functions and boundaries

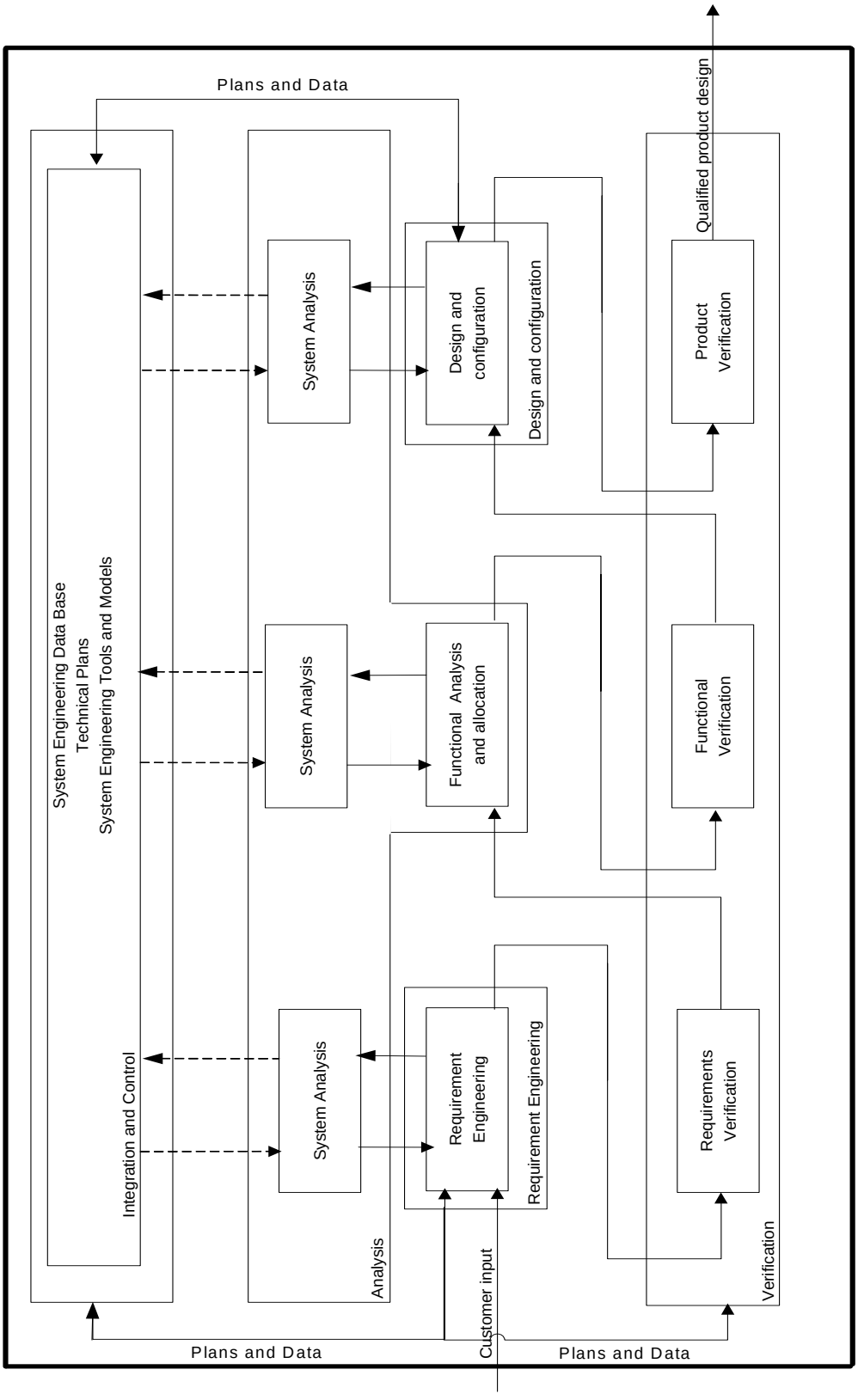

Figure 4-2: System engineering functions and relationships

4.2 The system engineering process

The system engineering activities of a project are conducted by an entity within the project team of a supplier. This entity is called in this document "system engineering organisation".

The system engineering process consists of activities to be performed by the system engineering organisation within each project phase. The objective is to obtain a product which satisfies the customer technical requirements within pre-established objectives of cost and time. The requirements for these activities are described in clause 5.

The system engineering process is intrinsically iterative across the whole life of a project, in particular in the initial phases (i.e. 0, A, and B) of the development of a complex system (e.g. a spacecraft), procured through a multilayered set of suppliers.

During these phases, the system engineering organisation derives design oriented technical solutions using as an input the design-independent customer requirements contained in a technical requirements specification (TS). This is achieved through an iterative top-down process by trading off several design solutions at increasing level of detail.

NOTE For definition and requirements for a technical requirements specification see ECSS-E-ST-10-06.

Through this process the system engineering organisation performs a multidisciplinary functional decomposition to obtain logical lower level products (both hardware and software). At the same time the system engineering organisation decides on balanced allocations, throughout the system, of resources allocated by the customer and respects agreed margin philosophies as a function of the relevant technology readiness levels.

The system engineering process is in turn applied by each system engineering organisation of each supplier of the elements of the product decomposition.

The functional decomposition defines, for each level of the system, the technical requirements for the procurement of subassemblies or lower level products as well as the requirements for the verification of the final characteristics of each product.

The system engineering process uses the results of these lower level verification activities to build a bottom-up multilayered evidence that the customer requirements have been met.

The system engineering process is applied with various degrees of depth depending on the level of maturity of the product (e.g. new development or off-the-shelf).

The system engineering process can be applied with different level of tailoring as agreed between customer and supplier in their business agreement.

The system engineering organization has interfaces with organizations in charge of management, product assurance, engineering disciplines, production, and operations and logistics.

NOTE 1 The system engineering process is defined in detail in ECSS-E-HB-10 "System engineering guidelines".

NOTE 2 The project phases are defined in ECSS-M-ST-10.

5
General requirements

5.1 System engineering plan

a. The system engineering organization shall produce a system engineering plan (SEP) in conformance with Annex D.

b. The system engineering organization shall establish the SEP with the contributions and constraints of management, product assurance, engineering disciplines, production, and operations and logistics.

c. The system engineering plan shall relate to the lower level plans and ensure consistency between these plans.

NOTE 1 The early version of the Project Management Plan (PMP), which includes the early version of the SEP, contains all the information which was traditionally contained in the Design and Development Plan (DDP). See Annex R which illustrates the mapping between a typical DDP and ECSS DRDs.

NOTE 2 The SEP content evolves with the phase of the project, with more information on risk analysis and new technologies in early phases 0, A and B, and more information on verification and validation aspects in phases C, D

5.2 Requirement engineering

5.2.1 General

a. The system engineering organisation shall analyse the requirements for the system issued by the customer.

NOTE This analysis enables transforming these requirements into a system solution.

b. The system engineering organisation shall derive, generate, control and maintain the set of requirements for the lower level elements, defining their design and operational constraints and the parameters of functionality, performance, and verification necessary to meet the system requirements issued by the customer.

c. The system engineering organisation shall ensure consistency of the requirements at system level, at lower levels, as well as amongst levels.

d. The system engineering organisation shall ensure conformance of each requirement with characteristics specified in ECSS-E-ST-10-06 clause 8.

NOTE Main characteristics are: traceable, unique, single, verifiable, unambiguous.

e. The system engineering organisation shall ensure that each requirement for the lower level elements has a justification reflected in the requirement justification file in conformance with Annex O.

NOTE This applies also to a standard as a whole. Tailoring of a standard in a list of applicable standards, or of a requirement in an applicable standard, is possible where each tailoring measure is duly justified.

5.2.2 Requirement traceability

a. The system engineering organisation shall ensure forward and backward traceability of all requirements:

1. to their sources;

NOTE For example: a higher level requirement, an imposed management constraint, an applicable standard, an accepted lower level constraint.

2. to the lower level requirements;

3. to changes in the design inducing modifications of the requirements;

4. to their verification close-out.

b. The system engineering organisation shall establish the requirements traceability matrix in conformance with Annex N.

c. The system engineering organisation shall ensure that the close-out traceability is documented in the VCD in conformance with ECSS-E-ST-10-02 Annex B.

5.2.3 Requirement engineering process

5.2.3.1 Technical requirements specifications

a. The system engineering organisation shall establish technical requirements specifications of the next lower level products consistent among them and with the technical specification received from the customer

b. The system engineering organisation shall ensure that the technical requirements specifications it establishes conform to ECSS-E-ST-10-06 and its DRD in Annex A.

c. The system engineering organisation shall establish for its own product and lower level ones a specification tree in conformance with Annex J.

d. In systems where the supply chain consists of at least 3 layers (including the customer), the system engineering organisation of the highest level supplier shall define at the beginning of a project, a set of requirements specifications covering aspects common to more than one lower level product.

NOTE 1 These "common" technical specifications have been historically called support specifications (e.g. GDIR "General Design and Interface Requirements", environmental, test, EMC requirements specifications) and are separated from other requirements specifications addressing product specific characteristics and functionalities.

NOTE 2 Requirements for equipment level products (or below) can be issued in self contained specifications.

5.2.3.2 Requirement consolidation

a. The system engineering organisation shall identify and resolve at the beginning of each project phase, incomplete, ambiguous, and contradictory requirements (with the customer for requirements issued by him).

b. The system engineering organisation shall reflect the consolidated requirements in updates of the specifications.

5.2.3.3 Requirement analysis

a. The system engineering organisation shall identify requirements impacting strongly on system risk.

b. The system engineering organisation shall perform the requirements analysis to the level of depth necessary to identify elements impacting on system risks.

5.2.3.4 Requirements verification methods

a. The system engineering organisation shall ensure that for each requirement contained in the technical requirements specification, one or a combination of verification methods are identified.

NOTE Technical requirements specification is defined in ECSS-E-ST-10-06 Annex A.

b. The system engineering organisation shall ensure that for each requirement contained in the technical requirements specification, the verification methods are reflected in the verification matrix.

NOTE Technical requirements specification is defined in ECSS-E-ST-10-06 Annex A.

5.2.3.5 Requirement allocation

a. The system engineering organisation shall ensure that the system requirements (and their verification methods) are allocated to lower levels and included in the specifications of the related products.

5.2.3.6 Requirements consistency

a. The system engineering organisation shall verify that requirements are individually and globally consistent and non redundant.

b. The system engineering organisation shall verify that the lower level requirements are consistent with system requirements.

5.2.3.7 Requirements validation

a. In phase 0 the system engineering organisation shall validate the requirements against the expressed needs together with the customer.

NOTE For definition of "needs" see ECSS-E-ST-10-06.

5.2.3.8 Requirements maintenance

a. The system engineering organisation shall ensure that agreed changes to requirements are implemented in system and lower levels specifications.

b. The system engineering organisation shall exercise the maintenance during the system life cycle, down to end of the Phase F Mission Close-out Review.

5.2.3.9 Requirements baseline

a. The system engineering organisation shall establish the list of documents constituting the system requirements baselines in contribution to the configuration baselines.

NOTE Details on configuration baselines are provided in ECSS-M-ST-40.

5.3 Analysis

5.3.1 System analysis

a. In phase 0 the system engineering organisation shall perform an analysis of the Mission Statement document, produce Mission Description document(s) in conformance with Annex B, and maintain this latter document for the final selected concept.

b. The system engineering organisation shall perform a functional analysis, produce the functional architecture, and produce the function tree which satisfy the customer technical requirements specification, in conformance with Annex H.

c. The system engineering organisation shall document the functional architecture in the design definition file (DDF) in conformance with Annex G.

d. The system engineering organisation shall justify the functional architecture in the DJF in conformance with Annex K.

e. The system engineering organisation shall perform a physical analysis, produce the physical architecture and produce the product tree in conformance with ECSS-M-ST-10 Annex B.

f. The system engineering organisation shall document the physical architecture in the DDF in conformance with Annex G.

g. The system engineering organisation shall justify the physical architecture in the DJF in conformance with Annex K.

h. The system engineering organisation shall analyse the performances of the system, including end-to-end evaluation, documenting the results of the analysis in the Design Justification File in conformance with Annex K.

i. The system engineering organisation shall analyse influence of mission, design, development, operations and constraints on cost and schedule as input to the project cost and schedule consolidation and to the utilisation recurring cost (design to cost).

j. The system engineering organisation shall ensure that any analysis is documented in an analysis report, in conformance with Annex Q.

5.3.2 System environments and design and test factors

a. The system engineering organisation shall establish the influence of all types of environments applied during each life profile event on system and its elements in terms of nominal and extreme environmental conditions including all applicable operational phases.

b. The system engineering organisation shall establish the criteria for qualification and acceptance in conformance with Annex K of system and system elements for all types of environment.

c. The system engineering organisation shall ensure that analyses include design induced effects between system components or the system and its external environment and account for analysis uncertainties, in conformance with Annex K.

d. The system engineering organisation shall establish the design and test factors and margins applicable for design in conformance with Annex K.

NOTE 1 Design factors are factors applied to specified loads to ensure robustness of the design.

NOTE 2 Test factors are factors applied to specified loads to demonstrate margins w.r.t. these loads (e.g. qualification / acceptance factors).

e. The system engineering organisation shall establish environment conditions for product verification.

5.3.3 Trade-off analyses

a. The system engineering organisation shall conduct or consolidate trade-off analyses to:

1. assist in selecting system concepts, designs and solutions (including people, parts and materials availability);
2. support material selection and process decisions;
3. support make-or-buy and supplier selection;
4. examine alternative technologies to satisfy functional and design requirements;
5. evaluate environmental and cost impacts of materials and processes;
6. evaluate alternative physical architectures to select preferred products and processes;
7. establish the system and its configuration items;
8. analyze planning critical paths and propose alternatives;
9. select standard components, techniques, services and facilities that reduce system life-cycle cost;
10. establish model and product verification philosophy for achieving qualification and acceptance objectives while considering testability;
11. assess design capacity to evolve.

b. The system engineering organisation shall evaluate alternative concepts, designs and solutions against each other in a Trade-off report in conformance with Annex L.

c. The system engineering organisation shall document alternative system concepts considered during system trade-off studies in a System Concept Report in conformance with Annex C.

5.3.4 Analysis methods, tools and models

a. The system engineering organisation shall define the analysis methods and tools to be used during the product life cycle, as well as the related models and data exchanges between the tools, and document these in the SEP in conformance with Annex D.

b. The system engineering organisation shall ensure that analysis tools are validated.

c. The system engineering organisation shall ensure that analysis tools are maintained.

d. The system engineering organisation shall ensure that analysis tools are capable of exchanging and using models and data.

NOTE 1 For exchange of models and data, see ECSS-E-TM-10-20 and ECSS-E-TM-10-21.

NOTE 2 Exchange can be either direct or via interfaces.

e. The system engineering organisation shall ensure that analysis tools are capable of transferring models and data for multi-disciplinary analysis.

NOTE 1 Details on product data exchange and system modelling and simulation are provided in ECSS-E-TM-10-20 and ECSS-E-TM-10-21.

NOTE 2 Exchange can be either direct or via interfaces.

f. The system engineering organisation shall ensure that models produced by analysis tools are validated based on documented procedures and results.

g. The system engineering organisation shall ensure that modelling and test accuracy as well as limitations are considered (as part of Annex K) when establishing the performances and specifying environmental conditions for product verification.

h. The system engineering organisation shall ensure that models are kept operational for the lifetime of the product.

5.4 Design and configuration

5.4.1 Design

5.4.1.1 General

a. The system engineering organisation shall establish a design of the system from its functional architecture, requirement allocation, and technology selection.

NOTE This includes definition of the interfaces and corresponding ICDs.

b. The system engineering organisation shall ensure that the design addresses system aspects, covering its whole lifecycle, producing the physical architecture documented in conformance with Annex G and the product tree in conformance with ECSS-M-ST-10 Annex B.

c. The system engineering organization shall take into account the outcome of the design and verification activities of the lower level products.

d. The system engineering organisation shall ensure that the design covers hardware, software, and man in the loop.

e. The system engineering organisation shall ensure that the design is supported by analyses consistent with the level of maturity of the design.

f. The system engineering organisation shall ensure that all interface points with the production organisation are duly supported by communication, cooperation and provision of inputs between the two organizations.

NOTE This relates to integration procedures and production master file.

5.4.1.2 Budgets

a. The system engineering organisation shall define and maintain all technical budgets of the system in conformance with Annex I in terms of target, current status and their trends.

b. The system engineering organisation shall apportion and control budget requirements to all levels of system decomposition.

c. The system engineering organisation shall apply the margin policy as defined in the SEP.

5.4.1.3 Design methods, tools and models

a. The system engineering organisation shall define the design methods, tools and related models to be used during the product life cycle and document them in the SEP.

b. The system engineering organisation shall ensure that design tools are validated and maintained.

c. The system engineering organisation shall ensure that design tools are capable of exchanging and using design models and data).

d. The system engineering organisation shall ensure that design models related to the product as documented in the final DDF and DJF are kept operational for the lifetime of the product.

e. The system engineering organisation shall ensure that design models produced by design tools shall are validated.

f. The system engineering organisation shall ensure that all design models refer to a coordinate system agreed with the customer and related to the project Coordinate System Document in conformance with ECSS-E-ST-10-09 Annex A with transformation methods as defined in ECSS-E-ST-10-09.

5.4.1.4 Design files

a. The system engineering organisation shall establish and maintain a design definition file in conformance with Annex G.

b. The system engineering organisation shall establish and maintain a design justification file in conformance with Annex K.

c. The system engineering organisation shall establish and maintain a product user's manual (PUM) or user's manual (UM) in conformance with Annex P.

NOTE In case the product considered is a space segment, the Space Segment User Manual defined in ECSS-E-ST-70 Annex E is generated with support of the system engineering organization.

5.4.2 Configuration

5.4.2.1 Configuration content

a. The system engineering organisation shall ensure that the configuration includes the complete system functional, physical and software characteristics, budgets, interfaces and relationships between external and internal items.

b. The system engineering organisation shall ensure that the configuration includes all lower decomposition levels.

c. The system engineering organisation shall ensure that the configuration is documented in the DDF and in configuration definition documents.

NOTE Details on configuration definition documents are provided in ECSS-M-ST-40.

5.4.2.2 Configuration baselines

a. The system engineering organisation shall establish the system configuration baselines to be placed under control at defined project milestones.

NOTE Details on system configuration baselines are provided in ECSS-M-ST-40.

5.4.2.3 Configuration assembly constraints

a. The system engineering organisation shall define the hierarchy and assembly sequence of the system elements with the physical architecture.

b. The system engineering organisation shall document the hierarchy and assembly sequence of the system elements with the physical architecture.

5.5 Verification

5.5.1 General

a. The system engineering organisation shall implement the product verification according to ECSS-E-ST-10-02.

NOTE By implementing the product verification as per ECSS-E-ST-10-02 the system engineering organisation defines the Verification Plan, as specified in ECSS-E-ST-10-02 Annex A.

5.5.2 Product verification

a. The system engineering organisation shall ensure that the verification of the product is performed on the physical architecture as defined in the DDF.

b. The system engineering organisation shall assign the product to a verification product category, as defined in ECSS-E-ST-10-02 Table 5-1.

c. The system engineering organisation shall specify the configuration and environment conditions for product verification and the criteria for its qualification and acceptance.

d. The system engineering organisation shall confirm that all product verification objectives are achieved by analysing the results of the verification activities.

NOTE This includes analysis of Verification Control Document and its closeout documents, as defined in ECSS-E-ST-10-02 Annex B.

e. The system engineering organisation shall ensure that validation of systems with man-in-the-loop takes into account the man related limitations.

f. The system engineering organisation shall ensure that the verification covers the complete product including hardware, software, man in the loop, operations and representative mission scenarios (including pre-launch, launch and early orbit, in-orbit, post-landing, or other mission scenario).

NOTE 1 The testing performed during and at the end of the integration of a system is defined as System Functional Test (SFT).

NOTE 2 For system composed of different segments (e.g. space segment, ground segment), the testing performed to ensure operability and functionality of the complete system is defined as System Validation Test (SVT).

5.6 System engineering integration and control

5.6.1 Management of system engineering activities

a. The system engineering organization shall define, plan, and manage the integrated technical effort in accordance with the SEP and the previous clauses of this document, including quantification of this effort as input to management.

b. The system engineering organization shall set up the system engineering organization and interfaces in accordance with the system engineering plan.

NOTE For example: to customer, to lower levels, management, product assurance, production, operations and logistics.

c. The system engineering organization shall initiate and control, in accordance with the SEP, the activities of engineering disciplines, of

product assurance, of production, and of operations and ILS relevant for the achievement of its objectives.

NOTE Examples of such activities are:

- Engineering disciplines: mechanical and thermal;
- PA: FMECA and RAMS;
- Production: producibility;
- ILS: operability, maintainability.

d. The system engineering organization shall make engineering decisions with the support and implementation of:

1. studies, trade-offs and analyses,
2. models, simulators, breadboards,
3. development activities,
4. technical optimisation efforts.

e. The system engineering organization shall ensure the availability of product and process data which enables the complete system to be produced, tested, delivered, operated, maintained, and properly disposed of.

f. The system engineering organisation shall establish a working link to the project configuration control to ensure that all binding changes resulting from engineering changes, dispositions and decisions are correctly picked- up and processed.

g. The system engineering organization shall ensure that the experience gained in past and in parallel activities is systematically considered.

5.6.2 Planning

a. The system engineering organization shall ensure that the SEP is in agreement with the project schedule.

NOTE Details on the project schedule content are provided in ECSS-M-ST-60, in particular the DRD Annex B.

5.6.3 Engineering data

a. The system engineering organization shall define the engineering data to be stored in a data repository.

b. The system engineering organization shall ensure that engineering data can be exchanged in electronic form between the different organizations in charge of the elements of the product decomposition levels via agreed and validated interfaces.

5.6.4 Interface control

a. The system engineering organization shall control external interfaces as well as internal interfaces to the system by means of technical requirements specification in conformance with ECSS-E-ST-10-06 Annex A and interface control documents in conformance with ECSS-E-ST-10-24 Annex A.

NOTE 1 The control of the external interfaces is performed in cooperation with the parties involved in the interface.

NOTE 2 Interface requirements can be rolled-out of the technical specification as interface requirements documents

b. When the interface requirements are rolled out in a self standing IRD, this document shall be in conformance with Annex M.

c. All interface requirements shall be accompanied by their verification requirements.

5.6.5 Coordinate systems and units

a. The system engineering organisation shall define the coordinate systems and related units in conformance with the Coordinate System Document DRD ECSS-E-ST-10-09 Annex A.

b. The system engineering organisation shall define the units system to be used during the product life cycle and document it in the SEP.

5.6.6 Technical budgets and margin policy

a. The system engineering organization shall control all technical budgets defined in conformance with Annex I.

b. The system engineering organization shall define the margin policy as applicable to the maturity level of the product.

NOTE Details are provided in the system engineering plan in Annex D <4.2>b.5.).

5.6.7 Technology

a. The system engineering organization shall identify candidate technologies, and document them in the Technology Matrix in conformance with Annex F.

b. The system engineering organization shall ensure that the technologies proposed are assessed and confirmed in terms of availability and maturity (according to TRL levels defined in 3.2.12), and documented in the Technology Plan in conformance with Annex E.

c. The system engineering organization shall demonstrate supportability and feasibility within the defined industrial organization's cost and schedule constraints.

5.6.8 Risk control

a. The system engineering organization shall contribute to the identification of the risk and of its mitigation measures.

b. The system engineering organization shall ensure the availability of engineering data and approaches in support of risk management.

NOTE Details on risk management are provided in ECSS-M-ST-80.

c. The system engineering organization shall implement and control the elements of the risk management plan which are within system engineering responsibility.

5.6.9 Changes and nonconformances control

a. The system engineering organization shall provide a technical assessment on any change proposal to the baseline of the product.

b. The system engineering organization shall provide a technical assessment on any nonconformance to the status of the product.

c. The system engineering organization shall implement and control agreed actions.

NOTE 1 Change is related to a request for deviation.

NOTE 2 Nonconformance is related to a request for waiver.

NOTE 3 The change procedure/control is defined as part of the configuration management as defined in ECSS-M-ST-40.

6
Overview of system engineering tasks per project phase

6.1 Overview

The allocation of specific system engineering requirements per phase depends strongly on the type of business agreement established between Customer and Supplier and the nature and level of complexity of the system subject of the agreement. The breakdown and the details of the tasks are defined in the business agreement specific documents.

NOTE Some projects define them in a Statement of work (SoW).

The actors in the customer-supplier relationship change between phases and across levels. In the following clauses each system engineering organisation is meant to be the supplier's system engineering organisation during that phase.

6.2 General

a. The system engineering organisation shall plan its activities in conformance with the project phases as defined by management.

NOTE The phases or combination thereof to be implemented for a project are specified in the business agreement.

b. The system engineering organisation shall plan the system engineering activities for the considered project phases in accordance with ECSS-M-ST-10.

NOTE This includes contribution to the associated reviews.

c. The system engineering organization shall monitor the execution of all system engineering activities including lower levels.

NOTE For details regarding system engineering activities, see ECSS-E-HB-10.

d. The system engineering organisation shall identify the critical elements.

e. The system engineering organisation shall ensure that for critical elements which are not at the next lower level, the technical requirements

specification, the design definition file and the design justification file are available early in the project to control the project risk.

NOTE Information regarding the expected delivery of system engineering documents for each project review is provided in Annex A.

The documents to be approved by the customer as well as the time of their approval are listed in the business agreement.

6.3 Phase 0: Mission analysis-need identification

a. The system engineering organization shall support the customer in identifying his needs.

b. The system engineering organization shall propose possible system concepts.

c. The system engineering organization shall support the MDR and ensure implementation of the MDR actions.

6.4 Phase A: Feasibility

a. The system engineering organization shall finalise the expression of the needs identified in Phase 0.

b. The system engineering organization shall propose solutions (including identification of criticalities and risks) to meet the perceived needs.

c. The system engineering organization shall support the PRR and ensure implementation of PRR actions.

6.5 Phase B: Preliminary definition

a. The system engineering organization shall establish the system preliminary definition for the solution selected at end of Phase A.

b. The system engineering organization shall demonstrate that the solution meets the technical requirements according to the schedule, the budget, the target cost and the organization requirements.

c. The system engineering organization shall support the SRR and PDR, and ensure implementation of the SRR and PDR actions.

6.6 Phase C: Detailed definition

a. The system engineering organization shall establish the system detailed definition.

b. The system engineering organization shall demonstrate its capability to meet the technical requirements of the system technical requirements specification.

c. The system engineering organization shall support the CDR and ensure implementation of the CDR actions.

6.7 Phase D: Qualification and production

a. The system engineering organization shall finalize the development of the system by qualification and acceptance.

b. The system engineering organization shall finalize the preparation for operations and utilization.

c. The system engineering organization shall support QR and AR and ensure implementation of the QR and AR actions.

6.8 Phase E: Operations / utilization

a. The system engineering organization shall support the launch campaign.

b. The system engineering organization shall support the entity in charge of the operations and utilization following the terms of a business agreement.

c. The system engineering organization shall support the FRR, ORR, LRR, CRR, ELR, and recurring products AR, and ensure implementation of the actions of those reviews.

d. The system engineering organization shall ensure execution of all system engineering activities and provision of documents in support to anomaly investigations and resolutions.

NOTE Phase E and its reviews as presented in Table A-1 refer only to mission level. In case of lower level product, activities to be considered by the system engineering organisation are only related to maintenance and anomaly investigations.

6.9 Phase F: Disposal

a. The system engineering organization shall support the entity in charge of the disposal following the terms of a business agreement.

b. The system engineering organization shall support the MCR and ensure implementation of the actions of the MCR.

NOTE Phase F and its review as presented in Table A-1 refer only to mission level. In case of lower level product, activities to be considered by the system engineering organisation are only related to disposal.

Annex A (informative) System engineering documents delivery per review

Scope of the Table A-1 is to present relation of documents associated to engineering activities to support project review objectives as specified in ECSS-M-ST-10.

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

The table lists the documents generated by the engineering organization necessary for the project reviews (identified by "+"), except for verification documents, which are identified in Table G-1 of ECSS-E-ST-10-02.

The various crosses in a row indicate the increased levels of maturity progressively expected versus reviews. The last cross in a row indicates that at that review the document is expected to be completed and finalized.

For the SEP, DDF and DJF, the elements of these documents which are not identified by a "+" in the table are not expected to be delivered for the quoted review.

NOTE All documents, even when not marked as deliverables in Table A-1, are expected to be available and maintained under configuration management as per ECSS-M-ST-40 (e.g. to allow for backtracking in case of changes).

Documents listed in Table A-1 are either ECSS-E-ST-10 DRDs, or DRDs to other ECSS-E-XX, ECSS-M-XX, or ECSS-Q-XX standards, or defined within the referenced DRDs.

Table A-1: System engineering deliverable documents

Document title	ECSS document	DRD ref.	Phase 0	Phase A	Phase B		Phase C	Phase D			Phase E				Phase F
			MDR	PRR	SRR	PDR	CDR	QR	AR	ORR	FRR	LRR	CRR	ELR	MCR
Mission description document	ECSS-E-ST-10	Annex B	+	+											
Specifications															
Preliminary technical requirements specification	ECSS-E-ST-10-06	Annex A	+	+											
Technical requirements specification	ECSS-E-ST-10-06	Annex A			+										
Interface requirements document	ECSS-E-ST-10	Annex M		+	+	+									
System engineering plan	ECSS-E-ST-10	Annex D	+	+	+	+	+	+	+						
Technology plan	ECSS-E-ST-10	Annex E		+	+	+									
Technology matrix	ECSS-E-ST-10	Annex F		+	+	+									
Verification plan	ECSS-E-ST-10-02	Annex B		+	+	+	+	+	+						
AIT QM/FM plan	ECSS-E-ST-10-03	Annex A				+	+	+	+						
Orbital debris mitigation plan	ISO 24113		+	+	+	+	+	+	+	+	+	+		+	+
Other related plans (as called in ECSS-E-ST-10 Annex D)				+	+	+	+	+	+						
Coordinate system document	ECSS-E-ST-10-09	Annex A		+	+	+	+	+							

Document title	ECSS document	DRD ref.	Phase 0	Phase A	Phase B		Phase C	Phase D			Phase E				Phase F
			MDR	PRR	SRR	PDR	CDR	QR	AR	ORR	FRR	LRR	CRR	ELR	MCR
Design definition file	ECSS-E-ST-10	Annex G		+	+	+	+	+							
Function tree	ECSS-E-ST-10	Annex H		+	+	+									
Product tree	ECSS-M-ST-10	Annex B		+	+	+									
Specification tree	ECSS-E-ST-10	Annex J			+	+									
Technical budget	ECSS-E-ST-10	Annex I		+	+	+	+	+	+						
Preliminary technical requirements specifications for next lower level	ECSS-E-ST-10-06			+	+										
Technical requirements specifications for next lower level	ECSS-E-ST-10-06				+	+									
Design definition file for next lower level						+	+	+	+						
Interface control document	ECSS-E-ST-10-24	Annex A			+	+	+	+	+	+	+	+			
Product User manual / User Manual	ECSS-E-ST-10	Annex P					+	+	+	+	+	+	+	+	+
Design justification file	ECSS-E-ST-10	Annex K		+	+	+	+	+							
Requirements traceability matrix w.r.t. next lower level	ECSS-E-ST-10	Annex N		+	+	+									
Requirement justification file	ECSS-E-ST-10	Annex O	+	+	+	+									
System concept report	ECSS-E-ST-10	Annex C	+	+											
Trade off reports	ECSS-E-ST-10	Annex L	+	+	+	+	+								

Document title	ECSS document	DRD ref.	Phase 0	Phase A	Phase B		Phase C	Phase D			Phase E				Phase F
			MDR	PRR	SRR	PDR	CDR	QR	AR	ORR	FRR	LRR	CRR	ELR	MCR
Verification control document	ECSS-E-ST-10-02	Annex C		+(1)	+(1)	+(1)	+	+	+	+	+	+	+	+	+
Test specification	ECSS-E-ST-10-03	Annex D					+	+	+	+	+	+	+	+	+
Analysis report	ECSS-E-ST-10	Annex Q		+	+	+	+	+	+	+	+	+	+	+	+
Mathematical model description					+	+	+	+							
Correlation report							+	+							
Test procedure	ECSS-E-ST-10-03	Annex C					+	+	+	+	+				
Test report	ECSS-E-ST-10-02	Annex D					+	+	+	+	+	+	+	+	+
Verification report	ECSS-E-ST-10-02	Annex H					+	+	+	+	+	+	+	+	+
Design justification file for next lower level							+	+	+						
Review of design report	ECSS-E-ST-10-02	Annex F					+	+							
Inspection report	ECSS-E-ST-10-02	Annex G					+	+	+						
GSE specifications						+	+	+	+						
GSE Data packages							+	+	+						
Other documents															

Note (1) : Document limited to the verification matrix

Annex B (normative) Mission description document (MDD) – DRD

B.1 DRD identification

B.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.3.1a.

B.1.2 Purpose and objective

The objective of the mission description document (MDD) is to provide input for the later selection of the best concept meeting the mission statement (MS) in iteration with the preparation of the preliminary technical requirements specification (TS) (as defined in ECSS-E-ST-10-06 Annex A).

It is prepared in Phase 0 and Phase A for each possible concept, as indicated in requirement 5.3.1a.

Links and chronology amongst the MS, TS, MDD, system engineering plan, project management plan and system concept report are provided on the Figure B-1.

The MDD is produced by system engineering organization of the mission responsible (typically an Agency or other institutional actors)) and defines a concept that aims at satisfying the preliminary technical requirements specification, and presents how the objectives, operation profile, major system events and capabilities, contingencies and performance standards are expected to be achieved.

For each mission concept, the MDD is a complete description of that concept. And to each MDD a SEP evaluating the related system engineering effort and a report evaluating the related programmatic aspect are associated.

The system concept report assesses the different concepts from a technical, programmatic and risk point of view, includes a trade-off including weighting factors which bears some management aspects, followed by a system concept selection.

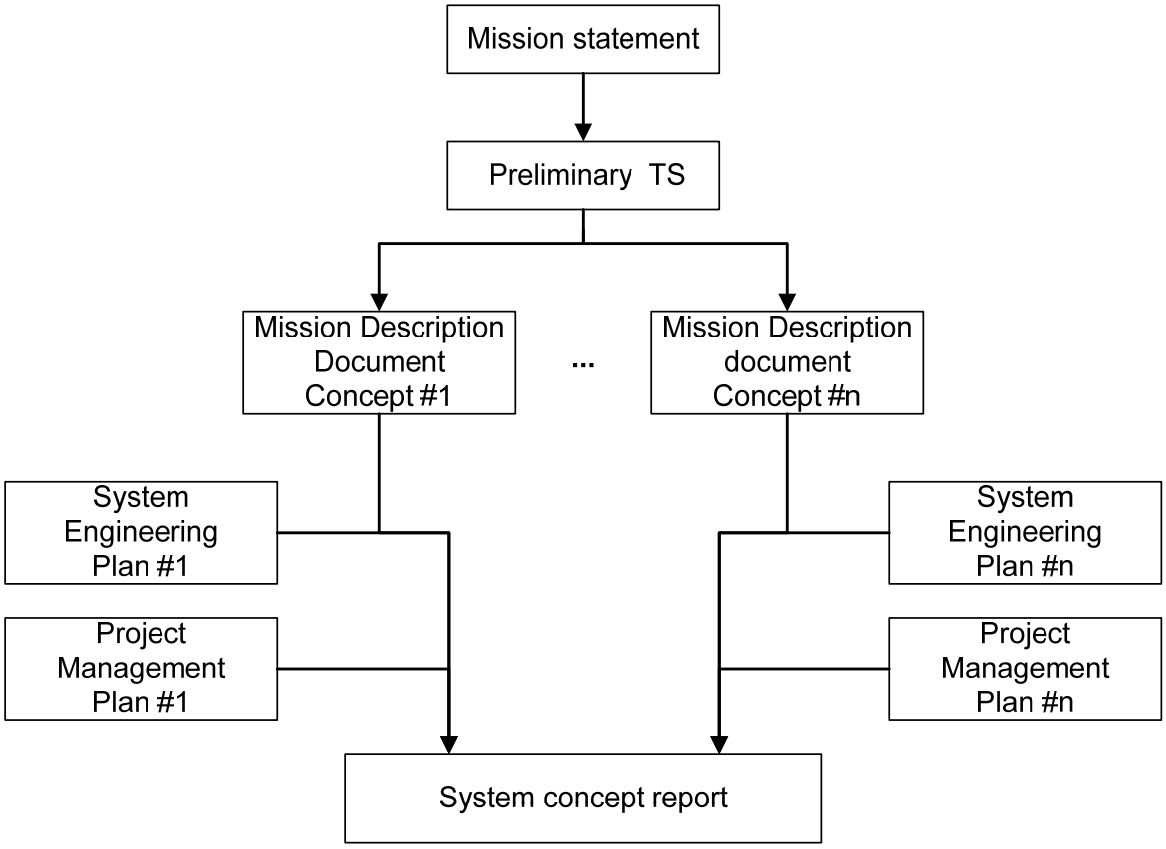

Figure B-1: Relationship between documents

B.2 Expected response

B.2.1 Scope and content

<1> Introduction

a. The MDD shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. logic, organization, process or procedure).

<2> Applicable and reference documents

a. The MDD shall list the applicable and reference documents in support to the generation of the document, and include, as a minimum, the current preliminary technical requirements specification.

<3> Preliminary technical requirements specification summary

a. The MDD shall provide a summary of the preliminary technical requirements specification objectives and list the design driving requirements, derived from the current initial specification.

<4> Concept description

a. The MDD shall provide:

1. Overview of the concept
2. Mission analysis
3. System description, element by element

NOTE For example: For a spacecraft, its ground control segment, and a user segment, e.g.

Space Segment

- Payload
- Platform
- Launch Vehicle
- Orbit related aspects
- On-Board Data Handling
- Reference Operation Scenarios / Observation characteristics
- Operability / Autonomy Requirements

Ground Segment

- Functional Requirements and Major Elements
- Monitoring and Control Segment
- Data Processing Segment

User segment

- Functional Requirements and Major Elements
- Monitoring requirements

b. Description of how the system works in each mission phase

1. Performance drivers
2. Constraints
3. Main events
4. Operations scenarios

NOTE For example: For a spacecraft, the following phase:

- Launch preparation
- Launch and Early Orbit Phase
- In Orbit Commissioning
- Nominal Operations
- Spacecraft Disposal

<5> Assessment of the performance

a. The MDD shall provide the

1. assessment against the current preliminary technical requirements specification requirements, and
2. identification of non-compliances, and their impact on the current preliminary technical requirements specification.

<6> Identification of risk areas

a. The MDD shall provide the list of identified risk related to the concept, including as a minimum technology, contingencies handling, and programmatic aspects.

<7> Conclusion

a. The MDD shall summarize the strengths and weaknesses of the concept.

B.2.2 Special remarks

None.

Annex C (normative)
System concept report – DRD

C.1 DRD identification

C.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.3.3c.

C.1.2 Purpose and objective

The system concept report describes the principal technical characteristics of alternative system concepts, relating to performance, architectures, driving technologies, interfaces, risk, their evaluation and classification, and later addresses the selected concept.

C.2 Expected response

C.2.1 Scope and content

a. The system concept report shall be an instantiation of the trade-off report at system level in Phase 0 and Phase A of a project, conforming to ECSS-E-ST-10 Annex L.

NOTE The system concept report can be extended to Phase B where needed (e.g. late trade-offs).

b. This report shall address all technical (e.g. engineering disciplines), programmatic and related aspects relevant to the system.

c. Where relevant, specific e.g. discipline trade-off's shall be performed, contributing to the system trade-off, each one being reported in a document conforming to ECSS-E-ST-10 Annex L.

C.2.2 Special remarks

None.

Annex D (normative)
System engineering plan (SEP) – DRD

D.1 DRD identification

D.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirements 5.1a and 5.3.4a.

D.1.2 Purpose and objective

The objective of the system engineering plan (SEP) is to define the approach, methods, procedures, resources and organization to co-ordinate and manage all technical activities necessary to specify, design, verify, operate and maintain a system or product in conformance with the customer's requirements. In particular the SEP is established to fulfil the major technical project objectives, taking into account the defined project phases and milestones (as defined in ECSS-M-ST-10).

The SEP covers the full project lifecycle according to the scope of the business agreement. It is established for each item of the product tree (as defined in ECSS-M-ST-10).

It highlights the risks, the critical elements, the specified technologies, as well as potential commonalities, possibilities of reuse and standardization, and provides means for handling these issues.

The SEP is an element of the project management plan (as defined in ECSS-M-ST-10).

NOTE It is important to adapt the SEP content to the phase of the project, with more information on risk analysis and new technologies in early phases 0, A and B, and more information on verification and validation aspects in phases C, D.

D.2 Expected response

D.2.1 Scope and content

<1> Introduction

a. The SEP shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. programme or project reference and phase).

<2> Applicable and reference documents

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

b. The SEP shall include the references to the following applicable documents:

1. Business agreement
2. Project management plan, as defined in ECSS-M-ST-10 Annex A
3. Product assurance plan, as defined in ECSS-Q-ST-10 Annex A
4. Configuration management plan, as defined in ECSS-M-ST-40 Annex A
5. Production plan
6. Mission operations plan, as defined in ECSS-E-ST-70 Annex G
7. ILS plan.

<3> Project overview

<3.1> Project objectives and constraints

a. The SEP shall contain the following description of:

1. The project objective and the main elements that characterize the user's need.
2. The objective of the system or product as established by the TS (as defined in the ECSS-E-ST-10-06 Annex A).
3. The main elements of the system architecture (i.e. first level elements of the architecture adopted for the system and identification of their reuse constraints).
4. The principal characteristics of the project lifecycle and the incremental development of the system (e.g. successive versions, progressive implementation of system functions).
5. The main elements supporting the project lifecycle (e.g. ground support equipments, and facilities).

6. The organizational constraints impacting system engineering activities (e.g. the external and internal industrial organization (e.g. contractors, partners, suppliers, own company) constraints).
7. The list of the critical issues identified at the beginning of the project phase(s).
8. The list of national and international regulations.
9. The capacity for verification and validation of the product, taking into account the means available, e.g. for tests, analysis, or simulation.

<3.2> Product evolution logic

a. The SEP shall detail the incremental development of the system:
   1. progressive implementation of system functionalities,
   2. identification of possible successive versions,
   3. objectives and strategy for the implementation of the successive versions.

<3.3> Project phase(s), reviews and planning

a. The SEP shall provide an implementation and schedule of the system engineering activities and identify for the considered phase(s), as a minimum:
   1. the main project milestones driving the system engineering process,
   2. the phase(s) of the project lifecycle and the main reviews in accordance to project management plan.

b. The SEP shall provide dates of milestones or the duration of phases and the critical path according to the project master schedule.

<3.4> Procurement approach

a. The SEP shall describe the strategy for acquisition of the items of the system or products defined in the product tree (e.g. make or buy, product line, incremental development).

<3.5> Initial critical issues

a. The SEP shall list the critical issues identified at the beginning of the project phase(s) covered in the SEP (e.g. any specific issues, problems, critical subjects, which require dedicated attention, investigation, action and planning).

<4> System design approach

<4.1> System engineering inputs

a. The SEP shall list the driving inputs for the system engineering activities described and defined by the:
   1. business agreement,

2. outputs from previous phase(s) or expected under the heading of activities which are not controlled within the context of this SEP (e.g. data provided by the customer, data coming from other projects, upstream or predevelopment studies, product lines),

3. project management plan, product assurance plan, risk management plan, and configuration and documentation management plans.

b. The SEP shall list the external means and facilities (e.g. equipment, software, and premises) made available by the customer or by any other entity external to the organization that is responsible of this SEP, and, for each identified mean or facility, identify the applicable interface requirements (e.g. interface control documentation) as well as the authority in charge of it.

c. The SEP shall list the internal means and facilities (e.g. equipment, software, and premises) made available by the organization in charge of the development of the system or product.

d. The SEP shall contain the Coordinate System Document (as defined in ECSS-E-ST-10-09 Annex A).

e. The SEP shall define the units system to be used in the project.

<4.2> System engineering outputs

a. The SEP shall list the specified system engineering outputs as defined in ECSS-E-ST-10 clause 6 for the specific project phase(s) covered in the SEP.

NOTE An overview of document delivery is given in Annex A.

b. The SEP shall describe the following:

1. The strategy for the system engineering activities in line with the guidelines addressed by the management plan. In particular, identifying intermediate technical events for each phase in compliance with the master program schedule.

2. The system design activities, with their objectives and major outputs according to the phase.

3. The major engineering activities for each intermediate technical events, showing their mutual interactions and their relationships with the principal milestones (i.e. internal or contractual) of the project.

4. The model philosophy (as defined in ECSS-E-ST-10-02 clause 4.2.5) in terms of number and characterization of models, from system to the requested lower level, necessary to achieve a high confidence in the product verification.

5. The margin policy according to project phase, product category and maturity level.

c. The SEP shall also describe

1. the method(s) and process(es) considered for the engineering activities (e.g. concurrent engineering, value analysis, or iteration cycle),

2. the interrelation between the different engineering disciplines and other project activities (e.g. production, quality assurance, and operations and logistics),
3. the interaction with other actors (e.g. customer and suppliers),
4. the consistency and coherency of simultaneous activities (e.g. performed in parallel),
5. which and how, control activities are implemented,
6. Assessment of potential COTS usage

d. In the case of a system incremental evolution, the SEP shall describe the design strategy for the:
1. development of the initial release of the product,
2. development, the verification of subsequent releases and their deployment,
3. introduction of new technologies,
4. tools and methods used for analysis,
5. control of the evolutions for each release.

<4.3> System engineering team responsibilities and organization

a. The SEP shall contain the following:
1. Definition of the entities participating in the system engineering activities and the corresponding functions according to the project management plan.
2. Identification of key engineering roles and responsibilities (e.g. system engineers, disciplines engineers, and technical managers).
3. Description of the co-operative work amongst the different teams participating in the system design.

<4.4> System engineering interfaces

a. The SEP shall describe the external and internal interfaces in line with the project management plan.

<5> Implementation and related plans

<5.1> System engineering tasks description

<5.1.1> System engineering process description

a. The SEP shall describe the system engineering process tailored to the specifics of the considered project, and identify all the system engineering tasks to be implemented from the starting conditions (e.g. kick-off) to the closing event (e.g. review), their relationship, and their interfaces with other actors of the project, and identify and describe any existing iteration within the process.

NOTE Details are provided in ECSS-E-HB-10 “System engineering guidelines”.

b. For each task, the input information and their origin, the document(s) delivered (i.e. expected output) and their destination, the system engineering function(s) performed and the contribution of other actors shall be identified.

NOTE Details are provided in ECSS-E-HB-10 "System engineering guidelines".

<5.1.2> Engineering disciplines integration

a. The SEP shall address the following activities that concern the different engineering disciplines, recalling the relevant applicable standards and ancillary dedicated plans that are considered integral part of this SEP.

b. The SEP shall define the process and control to be put in place to meet requirements for the thermal, structures, mechanisms, environmental control and life support, propulsion, pyrotechnics, mechanical parts, and materials functions and interfaces.

NOTE These requirements refer to Mechanical engineering as defined in ECSS-E-ST-3x series of standards.

c. The SEP shall define the process and control to be put in place to meet requirements for electrical and electronic engineering, covering all electrical and electronic aspects of the relevant space product, including functions such as power generation, storage, conversion and distribution, and optical, avionics and microwave domains, electromagnetic compatibility, and electrical interfaces.

NOTE These requirements refer to Electrical and electronic engineering as defined in ECSS-E-ST-20.

d. The SEP shall define process and control to be put in place to meet requirements for software engineering, covering, amongst others, flight and ground software, checkout software and simulation software.

NOTE These requirements refer to Software engineering as defined in ECSS-E-ST-40.

e. The SEP shall define process and control to be put in place to meet requirements for communication engineering, covering, amongst others, spacecraft-to-ground, spacecraft-to-spacecraft, ground-to-ground and on-board communications links.

NOTE 1 These requirements refer for Communications engineering as defined in ECSS-E-ST-50.

NOTE 2 It includes aspects such link budgets, data management, RF, audio and video communications and protocols.

f. The SEP shall define process and control to be put in place to meet requirements for control engineering, covering, amongst others, AOCS, robotics, rendez-vous and docking.

NOTE These requirements refer to Control engineering as defined in ECSS-E-ST-60.

g. The SEP shall define the process and control to be put in place to meet requirements specifying natural environment for all space regimes (e.g. debris regulations, or planetary contamination protection) and general models and rules for determining the local induced environment

NOTE These requirements refer to Space environment as defined in ECSS-E-ST-10-04.

h. The SEP shall define the process and control to be put in place to meet requirements for the approach, methods, procedures, organization and resources to be implemented to ensure proper technical interfaces between system engineering and production.

i. The SEP shall define the process and control to be put in place to meet requirements of operations of the space segment, covering, amongst others:

1. mission operation definition and preparation,
2. mission and trajectory analysis, and
3. operability analysis (e.g. autonomy, operational scenario, nominal and non-nominal modes, failure detection isolation and recovery).

NOTE These requirements refer to Operations engineering as defined in ECSS-E-ST-70.

j. The SEP shall define the process and control to be put in place to meet requirements for ground and in-orbit logistics and maintenance, addressing, amongst others, technical activities, related engineering standards, methods and analyses to be performed to ensure that the development of space systems (i.e. manned and unmanned) properly takes into account and integrates the supportability and support aspects for the whole life cycle.

k. The SEP shall define the process and control to be put in place to meet requirements for human activities and environments associated with space systems.

NOTE These requirements refer to Human factors engineering as defined in ECSS-E-ST-10-11.

l. The SEP shall define process and control to be put in place to meet requirements for implementation of design selections relating to humans for any item with associated human interface, including computer based system and equipment.

<5.1.3> Work package

a. The SEP shall define and describe the work package(s) for the relevant engineering tasks, which are maintained in the work breakdown structure.

<5.2> Related plans

a. When the SEP includes sub-plans covering parts of system engineering activities, these sub-plans shall be annexed to the SEP.

b. The system engineering organization shall identify in the SEP the other plans relevant to its activity belonging to the following categories:

NOTE Some of these plans can be integrated in the SEP in the early phases of a project.

1. Programmatic plans

   NOTE Examples of programmatic plans are: the SEP plans of sub-products constituting the system or product, Industrial procurement plan, risk management plan, off-the-shelf plan (see ECSS-Q-ST-20-10).

2. Verification plans

   NOTE 1 Examples of verification plans are: verification plan (VP), AIT plan, AIV plan and technology plan, system calibration plan, Security Aspects Verification Plan. Some of those DRDs are defined in this document, in ECSS-E-ST-10-02 or ECSS-E-ST-10-03.

   NOTE 2 VP and AIT plans can be integral parts of the SEP, or rolled out separately (without overlap), or combined as the AIV Plan which can also be rolled out separately. However, the existence of the AIV Plan excludes independent VP and AIT plans

3. Engineering discipline plans

   NOTE Examples of engineering discipline plans are: Fracture Control Plan (see ECSS-E-ST-32), Micro-gravity Control Plan, Electro-Magnetic Compatibility Plan (see ECSS-E-ST-20), Audible Noise Control Plan, Radio Frequency Plan, Alignment Requirements and Control Plan, System Performance Simulations Plan, Software Development Plan, Orbital Debris Mitigation Plan and Disposal Plan (as defined in ISO 24113), Planetary protection Plan, Cleanliness and Contamination Control Plan.

4. Operations plans

   NOTE Examples of operation plans are: launch site operations and logistics plan, system commissioning and operation support plan,

c. The SEP shall describe the constraints and the interactions impacting the system engineering activities derived from the analysis of the plans identified as relevant in D.2.1<5.2>b.

<5.3> System engineering methods, tools and models

a. The SEP shall list and briefly describe the methods, tools, and data models that the system engineering team uses in performing their tasks.

b. In relation to requirements traceability and demonstration of verification (compliance with requirements, VCD), the specific methods and tools shall be described (including interfaces to next lower level suppliers), and reuse of elements (e.g. COTS) identified.

<5.4> Critical issues

a. The SEP shall describe any specific issues, problems requiring dedicated attention, investigations or actions during the current phase and identify risks, and risk mitigation measures.

<6> System engineering for the following phase(s)

a. The SEP shall introduce the system engineering activities, to be conducted during subsequent phase(s) of the project, and as a minimum, list any identified critical issue and risk to be mitigated during the subsequent phase(s).

D.2.2 Special remarks

None.

Annex E (normative) Technology plan (TP) – DRD

E.1 DRD identification

E.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.6.7b.

E.1.2 Purpose and objective

The objective of the technology plan (TP) is to define the approach, methods, procedures, resources and organization to evaluate the ability of a critical technology to meet the intended requirements. Also, the objective of this plan is to ensure effective preparation of the technologies necessary for a timely implementation of the system, in accordance to the requirements imposed by the specific characteristics of the relevant product.

It is established for each item of the function tree (as defined in ECSS-E-ST-10, Annex H), and highlights the technical requirements, and the critical technology of each item.

The TP is part of the system engineering plan (SEP) (as defined in ECSS-E-ST-10, Annex E).

E.2 Expected response

E.2.1 Scope and content

<1> Introduction

a. The TP shall contain a description of the purpose, objective, content and the reason prompting its preparation (e.g. programme or project reference and phase).

<2> Applicable and reference documents

a. The TP shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents:

1. SEP
2. Technology matrix (as defined in ECSS-E-ST-10, Annex F)
3. Function tree
4. Specification tree.

<3> Project overview

a. The TP shall contain a summary of the main aspects of:

1. project objectives and constraints (i.e. section <3.1> of ECSS-E-ST-10, Annex D "SEP DRD");
2. product evolution logic (i.e. section <<3.2> of ECSS-E-ST-10, Annex D "SEP DRD");
3. project phase(s), reviews and planning (i.e. section <3.3> of ECSS-E-ST-10, Annex D "SEP DRD"),
4. Procurement approach (i.e. section <3.4> of ECSS-E-ST-10, Annex D "SEP DRD")

<4> Tasks description

<4.1> TP expected outputs

a. The TP expected output shall be an answer concerning the possibility for using the identified or needed technology to perform a function.

<4.2> TP inputs

a. For each system function, the TP input shall be:

1. technical requirements,
2. the selected technology or technological element and its TRL,
3. the list of the identified project risks and critical aspects, and
4. the schedule for Engineering activities.

<4.3> TP tasks

a. The TP shall establish and describe the necessary activities to complete the acquisition of each technology or technological element, including verification strategies and methods, and the link to product assurance aspects.

b. The TP shall define the model philosophy for each technology or technological element, based on an assessment on the maturity status and on the criticality of the technology with respect to functions' requirements.

c. The TP shall describe the technology development activities, their required or possible interrelations and timings, as necessary for the satisfactory acquisition of the technologies and procurement of the technological elements.

d. The TP shall identify technical milestones, showing their interactions and relationships with the SEP milestones.

<4.4> Responsibilities and organization

a. The TP shall contain the following:

1. definition of the entities participating in the engineering activities and the corresponding functions according to the SEP;
2. identification of key engineering roles and responsibilities for each technology or technological element.

<4.5> TP interfaces

a. The TP shall describe the external and internal interfaces in conformance to the SEP.

<5> Critical issues

a. The TP shall describe, for any identified technology risk and related critical aspects for the project, the specific actions taken for risk mitigation based on identified technology readiness level (TRL).

E.2.2 Special remarks

a. The content of the TP may be merged with the content of the SEP.

b. The TP shall introduce the related activities, to be conducted during all phase(s) of the project.

Annex F (normative) Technology matrix - DRD

F.1 DRD identification

F.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.6.7a.

F.1.2 Purpose and objective

The technology matrix presents, for each technical requirement/function, the list of technologies or technological elements, which have the potential to meet this requirement. It summarizes candidate technologies per individual requirement.

The technology matrix is part of the Design Justification File (as defined in ECSS-E-ST-10, Annex K). It is the basic document for presenting all identified potential technologies for the product.

F.2 Expected response

F.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

a. The technology matrix shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents:

1. Specification tree
2. Preliminary technical requirements specifications
3. Function tree.

<3> List of technical requirements/functions

a. The technology matrix shall list the system technical requirements/functions as defined in the functional architecture and its corresponding function tree, and their associated preliminary TS.

<4> List of potential technologies for each technical requirement/function

a. The technology matrix shall list the system technical requirements/functions and for each, a potential technology or technological element.

NOTE Sources to identify potential technologies are technology watch, corporate technology plan, or research and development programme.

b. For each technology or technological element, the following information shall be listed:

1. index of technology readiness and maturity as defined in proposed table in definition 3.2.12 “technology readiness level”;
2. proof of company's maturity concerning the knowledge and mastership of the technology, including a description of the necessary technology acquisition activities;
3. identification of potential risks, e.g. technology availability, programmatic and financial aspects.

<5> Ranking of the potential technologies for each function

a. The technology matrix shall propose a ranking of the potential technology or technological element for each system requirement/ function.

<6> Conclusion

a. The technology matrix shall provide, for each system requirement/function, the selected technology or technological element, a list of the identified project risks and critical aspects, and an identified back-up technological solution.

F.2.2 Special remarks

None.

Annex G (normative)
Design definition file (DDF) - DRD

G.1 DRD identification

G.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirements 5.3.1c, 5.3.1f, 5.4.1.1b and 5.4.1.4a.

G.1.2 Purpose and objective

The objective of the design definition file (DDF) is to establish the technical definition of a system or product that complies with its technical requirements specification (as defined in ECSS-E-ST-10-06 Annex A).

The design definition file is a basic structure referring to all information relative to the functional and physical architectures and characteristics of a system or product, necessary for its identification, manufacturing, utilization, support, configuration management and removal from service.

The DDF is a collection of all documentation that establishes the system or product characteristics such as lower level technical specifications, design and interface description, drawings, electrical schematics, specified constraints (e.g. on materials, manufacturing, processes, and logistic).

It details the as-designed configuration baseline (as defined in ECSS-M-ST-40) of the system or product and is built up and updated under the responsibility of the team in charge of system engineering. It is the technical baseline for the production, assembly, integration and test, operations and maintenance of the product.

The DDF, the technical requirements specification, and the Design Justification File (as defined in ECSS-E-ST-10 Annex K) are the basic documents used for product development. They are interrelated such as:

- the design (i.e. DDF) is the response to the requirements stated in the TS,
- the justification (i.e. DJF) demonstrates the conformance of the design (i.e. DDF) to the requirements stated in the TS.

NOTE The DDF is a logical file covering all TS disciplines required for the considered system. In general, the elements of the DDF are “rolled out” as separate documents.

G.2 Expected response

G.2.1 Scope and content

<1> Introduction

a. The DDF shall contain a description of the purpose, objective and the reason prompting its preparation (e.g. programme or project reference and phase).

<2> Applicable and reference documents

a. The DDF shall contain the list of applicable and reference documents, used in support to the generation of the document.

b. The DDF shall include the reference to the following applicable documents:

1. Business agreement
2. System engineering plan (as defined in ECSS-E-ST-10 Annex D)
3. Coordinate system document (as defined in ECSS-E-ST-10-09 Annex A)
4. Technical requirements specification (TS)
5. Product assurance plan
6. Configuration management plan (as defined in ECSS-M-ST-40)
7. Configuration status report (as defined in ECSS-M-ST-40).

c. The DDF shall refer to DDFs of next higher and lower level products.

<3> Summary of the project and technical requirements

a. The DDF shall contain a brief description of the product and of the main technical requirements throughout its life cycle phases (e.g. launch, deployed, operations, end-of-life).

b. The DDF shall contain the description of the system or product design documentation, based on the product tree (as defined in ECSS-M-ST-10) and also include, or refer to, the specifications tree (as defined in ECSS-E-ST-10 Annex J).

c. The DDF of a system shall contain at least the technical requirements specifications of the elements in which the system is broken down

<4> Functional description

<4.1> Functional architecture

a. The DDF shall contain the description of the functional architecture of the system or product i.e. the arrangement of functions, their sub-functions

and interfaces (internal and external), and the performance requirements to satisfy the requirements of the TS.

b. The DDF shall present the data and their flow interchanged between the different functions, the conditions for control, and the execution sequencing for the different operational modes and states.

NOTE The Functional Architecture is an output of the functional analysis process (as defined in ECSS-E-ST-10 clause 5.3.1a)

<4.2> Function tree

a. The DDF shall contain or refer to the system or product function tree, the latter conforming to ECSS-E-ST-10 Annex H.

<4.3> Description of functional chains

a. The DDF shall describe the functional chains that contribute to the realization of the functional requirements of the TS and their contributing functions, consider the different operational modes and states, and indicate the selected physical implementation for each of the functions.

<5> Physical description

<5.1> Physical architecture

a. The DDF shall contain the description of physical architecture of the system or product i.e. the arrangement of elements, their decomposition, interfaces (internal and external), and physical constraints, which form the basis of a system or product design to satisfy the functional architecture and the technical requirements.

NOTE The Physical Architecture is an output of the preliminary design definition activities (as defined in clause 5.3.1f).

<5.2> Product tree

a. The DDF shall contain or refer to the product tree of the system or product, as defined in ECSS-M-ST-10 Annex B.

NOTE The Product Tree is a breakdown of the Physical Architecture.

<5.3> Specification tree

a. The DDF shall contain or refer to the specification tree of the system or product, the latter conforming to Annex J.

<5.4> Description of elements of the physical architecture

a. The DDF shall provide

1. the nomenclature of the system or product,
2. the overall system or product drawings,

3. for each element of the system, the description of the different constituents of the physical architecture,
4. the characteristics of the respective elements,
5. their configuration management identifier (e.g. hardware part number, software version number, drawings number, electrical schematics numbers).

b. The DDF shall reference any documentation containing detailed technical descriptions and associated matrices to ensure overall consistency and completeness.

<5.5> Description of interfaces

a. The DDF shall describe the physical and functional characteristics of the internal and external interfaces of the system and refer to the relevant IRD and ICD, respectively conforming to Annex M and ECSS-E-ST-10-24.

<6> System technical budget, margins and deviations

a. The DDF shall present the budget allocation of the technical parameters of the system and provide the actual status of the system margins, and deviations.

b. The DDF shall contain or refer to the system or product technical budget, the latter conforming to Annex I.

<7> System design constraints

<7.1> Constraints for production

a. The DDF shall present the constraints induced by the system or product design definition on the production activities e.g. operational allowable envelopes, restrictions on assembling sequences, procedures and testing modes, exclusion zones, manufacturing environmental conditions, and conditions for procurement.

<7.2> Constraints for operation

a. The DDF shall present the constraints induced by the system or product design definition on the implementation of the operations e.g. operational allowable envelopes, restrictions on operating modes, and exclusion zones.

<7.3> Constraints for transportation and storage

a. The DDF shall present the constraints induced by the system or product design definition on the transportation activities and during the periods of storage of the product e.g. allowable envelopes, restrictions on transportation and storage, exclusion zones, packaging, shock levels, temperature environments, humidity, cleanliness, regulations, and dangerous materials.

<7.4> Constraints for maintainability

a. The DDF shall present the constraints induced by the system or product design definition on the maintenance activities and procedures e.g. operational allowable envelopes, accessibility, tooling, support materials, parts availability, and deliveries.

<8> Engineering database

a. The DDF shall contain the information on the system or product engineering database that contains the complete set of design parameters, or a reference to it.

NOTE Information about the set of design parameters is provided in ECSS-E-TM-10-10.

<9> Conclusion

a. The DDF shall list and summarize all deviations of the design with respect to the technical specifications and constraints induced by the system or product design definition.

G.2.2 Special remarks

None.

Annex H (normative) Function tree - DRD

H.1 DRD identification

H.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.3.1b.

H.1.2 Purpose and objective

The objective of the function tree document is to describe the hierarchical decomposition of a system or product capabilities into successive level of functions and sub-functions.

The function tree is part of the Design Definition File. It is the starting point for the establishment of the Product Tree (as defined in ECSS-M-ST-10) and is a basic structure to establish preliminary technical requirements specification(s) (as defined in ECSS-E-ST-10-06 Annex A).

H.2 Expected response

H.2.1 Scope and content

<1> Introduction

a. The function tree document shall contain a description of the purpose, objective and the reason prompting its preparation.

<2> Applicable and reference documents

a. The function tree document shall contain the list of applicable and reference documents, used in support to the generation of the document.

<3> Project summary and user's need presentation

a. The function tree document shall contain a brief description of the project and of the key user's needs.

<4> Tree structure

a. The function tree document shall provide the complete list of functions that the system or product shall perform, and contain a graphical representation where the main specified function(s) (i.e. at the top level of the tree) is/are decomposed into lower level functions.

b. When recurrent products from previous space projects are used, the product's functions shall be identified in the tree structure, and addition, every necessary function by the system or product that is not under the supplier's responsibility identified in the tree structure.

H.2.2 Special remarks

a. The function tree shall be coherent with other functional descriptions of the system or product (e.g. functional architecture, functional block diagram).

Annex I (normative) Technical budget - DRD

I.1 DRD identification

I.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.4.1.2a.

I.1.2 Purpose and objective

The technical budget defines for each key engineering parameter of a system or product, the nature of this parameter, its measure, specified value, metrics requirements and current actual or computed value and assessed value.

The technical budget is part of the Design Definition File (as defined in ECSS-E-ST-10 Annex G). It is the basic document for providing adequate control of the key engineering parameter properties to meet the system or product technical requirements.

I.2 Expected response

I.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

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

<3> List of selected key engineering parameters

a. The technical budget shall:

1. list the selected key engineering parameters (those specified by the customer and those selected by the supplier),

NOTE Examples of key engineering parameters are mass, communication links, power, and on-board computer memory capacity.

2. present the reason for their selection,
3. identify for each key engineering parameters the stages of maturity of the design.
4. present the related margin policy for these parameters.

<4> Assessment of key engineering parameters

a. For each key engineering parameter, the technical budget shall:

1. provide the specified value of the parameter,
2. provide the supplier's margin resulting of the allocation of the parameter to the lower level products,
3. provide the specified values with the reference to the relevant technical requirement of the lower level products,
4. propose a specific program to conform to the specified value in case of nonconformance,
5. contain a chart of parameter history that presents the evolution of the parameter's value at the different design maturity steps for which the evaluation of the parameter is performed,
6. list the documentation sources (e.g. analysis report and verification report).

<5> Conclusion

a. The technical budget shall contain a conclusion that identifies the key engineering parameters having a negative margin, and identify for each of those:

1. the impact on the technical requirements and the associated risk for the project, and
2. the specific program to conform to the specified value and for project risk mitigation.

I.2.2 Special remarks

None.

Annex J (normative) Specification tree - DRD

J.1 DRD identification

J.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.2.3.1c.

J.1.2 Purpose and objective

The objective of the specification tree document is to define the hierarchical relationship of all technical requirements specifications for the different elements of a system or product.

The specification tree is part of the Design Definition File (as defined in ECSS-E-ST-10 Annex G). It is the basic structure to perform the system or product requirements traceability and to manage their internal interfaces.

J.2 Expected response

J.2.1 Scope and content

<1> Introduction

a. The specification tree document shall contain a description of the purpose, objective and the reason prompting its preparation.

<2> Applicable and reference documents

a. The specification tree document shall contain the list of applicable and reference documents, used in support to the generation of the document.

<3> Project summary and user's need presentation

a. The specification tree document shall contain a brief description of the project and the key user's needs.

<4> Tree structure

a. The specification tree document shall provide the complete list of specifications defining the system or product, and contain a graphical representation where the system or product specification (i.e. at the top level of the tree) is decomposed into lower level product specifications.

b. When recurrent products from previous space projects are used, their specification shall be identified in the tree structure, and in addition, for every necessary product that is not under the supplier's responsibility, their specification shall be identified in the tree structure.

J.2.2 Special remarks

a. The specification tree shall be coherent with the product tree (see ECSS-M-ST-10) and the business agreement structure (see ECSS-M-ST-60).

Annex K (normative) Design justification file (DJF) - DRD

K.1 DRD identification

K.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirements 5.3.1d, 5.3.1g, 5.3.1h and 5.4.1.4b.

K.1.2 Purpose and objective

The objective of the design justification file (DJF) is to present the rationale for the selection of the design solution, and to demonstrate that the design meets the baseline requirements.

The DJF is progressively prepared during the detailed design process and according to the system engineering plan (SEP) (as defined in ECSS-E-ST-10 Annex D), and serves the following purposes:

- it provides access to the necessary justification information,
- it presents a review of all acquired justifications,
- it constitutes a basic element for decision taking concerning the product definition qualification.

The DJF together with the Design Definition File (DDF) (as defined in Annex G) and the technical requirements specification (TS) (as defined in ECSS-E-ST-10-06 Annex A) are the basic documents used for the development of the product. These documents are used to monitor the evolution of the design.

The DJF is a collection of all documentation that traces the evolution of the design during the development and maintenance of the product. The DJF is updated according to the evolution of the DDF, in accordance with the above-mentioned objectives.

The DJF provides also access to coherent and substantiated information which can be used to support decision-making in the analysis of change requests for the management of non conformances.

The DJF contains results obtained during the evolution of the design as a consequence of the activities performed along the design process:

- Analysis and trade-off reports concerning the evaluation of alternative design solutions and the justification of the choice.

- All results obtained during the verification of the design as a consequence of the activities performed along the verification process.
- Test Reports on engineering model, structural and thermal model and qualification model (e.g. Protoflight Models).

NOTE The DJF is a logical file covering all technical disciplines required for the considered system. In general, the elements of the DJF are "rolled out" as separate documents.

K.2 Expected response

K.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

a. The DJF shall list the applicable and reference documents in support to its generation.

b. The applicable document list shall contain the reference to the relevant product specifications, and the relevant DDF and system engineering plan.

c. The reference document list shall contain the reference to:

1. Trade-Off-Reports, as defined Annex L.
2. Analysis Reports (e.g. requirements allocation analysis, functional analysis).
3. Requirements Traceability Matrix, as defined in Annex N (with link to analysis).
4. Verification Control Document
5. All verification documentation, such as:
   (a) Analysis Reports (e.g. reports w.r.t. qualification aspects)
   (b) Test Reports
   (c) ROD Reports
   (d) Inspection Reports
   (e) Verification Reports

<3> Design description

a. The DJF shall contain a description of the expected product, its intended mission, architecture and design, and the functioning principles on which it is based.

b. The DJF shall define the requirement criteria levels for qualification and acceptance verification of the product.

<4> Design Justification File Synthesis

a. The DJF shall present status of the design justification in response to requirements, with emphasis on the driving requirements that have a big impact on the system design, production and maintainability (see also K.2.1<8.2.4>a.)

b. The DJF shall present an overall system qualification status synthesis, including:

1. the list of requirements which have not been met (e.g. nonconformances), including proposed actions,
2. the list of all critical points, and how criticalities have been or are intended to be resolved,
3. the identification of requirements which have not been justified yet, and associated risks analysis, with emphasis on those that can have an impact at system level.

<5> Justification of the Functional Architecture

a. The DJF shall contain the demonstration that all requirements of the preliminary technical requirements specification are allocated to functional blocks of the system functional architecture.

b. Where requirements assigned to functional blocks do not have their origin within any of the customer preliminary technical specifications, these requirements shall be justified.

<6> Justification of the Physical Architecture

a. The DJF shall contain the demonstration that the system design conforms to the requirements of the technical specification, and identify products which are reused (e.g. COTS).

b. The DJF shall also provide the justification for the choice of architectural elements at the next lower level, or lower levels in case of system critical elements.

c. Where requirements do not have their origin within any of the upper level technical specifications, these shall be justified.

<7> Development activities and synthesis of development results

a. The DJF shall present the development activities (e.g. assessments, analyses, tests, and trade-offs) and the design drivers, which lead to and justify the design as defined in the DDF, in line with the development approach identified in the SEP.

b. The justification shall concern all the engineering disciplines contributing to design and development of the product (including its operational modes and scenarios).

c. The DJF shall include the status of DJF of lower level products.

NOTE Activities related to verification are dealt with in section K.2.1<8>.

d. For the system and each discipline, following information shall be produced:

1. Activity inputs, such as requirements, operational modes, assumptions, analysis cases, boundary conditions, model descriptions and limitations.

2. Activity results, such as

(a) raw results,

(b) evaluation of results,

(c) evaluation of margins with respect to the technical requirements contained in the TS,

(d) identification of any marginal areas.

3. Activity synthesis, such as

(a) evidence of compliance to the technical requirements contained in the TS,

(b) list of technical requirements which have not been met, including proposed actions,

(c) list of all critical points, and how criticalities have been or are intended to be resolved,

(d) identification of aspects of the design, which are not yet justified, and assessment of inherent risks.

e. The DJF shall reference the requirements traceability matrix, e.g. w.r.t. building up the justification of a considered system top level requirements in terms of the various elements contributing to it, including where relevant contribution from other disciplines (e.g. pointing as a function of thermal, structures, and AOCS).

<8> Verification activities and synthesis of results

<8.1> Verification plan

a. The DJF shall integrate or refer to the document that conforms to the verification plan DRD defined in ECSS-E-ST-10-02 Annex A.

NOTE The verification activities are detailed in the Verification Plan (VP), which also contains the justification of the verification strategy (as defined in ECSS-E-ST-10-02).

<8.2> Qualification verification and synthesis of results

<8.2.1> Qualification evidence

a. The DJF shall present the evidence of the qualification of the design in conformance to the applicable technical requirements and proper qualification margins.

NOTE This is done in line with the qualification approach identified in the VP.

b. The DJF shall cover the system and all disciplines relevant to the product in all its operational modes and scenarios, addressing all applicable technical requirements and proper qualification margins.

NOTE 1 This is done in line with the system verification matrix.

NOTE 2 The formal compliance with the qualification requirements is recorded in the VCD, together with references to the close-out documents.

<8.2.2> Implementation of the qualification plan

a. The DJF shall present the implementation of the qualification plan and the status thereof, addressing the detailed definition of qualification activities (e.g. analysis, test, ROD, and inspection), including the detailed definition of the tests, the prediction of expected test results, test success criteria, test specifications, and model validations.

NOTE Details on test specifications are provided in ECSS-E-ST-10-03 Annex B.

<8.2.3> Validation of models

a. The DJF shall contain all evidence (e.g. analyses, test results, and model descriptions and correlations) regarding the suitability and validation of all models used for the analysis of the system.

<8.2.4> Requirements status log

a. The DJF shall include a requirement status log addressing each requirement in turn, and including the

1. reference to relevant elements of the verification plan,
2. synthesis of the justifications acquired, calling up references to the supporting activities and evidence (e.g. Technical Notes listed in section K.2.1<4>),
3. list of justifications to be acquired and related activities,
4. conclusion / action flag.

<8.2.5> Manufacturing process status log

a. The DJF shall include a requirement status log, addressing design relevant aspects of manufacturing processes, and recording their characteristics in regard to qualification.

<8.3> Acceptance verification

a. The DJF shall present the implementation of the acceptance verification and the status thereof, addressing the detailed definition of acceptance activities (e.g. inspection, test, analysis), including the detailed definition of the tests, the prediction of expected test results, test success criteria, and test specifications.

NOTE Details on test specifications are provided in ECSS-E-ST-10-03 Annex B.

a. The DJF shall cover the system and all disciplines relevant to the product, addressing all acceptance verification activities in line with the system verification Plan (VP).

<9> Justification of System Technical Budgets and Margins

a. The DJF shall present a synthesis of all technical budgets and margins for specific parameters according to the functional and physical architectures.

NOTE For technical budgets and margins, see ECSS-E-ST-10 Annex I.

<10> Justification of Constraints imposed by the System Design

<10.1> Design constraints on the production

a. The DJF shall present the justification of constraints induced by the system or product design definition on the production activities e.g. operational allowable envelopes, restrictions on assembling sequences, procedures and testing modes, exclusion zones, manufacturing environmental conditions, and conditions for procurement.

<10.2> System design constraints for operation

a. The DJF shall present the justification of constraints induced by the system or product design definition on the implementation of the operations e.g. operational allowable envelopes, restrictions on operating modes, and exclusion zones.

<10.3> System design constraints for transportation and storage

a. The DJF shall present the justification of constraints induced by the system or product design definition on the transportation activities and during the periods of storage of the product e.g. allowable envelopes, restrictions on transportation and storage, exclusion zones, packaging, shock levels, temperature environments, humidity, cleanliness, regulations, and dangerous materials.

<10.4> System design constraints for maintainability

a. The DJF shall present the justification of constraints induced by the system or product design definition on the maintenance activities and procedures

e.g. operational allowable envelopes, accessibility, tooling, support materials, parts availability, and deliveries.

<11> Constituent documents

a. The DJF shall integrate or refer to the documents that conform to the:

1. ECSS-E-ST-10 Annex L, Trade-Off-Report - DRD
2. ECSS-E-ST-10 Annex Q, Analysis Report - DRD
3. ECSS-E-ST-10 Annex O, Requirement Justification File - DRD
4. ECSS-E-ST-10 Annex N, Requirements Traceability Matrix – DRD
5. ECSS-E-ST-10-02 Annex B, Verification Control Document - DRD
6. ECSS-E-ST-10-02 Annex C, Test Report - DRD
7. ECSS-E-ST-10-02 Annex D, Review Of Design Report - DRD
8. ECSS-E-ST-10-02 Annex E, Inspection Report - DRD
9. ECSS-E-ST-10-02 Annex F, Verification Report - DRD

b. The DJF shall include or refer to the DJF of lower level elements of the product.

K.2.2 Special remarks

None.

Annex L (normative) Trade-off report - DRD

L.1 DRD identification

L.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.3.3b.

L.1.2 Purpose and objective

The Trade-off report provides the system-engineering point of view on alternative design solutions, an evaluation and a classification of the alternative design solutions, and the justification of their ranking.

L.2 Expected response

L.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

a. The trade-off report shall list the applicable and reference documents in support to the generation of the document and include the reference to the following applicable documents:

1. Mission description document, if relevant
2. Technical requirements specification
3. System engineering plan
4. Project phasing and planning requirement document.

<3> Objective and context of the trade-off study

a. The trade-off report shall contain a brief description of the purpose of the trade-off study and its context (e.g. logic, organization, process or procedure).

<4> Key technical requirements

a. The trade-off report shall list the key technical requirements from the TS (as defined in ECSS-E-ST-10-06) to be satisfied by the possible alternative design solutions to conform to the needs or requirements of the user.

b. The research of possible alternative design solutions should not preclude the identification of design solutions which are not currently mature enough, but which can be potential design solution for future similar applications.

NOTE A possible design solution is a technical answer that has the capability to meet a set of technical requirements.

c. The system trade-off report shall identify and present the sources of information used to identify the possible design solution, e.g. R&D results, lessons learned, or similar applications.

<5> Evaluation criteria

a. The trade-off report shall list the selected evaluation criteria and precise the justification for selecting those criteria, and provide the weighting of criteria and their justifications.

NOTE The criteria are selected theme by theme from the Technical Specification (as defined in ECSS-E-ST-10-06 Annex A), the programmatic aspects (including e.g. budget, schedule, etc… for development, manufacturing, as well as target cost for operations and recurrent items), and the technical risks.

b. The trade-off report shall identify the entity responsible for the evaluation of the design solutions for any criteria, as well as the source and agreement regarding weighting factors (e.g. with management).

<6> Presentation of the alternative design solutions

a. The trade-off report shall present every different alternative design solutions proposed by the organization in charge of the development of the system or product, the proposals from the customer and supplier if any, and emphasize the technical description that is correlated to the criteria of evaluation.

b. The trade-off report shall characterize each alternative design solution in terms of technology status or maturity, performances capability, and risks.

<7> Evaluation of the alternative design solutions

a. The system trade-off report shall present the result of the evaluation of every identified alternative design solution with regard to the key technical requirements.

b. For each alternative design solution the following shall be performed:

   1. assessment of all the key technical requirements / evaluation criteria,

   2. presentation of the pros and cons of the design solution, and

   3. identification of the technical and programmatic risks.

c. The trade-off report shall present, in a table, the result of the evaluation per criteria.

<8> Classification of the alternative design solutions

a. Based on the proposed scheme for weighting the evaluation criteria, the trade-off report shall provide a classification of the different alternative design solutions.

<9> Analysis of the robustness of the classification

a. The trade-off report shall provide the result of a sensitivity analysis of the criteria that provide advantage to the solution ranked first, e.g. when changing the weighting of the evaluation criteria.

<10> Conclusion

a. The trade-off report shall recommend one solution and explain the reason for this choice (e.g. evaluation criteria where the selected solution take advantage), and precise the condition for the application of the recommended solution.

b. The trade-off report shall present the identified technical and programmatic risks induced by the choice of the recommended solution, and any additional activity necessary to be performed for risk mitigation.

L.2.2 Special remarks

None.

Annex M (normative) Interface requirement document (IRD) - DRD

M.1 DRD identification

M.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.6.4b.

M.1.2 Purpose and objective

For a product, the interface requirement document (IRD) is a specific type of technical specification that defines the requirements for the interfaces among the items - at the same level in the product tree structure - constituting this product.

The IRD is a document either included in or called up by the technical requirements specification (TS) (as defined in ECSS-E-ST-10-06 Annex A) of the product.

M.2 Expected response

M.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

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

b. The IRD shall include the following references:

1. Product tree (as defined in ECSS-M-ST-10 Annex B)
2. Specification tree (as defined in ECSS-E-ST-10 Annex J).

<3> Interface requirements

a. The interface requirements shall be grouped per couple of product elements having an interface.

b. The interface requirements shall be expressed according to ECSS-E-ST-10-06.

c. The interface requirements shall be grouped per nature of interface.

NOTE For example: Nature of interface includes, but is not restricted to, mechanical, electrical, thermal and software interfaces.

M.2.2 Special remarks

a. The content of the IRD may be merged with the content of the technical requirements specification (as defined in ECSS-E-ST-10-06 Annex A) of the elements of the product.

Annex N (normative) Requirements traceability matrix (RTM) - DRD

N.1 DRD identification

N.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.2.2b.

N.1.2 Purpose and objective

The requirement traceability matrix (RTM) defines the relationships between the requirements of a deliverable product defined by a technical requirements specification and the apportioned requirements of the product's lower level elements.

The purpose of the RTM is to help verify that all stated and derived requirements are allocated to system components and other deliverables (forward trace).

The matrix is also used to determine the source of requirements (backward trace). Requirements traceability includes tracing any information that satisfy the requirements such as capabilities, design elements, and tests.

The RTM is also used to ensure that all requirements are met and to locate affected system components when there is a requirements change. The ability to locate affected components allows the impact of requirements changes on the system to be determined, facilitating cost, benefit, and schedule determinations.

N.2 Expected response

N.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

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

b. The RTM shall include the following:

1. Technical requirements specification (as defined in ECSS-E-ST-10-06 Annex A) of the product and its lower level elements
2. Product tree (as defined in ECSS-M-ST-10 Annex B)
3. Specification tree (as defined in ECSS-E-ST-10 Annex J).

<3> Requirement traceability

a. The RTM shall list all the technical requirement of the product TS.

b. The RTM shall list all the lower level elements constituting the product and their technical requirements (contained in the lower-level element TS).

c. The requirement identification shall be identical in the RTM and the different TS.

d. Each technical requirement of the product shall be linked to at least one requirement of a lower level element.

NOTE The required visibility of the traceability down the elements of the product tree is depending on the criticality of some lower level elements w.r.t. the product requirements.

e. Each technical requirement of a lower level element should be linked to a technical requirement of the product.

f. When a technical requirement of a lower level element is not linked to a technical requirement of the product, this requirement shall be justified and an evaluation of its existence or removal on the product shall be agreed between the customer and the supplier.

N.2.2 Special remarks

None.

Annex O (normative) Requirements justification file (RJF) - DRD

O.1 DRD identification

O.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.2.1e.

O.1.2 Purpose and objective

The requirement justification file (RJF) is a generic title referring to all documentation which:

- Records and describes the needs and the associated constrains resulting from the different trade-offs.
- Demonstrates how the requirements of the technical requirements specification (TS) (as defined in ECSS-E-ST-10-06 Annex A) at each level can satisfy the needs and the constraints of the TS of the level above.

NOTE A top level RJF document is established at the upper level of the project structure that is, according to ECSS-M-ST-10, the first-level customer situated at level 0 of the customer supplier network. For other levels, the RJF is part of the design justification file (DJF) (as defined in, Annex K).

O.2 Expected response

O.2.1 Scope and content

<1> Introduction

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

<2> Applicable and reference documents

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

b. The RJF shall include the reference to the technical requirements specification.

<3> Selected concept/solution justification

a. The RJF shall present the rationale for the selection of a concept for the technical requirements specification.

NOTE For justification, reference can be made to the system concept report of the considered project.

<4> Life profile justification for the selected concept/solution

a. The RJF shall present and justify the life profile situations for the concept presented in the technical requirements specification.

NOTE For justification, reference can be made to the system concept report of the considered project where relevant.

<5> Environments and constraints justification

a. The RJF shall present and justify the different environments and constraints for each life profile situations for the concept presented in the technical requirements specification.

NOTE For justification, reference can be made to the system concept report of the considered project where relevant.

<6> Technical requirements justification

a. The RJF shall list all the technical requirements, and their identifier, expressed by the corresponding TS as they are organized in these documents.

b. For each technical requirement the following information shall be provided:

1. the justification of the requirement (i.e. justified source),
2. the Entity or owner responsible for the requirement,
3. if one technical requirement is induced by several sources, the reason of the specified performance,
4. the justification of the quantified performance (such as the range, the approach used to determine the level, e.g. measure, estimation),
5. the justification of the selected verification method.

<7> Requirement traceability

a. The RJF shall present the requirement traceability between the technical requirements of the TS, and their justified source.

<8> Compliance matrix for COTS

a. For COTS, the RJF shall contain a compliance matrix between the technical specification/characteristics of the COTS and the technical requirement expressed by the TS.

O.2.2 Special remarks

a. The RJF may be part of the design justification file (DJF) (as defined in ECSS-E-ST-10 Annex K).

Annex P (normative)
Product user manual (PUM or UM) - DRD

P.1 DRD identification

P.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10 requirement 5.4.1.4c.

P.1.2 Purpose and objective

The objective of the product user manual (PUM) is to provide information on design, operations and data of the product that is required by the user to handle, install, operate, maintain and dispose the product during its life time.

P.2 Expected response

P.2.1 Scope and content

<1> Introduction

a. The introduction shall describe the purpose and objective of the PUM.

<2> Applicable and reference documents

a. The PUM shall list the applicable and reference documents in support of the generation of the document.

<3> Product function definition

<3.1> Product expected functions

a. The PUM shall provide a general description of the expected functions of the product during its lifetime in expected operational context and environment.

<3.2> Product functional constraints

a. The PUM shall describe all product functional constraints.

<3.3> Life time phases and purposes

a. The PUM shall address the whole product life cycle and all its modes:

1. Handling
2. Storage
3. Installation
4. Operations (nominal and contingency)
5. Maintenance
6. Disposal.

b. The PUM shall consider potential consequences of the environment on those sequences (e.g. sensor blinding, eclipses);

<4> Product description

<4.1> Design summary

a. The PUM shall include the following:

1. summary of the product design, showing the definition of the product, its constituents, the distribution of functions and the major interfaces;
2. block diagram of the product;
3. top-level description of the product software architecture;
4. description of nominal product operations scenarios and constraints e.g. mutually exclusive modes of operation, power or resource sharing.

<4.2> Product level autonomy

a. The PUM shall include the following:

1. description of product-level autonomy provisions in the areas of fault management (FDIR);
2. definition, for each autonomous function, of the logic or rules used and of its internal (product constituents) and external interfaces.

<4.3> Product configurations

a. The PUM shall include the following:

1. drawings of the overall product configuration in all product modes;
2. definition of the product reference axes system(s);
3. drawings of the product layouts.

<4.4> Product budgets

a. The PUM shall provide the distribution (or allocation) of the following budgets, per product constituent, or per operating mode, as appropriate:

1. mass properties;

2. alignment;
3. power consumption for all operational modes;
4. thermal budget and constraints and predictions;
5. Description of interfaces and related budgets. (e.g. RF links);
6. telemetry and telecommand date rates;
7. memory;
8. timing.

<4.5> Interface specifications

a. The PUM shall provide a cross-reference to the applicable version of the ICD.

<4.6> Handling

a. The PUM shall describe the conditions and procedures for the handling of the product, be it integrated or stand-alone.

b. The PUM shall describe the specific design features, transport and environmental conditions, required GSE, and limitations for the handling of the product.

<4.7> Storage

a. The PUM shall describe the conditions and procedures for the storage of the product, be it integrated or stand-alone.

b. The PUM shall describe the specific design features, environmental conditions, required GSE, monitoring requirements, life-limited items, health maintenance procedures (activation, monitoring) and limitations for the storage of the product.

<4.8> Installation

a. The PUM shall describe the conditions and procedures for the installation of the product, be it integrated or stand-alone.

b. The PUM shall describe the specific design features, required GSE, modes, environmental conditions, and limitations for the installation of the product.

<4.9> Product operations

<4.9.1> General

a. The PUM shall include timelines, modes and procedures, constraints to operate the product during its life cycle in nominal and contingency conditions, and highlight critical operations.

NOTE 1 When the product is a space segment, the product operations aspects are included in a specific part of the UM called Flight Operations Manual (FOM).

NOTE 2 The implementation of the FOM by the ground segment responsible organisation is contained in the Mission Operations Plan (MOP, as defined in ECSS-E-ST-70 Annex G).

<4.9.2> Timelines

a. The PUM shall include:

1. Baseline event timelines for all nominal and contingency modes and phases.
2. Related constraints.

b. Each timeline shall contain a detailed description (i.e. down to the level of each single operational action) of the complete sequence of operations to be carried out, including a description of the rationale behind the chosen sequence of events, a definition of any constraints (e.g. absolute timing, relative timing) and the interrelationships between operations in the sequence.

<4.9.3> Product modes

a. The PUM shall describe all nominal and contingency modes, including:

1. their purpose (i.e. circumstances under which they are used),
2. the related procedures,
3. operational constraints,
4. resource utilization,
5. the definition of the associated modes, and
6. monitoring requirements.

b. The PUM shall describe the allowable mode transitions and the operations procedure corresponding to each such transition.

c. Appropriate cross-reference shall be made to product constituent modes and procedures.

<4.9.4> Product failure analysis

a. The PUM shall provide the results of the product failure modes, effects and criticality analysis (FMECA) and the resulting list of single point failures.

b. Potential product failures shall be identified by means of a fault-tree analysis (FTA).

<4.10> Maintenance

a. The PUM shall describe the conditions, procedures and logistics for the maintenance of the product, be it integrated or stand-alone.

NOTE The description can refer to the document that conforms to the Integrated Logistic Support Plan in conformance with ECSS-M-ST-70.

<4.11> Disposal

a. The PUM shall describe the conditions and procedures for the disposal of the product, be it integrated or stand-alone.

b. The procedures shall include passivation, as relevant.

c. The PUM shall identify the risks during and after disposal.

<5> Products constituents description

<5.1> General

a. The information specified in P.2.1<5.2> to P.2.1<5.9> shall be provided for each product constituent.

<5.2> Product constituent design summary

a. The PUM shall describe the product constituent including:

1. the overall functions of the product constituent and the definition of its operational modes during the different mission phases;
2. description of any product constituent management functions, fault management concept and redundancy provisions;
3. a summary description of the component units/equipment and software including the functions which each supports;
4. product constituent functional block diagrams and a diagram showing the source of telemetry outputs and the sink of telecommand inputs;
5. interfaces;
6. budgets.

<5.3> Product constituent design definition

a. The following shall be provided for each product constituent:

1. a detailed design description, including block diagrams, functional diagrams, logic and circuit diagrams;
2. physical characteristics including location and connections to the support structure, axes definition and alignment where relevant, dimensions and mass properties;
3. principle of operation and operational constraints of the product constituent;
4. if a product constituent is composed of many complex elements, it may be necessary to provide a lower level of breakdown.

<5.4> Software

a. The PUM shall include:

1. description of software design,
2. product constituent software,

3. application process service software, and

4. memory map.

b. The PUM shall describe the organization of the software and its physical mapping onto hardware.

c. The PUM shall describe the details of each software component i.e. scheduler, interrupt handler, I/O system, telecommand packet handling system, telemetry packet handling system, including for each component its functions, component routines, input/output interfaces, timing and performance characteristics, flowcharts and details of any operational constraints.

d. For the application process service software, the PUM shall:

1. describe the services implemented making cross-reference to ECSS-E-ST-70-41 "Telemetry and telecommand packet utilization", as tailored for the mission;

2. summarize all telemetry and telecommand structures (e.g. packets) including the conditions under which they are generated, the generation frequency, content and interpretation.

e. For each memory block, a map shall be provided showing RAM and ROM address areas, areas allocated for program code, buffer space and working parameters (e.g. content of protected memory).

<5.5> Product component performance

a. The PUM shall describe all relevant product constituent performance characteristics, define the expected performance degradation as a function of time during the mission, and identify the resulting impact in terms of modifications to operational requirements or constraints.

<5.6> Product component telemetry and telecommand lists

a. For each product constituent, the following lists shall be provided:

1. a list of the housekeeping telemetry parameters;

2. a list of the telecommands.

b. Each housekeeping telemetry shall have a functional description with validity conditions, telecommand relationship, and all technical information necessary for using it.

c. Each telecommand shall have a functional description with utilization conditions (e.g. pre-transmission validity, criticality level), command parameters (syntax and semantics) and execution verification in telemetry.

<5.7> Product component failure analysis

a. The PUM shall describe:

1. Identification of potential product constituent failures by means of a systematic failure analysis (including a subsystem FMECA and FTA).

2. Identification of the methods by which the higher levels can identify a failure condition from analysis of the telemetry data and isolate the source of the failure.

<5.8> Product components operations

a. The PUM shall describe:

1. product constituent modes;
2. nominal operational procedures;
3. contingency procedures.

b. product constituent modes shall be defined for all distinct nominal and back-up modes of the subsystem including:

1. purpose (i.e. conditions under which each is used);
2. operational constraints;
3. resource utilization;
4. the definition of the associated modes for each product constituent and its software functions;
5. higher level monitoring requirements;
6. identification of the allowable mode transitions and any product constituent operational constraints.

c. Nominal operational procedures shall be defined for each nominal mode transition identified under P.2.1<5.8>b.6.

d. For each procedure described in P.2.1<5.8>c., the following shall be provided:

1. an introduction describing the purpose of the procedure and the phase(s) or conditions when applicable;
2. the body of the procedure, structured according to operational steps, including:
   (a) pre-conditions for the start of the step defining, where applicable:
   - product or product constituent level pre-requisites (e.g. configuration and resource requirements, such as power, fuel);
   - external interfacing products pre-requisites.
   (b) telecommands to be sent;
   (c) telemetry data to be monitored to verify correct execution of the step;
   (d) interrelationships between steps (e.g. conditional branching within the procedure, timing requirements or constraints, hold and check points);
   (e) conditions for completion of the step.

e. Contingency procedures shall be defined for each failure case identified in the product constituent failure analysis (FMECA/FTA).

NOTE This can utilize a nominal operational procedure already identified in P.2.1<5.8>c. above.

f. For contingency procedures, the same details shall be provided as for nominal operational procedures in P.2.1<5.8>d. above.

g. Where the recovery method for a failure or group of failures is mode, mission, or phase dependent, separate procedures shall be described for each mode/mission phase.

<5.9> Product component data definition

a. For each operational mode of the product constituent, sensor output data, conditions under which they are generated, their contents, and data rate shall be described.

b. Required on-board processing performed on sensor data and algorithms used for this shall be described.

P.2.2 Special remarks

a. Where the objective is to allow for the accommodation of equipment designed a posteriori w.r.t an existing platform or vehicle, the following documents shall be part of the UM:

1. The accommodation handbook describing the location, mounting, all interfaces and clearances of equipment in a platform or vehicle.

2. The installation plan describing the approach, methods, procedures, resources and organization to install, commission, and check the operation of the equipment in its fixed operational environment.

Annex Q (normative) Analysis report – DRD

Q.1 DRD identification

Q.1.1 Requirement identification and source document

This DRD is called from ECSS-E-ST-10, requirement 5.3.1j.

Q.1.2 Purpose and objective

The analysis report describes, for each analysis, the relevant assumptions, utilized methods, techniques and results.

NOTE When the analysis report is used for product verification purposes, specific requirements as per clause Q.2.1<8> apply.

Q.2 Expected response

Q.2.1 Scope and content

<1> Introduction

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

b. Any open issue, assumption and constraint relevant to this document shall be stated and described.

<2> Applicable and reference documents

a. The analysis report shall list the applicable and reference documents in support to the generation of the document, and make a clear reference to the configuration baseline of the product considered for the analysis.

<3> Definitions and abbreviations

a. The analysis report shall list the applicable dictionary or glossary and the meaning of specific terms or abbreviations utilized in the document with the relevant meaning.

<4> Analysis approach

a. The analysis report shall summarize the analysis content and the method utilized.

<5> Assumptions and limitations

a. The analysis report shall describe the basic assumptions, the boundary conditions, validity of the analysis, life profile aspects, and all other related limitations.

<6> Analysis description

a. The analysis report shall describe and justify the analysis methods used including software, tools and associated models.

<7> Analysis results

a. The analysis report shall present the main calculations, associated results, accuracies, sensitivities, margins where relevant.

<8> Conclusions

a. The analysis report shall:

1. summarize the analysis results,
2. summarize the conditions of validity of this analysis,
3. clearly state and describe any open issue.

b. Where the analysis report is used for the verification of requirements it shall list the requirements to be verified (in correlation with the VCD), summarize the analysis results, present comparison with the requirements, and indicate the verification closeout judgements (e.g. requirement met / not met).

Q.2.2 Special remarks

None.

Annex R (informative) Mapping of typical DDP to ECSS documents

Design Development Plan (DDP) content	ECSS coverage
Introduction • General summary of the scope, objective and constraints • Definition of responsibilities and pre-requisites	M-ST-10 - PMP <3> E-ST-10 - SEP <3.1> M-ST-10 - PMP <4>
System definition including high level product tree • Identification of customer furnished products • Availability of and need to reuse existing products • Specification tree	M-ST-10 - PT M-ST-60 - 9.6.2 req. E-ST-10 - SEP <4.2>.6 and <5.2.13> M-ST-10 - PT <3>.e E-ST-10 - Annex J
Technology assessment Availability of and need to develop new technologies	E-ST-10 - SEP <5.2.5> E-ST-10 - TP <4.3>
System design flow and philosophy of models • Model philosophy • Design margin philosophy for budgets - Margin philosophy for requirements as flown down from system to subsystem- assembly – and equipment level - Management of system resource allocation over the entire project phases and resource reporting to the next higher level - Rationale	E-ST-10 - SEP <4.2>.4 E-ST-10 - SEP <4.2>.5
System control and verification • Qualification and acceptance philosophy • Budget allocation philosophy • Compliance to requirements demonstration philosophy • High-level Assembly, Integration & Verification Plan, incl.: - end to end test - mission simulation and Dress Rehearsals	E- ST-10 - SEP <5.2.2> -> E- ST-10-02 - VP -> E- ST-10-02 - VCD (inc. VM)

Planning and definition of milestones and reviews including the analysis of the critical path(s) • definition and scope of reviews in terms of - baselining of requirements and requirements control - design releases and control of released design including external and internal interfaces	M- ST-10 - PMP <7> -> M- ST-60 - S M- ST-10-01 E-ST-10 - SEP <3.3>
Definition of required Ground Support Equipment and schedule of development and delivery	
Risk assessment linked to development choices	E- ST-10 - SEP <5.4> <3.5> M- ST-80 - RAR

M-ST-10 - PMP	= ECSS-M-ST-10, Project management plan DRD - Annex A
M-ST-10 - PT	= ECSS-M-ST-10, Product tree DRD - Annex B
M-ST-60 - S	= ECSS-M-ST-60, Schedule DRD - Annex B
M-ST-80 - RAR	= ECSS-M-ST-80, Risk assessment report DRD - Annex C
E-ST-10 - SEP	= ECSS-E-ST-10, System engineering plan DRD - Annex D
E-ST-10 - TP	= ECSS-E-ST-10, Technology plan DRD - Annex E
E-ST-10-02 - VP	= ECSS-E-ST-10-02, Verification plan DRD - Annex B
E-ST-10-02 - VCD	= ECSS-E-ST-10-02, Verification control document DRD - Annex C (Note: Verification matrix = 1st issue of CVD)

Bibliography

ECSS-S-ST-00	ECSS system – Description, implementation and general requirements
ECSS-E-ST-10-03	Space engineering – Testing
ECSS-E-ST-10-04	Space engineering – Space environment
ECSS-E-ST-10-11	Space engineering – Human factors engineering
ECSS-E-ST-20	Space engineering – Electrical and electronic
ECSS-E-ST-3x series	Space engineering – Materials series
ECSS-E-ST-40	Space engineering – Software general requirements
ECSS-E-ST-50	Space engineering – Communications
ECSS-E-ST-60	Space engineering – Control engineering
ECSS-E-ST-70	Space engineering – Ground systems and operations
ECSS-E-ST-70-41	Space engineering – Telemetry and telecommand packet utilization
ECSS-E-HB-10	Space engineering – System engineering guidelines
ECSS-E-TM-10-10	Space engineering – Logistic engineering
ECSS-E-TM-10-20	Space engineering – Product data exchange
ECSS-E-TM-10-21	Space engineering – System modelling and simulation
ECSS-M-ST-60	Space project management – Cost and schedule management
ECSS-M-ST-70	Space engineering – Integrated logistic support
ECSS-M-ST-80	Space project management – Risk management
ECSS-Q-ST-10	Space product assurance – Product assurance management
IEEE P1220	Standard for application and management of the systems engineering process
ISO/CD 24113	Space systems – Space debris mitigation