ECSS-E-10 Part 1B
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Space engineering

System engineering — Part 1: Requirements and process

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Foreword

This Standard is one of the series of ECSS Standards intended to be applied together with the management, engineering and product assurance standards 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.

This Standard is published in several parts:

- Part 1: defining the requirements and process for system engineering,
- Part 17: defining the content of the document requirements definitions (DRDs) that are specific to Part 1.

The other parts are described in Annex A.

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

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

This Standard has been prepared by the ECSS-E-10 Part 1 Working Group, reviewed by the ECSS Engineering Panel and approved by the ECSS Steering Board.

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Introduction

This Standard covers each conventional phase of the acquisition of a space system, for the complete system life cycle, from capture of users needs to utilization and disposal.

It also covers all the project phases of each product resulting from the decomposition of the system.

Clause 4 describes the system engineering functions in general and the related requirements.

Clause 5 describes the mapping of the system engineering process onto the different phases and tasks of project development in order to support the reader for practical implementation, as well as the related requirements.

The system engineering activities covered in this Standard are:

a. Integrate the activities of other engineering disciplines covered by the ECSS-E series of standards.

b. Interface with the management and product assurance activities covered by the ECSS-M and ECSS-Q series of standards. In particular:

   1. This Standard follows
      (a) the project breakdown structure of ECSS-M-10,
      (b) the project organization of ECSS-M-20 (it is part of it),
      (c) the project phasing and planning given in ECSS-M-30, and
      (d) the risk management detailed in ECSS-M-00-03.
   2. This Standard is consistent and conforms to
      (a) the requirements on configuration management in ECSS-M-40,
      (b) information documentation in ECSS-M-50,
      (c) cost and schedule management in ECSS-M-60, and
      (d) integrated logistic support in ECSS-M-70.
   3. This Standard is consistent and conforms to the requirements on
      (a) quality assurance detailed in ECSS-Q-20,
      (b) dependability detailed in ECSS-Q-30,
      (c) safety detailed in ECSS-Q-40,
      (d) EEE component control detailed in ECSS-Q-60,

(e) materials, mechanical parts and processes detailed in ECSS-Q-70, and

(f) software product assurance detailed in ECSS-Q-80.

NOTE The references to other ECSS-E-10 Standards and DRDs are made using the structure of the ECSS-E-10 branch as defined in Annex A.

1

Scope

The purpose of this Standard is to lead the actors of the “customer–system–supplier model” (as described in 4.1.2) through the development of systems (including hardware, software, man-in-the-loop, facilities and services) for space applications. It specifies system engineering implementation requirements for space systems and space products development.

The objectives of this Standard are as follows.

a. To assist in defining, performing, managing, and evaluating system engineering efforts to ensure that the programme has a firm organizational basis, able to minimize technical risk due to uncertain understanding of delegated technical responsibilities.

b. To facilitate minimization of cost by defining essential system engineering tasks, their objectives and their organization.

c. To incorporate the key aspects of the space standardization initiatives to improve capture requirements, implement multi-disciplinary team-work including suppliers, establish the requirements at an early stage in the process, focus on process control rather than inspection, and encourage overall risk management rather than risk avoidance.

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

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

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2

Normative references

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

ECSS-P-001B Glossary of terms

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3

Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms have a specific definition for use in ECSS Standards as given in ECSS-P-001.

acceptance

approval

analysis

configuration baseline

design

development

element

equipment

inspection

margin

need

product tree

qualification

requirement

specification

subsystem

system

test

verification

For the purposes of this document, the terms and definitions given in ECSS-P-001 and the following apply.

3.1.1
consolidated document
document which has reached an increased level of maturity (compared to the document on which it is based) as a result of discussion, gathering and processing of data from the relevant sources, and is in a stable state on which to base all further activities

3.1.2
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

3.1.3
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

3.1.4
effectiveness analysis
assessment of how well a product associated with an alternative logical, physical or design solution is expected to perform or operate, given an anticipated usage scenario

3.1.5
hybrid model philosophy
model philosophy representing a compromise between prototype and protoflight approaches

NOTE It is based on a protoflight model on which a partial protoflight qualification test campaign is carried out. Specific qualification tests in critical areas are carried out on dedicated models.

3.1.6
integration
process of physically and functionally combining lower level products (hardware or software) to obtain a particular functional configuration

3.1.7
kick-off meeting
meeting of all relevant parties involved in an activity to verify that all conditions for the initiation and execution of the activity are agreed and met, and provide authorization to proceed

3.1.8
mission statement
set of collected needs

NOTE Document commonly used within the space community, see also ECSS-P-001.

3.1.9
protoflight model philosophy
model philosophy in which a single model (i.e. protoflight model) is flown after protoflight qualification and an acceptance test campaign

NOTE This is the typical philosophy for projects with no technology-critical design and compromise permitted to reduce cost accepting a medium risk.

3.1.10
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.

3.1.11
system engineering
the interdisciplinary approach governing the total technical effort required to transform a requirement into a system solution

[IEEE P1220]

3.1.12
system engineering process
set of inter-related or interacting activities, each transforming inputs into outputs, to implement system engineering

3.1.13
technical requirement
requirement stated in technical terms

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

3.1.14
test effectiveness
number of failures per product found in ground tests divided by the total number of failures which can be found in all the acceptance test campaigns and during the first 45 days of presence in space

3.1.15
time line analysis
analytical task conducted to determine the time sequencing between two or more events and to define any resulting time requirements

3.2 Abbreviated terms

The following abbreviated terms are defined and used within this document:

Abbreviation	Meaning
AIT	assembly, integration and test
AR	acceptance review
CAD	computer aided design
CDR	critical design review
CIDL	configuration item data list
COG	centre of gravity
COTS	commercial off-the-shelf
DDF	design definition file
DJF	design justification file
DRD	document requirements definition
ECSS	European Cooperation for Space Standardization

EEE	electronic, electrical, electromechanical
EGSE	electrical ground support equipment
ELR	end-of-life review
EM	engineering model
EMC	electromagnetic compatibility
EOL	end-of-life
FGSE	fluid ground support equipment
FM	flight model
FOP	flight operations plan
FQR	flight qualification review
FRR	flight readiness review
GOP	ground operations plan
GSE	ground support equipment
ICD	interface control document
ILS	integrated logistic support
IOOR	in-orbit operations review
IRD	interface requirements document
KO	kick-off
LRR	launch readiness review
LSA	logistic support analysis
MCR	mission closed-out review
MDR	mission definition review
MGSE	mechanical ground support equipment
NRB	nonconformance review board (formerly MRB)
OGSE	operational GSE
ORR	operational readiness review
PA	product assurance
PDM	product documentation model
PDR	preliminary design review
PFM	protoflight model
PPPR	project phasing and planning requirement document
PRR	preliminary requirement review
QM	qualification model
QR	qualification review
RF	radio frequency
RFW	request for waiver
RID	review item discrepancy
ROD	review of design
R&D	research and development
SE	system engineering
SEP	system engineering plan
SRR	system requirements review
STD	standard
STM	structural thermal model

tbd	to be defined
TRB	test review board
TRR	test readiness review
VCD	verification control document
w.r.t.	with respect to

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4

General requirements

4.1 Overview

4.1.1 The system engineering discipline

The key to the success of the system engineering implementation (which is defined as an interdisciplinary approach governing the total technical effort to transform a requirement into a system solution) is the integration of the engineering disciplines defined in ECSS-E-00, in order to design and verify a product, that meets the customer needs.

For the definition of lower levels of system decomposition, this Standard, in line with other ECSS Standards, does not impose a unique terminology on the assumption that it is the responsibility of each programme to optimize its breakdown choosing from the terms defined in ECSS-E-00.

In this respect the provisions formulated here for a space system apply, with appropriate tailoring, to a lower level of decomposition, on the grounds that products of practically any level are:

- the final result of an interdisciplinary process starting with the capture of the users needs and concluding with the delivery of a verified product and its acceptance;
- the result of the design integration of different parts and functions.

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

a. system engineering integration and control,

b. requirement engineering,

c. analysis,

d. design and configuration,

e. verification.

This functional decomposition represents neither a compulsory organization or hierarchical requirement nor the process, but rather a useful conceptual partition of the system engineering discipline, whereby each element (function) embraces tasks, which are homogeneous in objective and nature, and all elements together encompass the totality of the system engineering discipline's scope.

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

The participation of each SE discipline follows an iterative process at each phase of the SE process.

This Standard assumes the involvement of suppliers in close cooperation with the organization responsible for the system at each level of the product tree, for each of its elements, and for all SE disciplines.

For each function, general requirements and recommendations are given, covering all the system engineering activities as a means of obtaining a beneficial, reasonable, programme-independent reference.

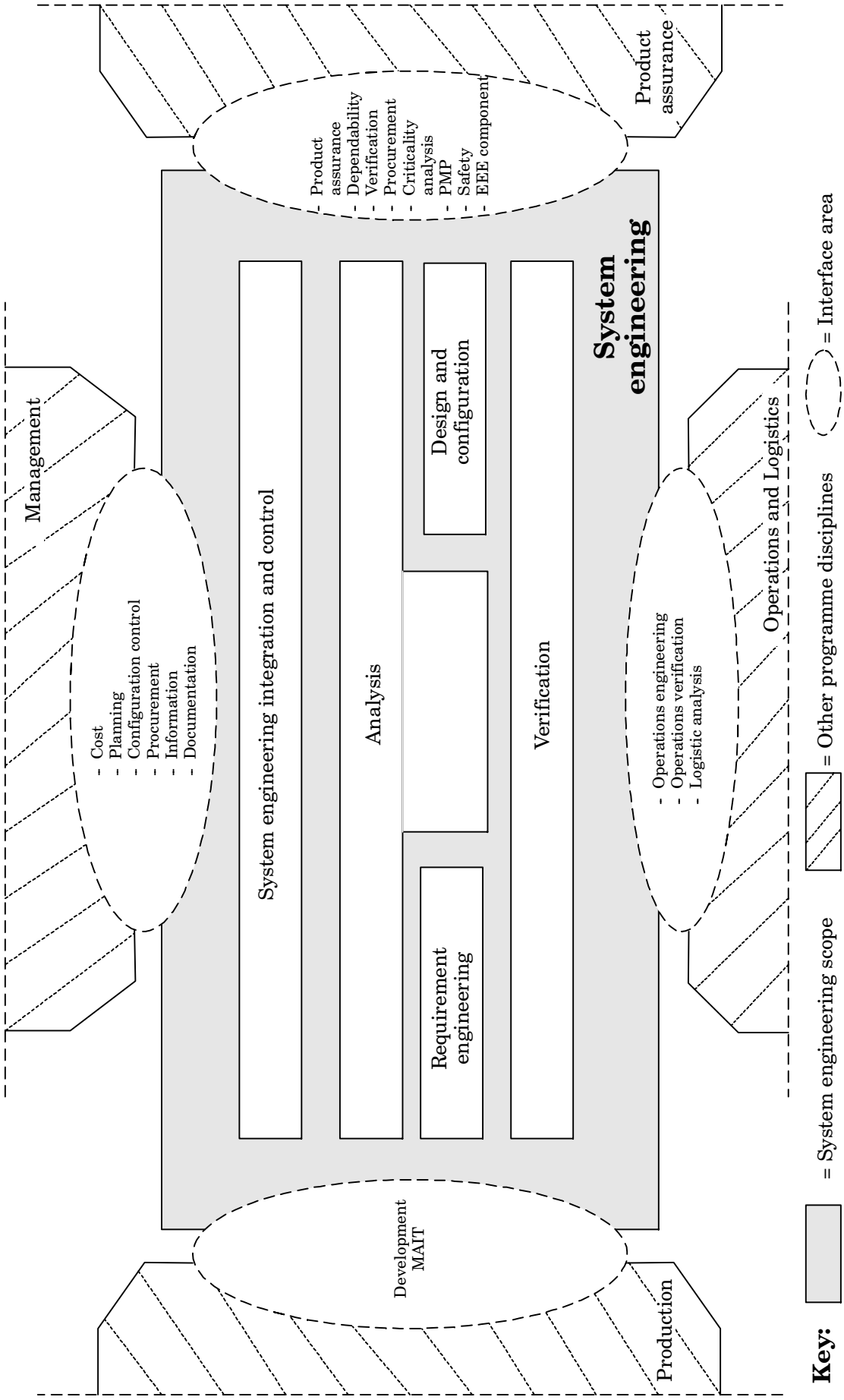


Figure 1: System engineering functions and boundaries

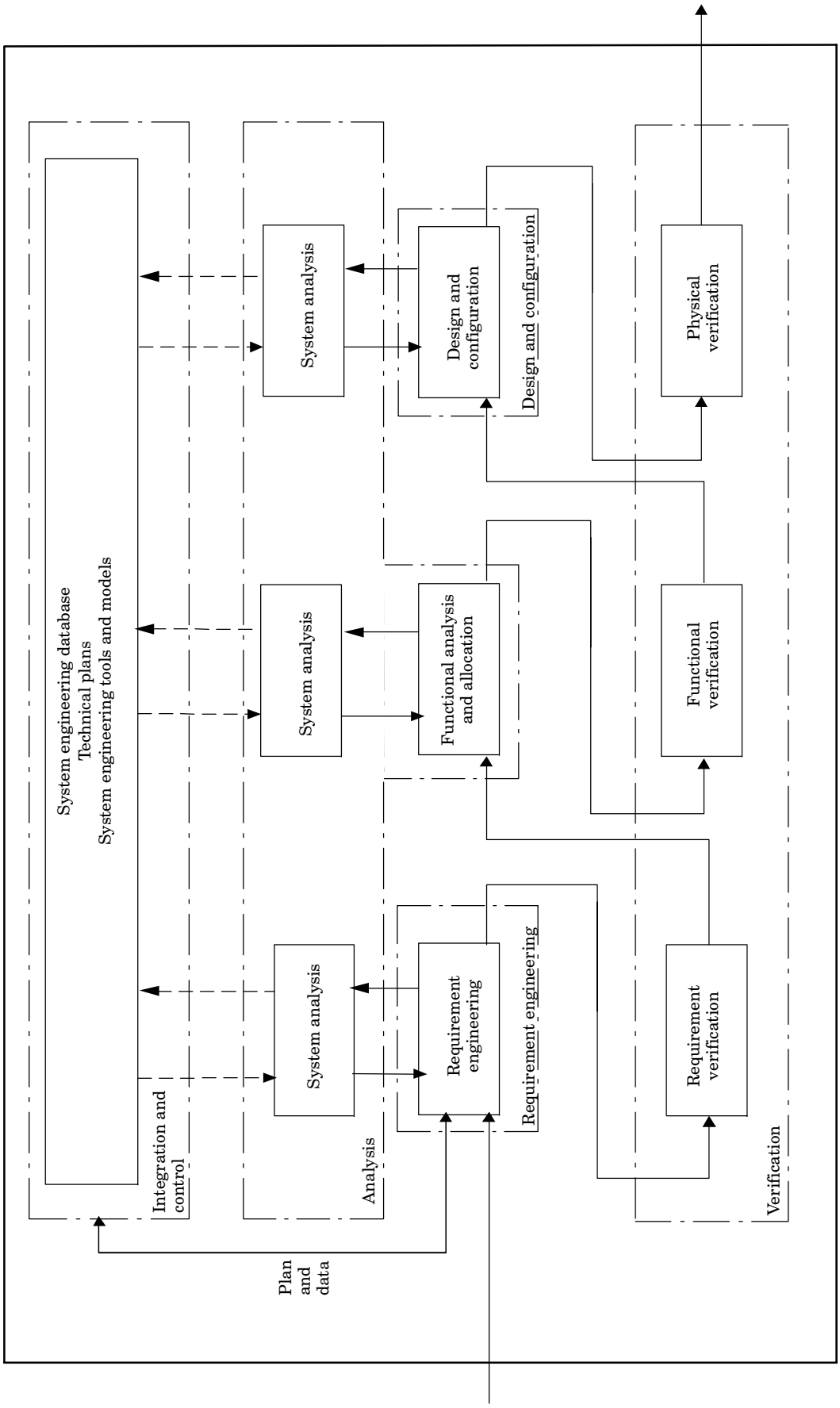


Figure 2: System engineering function relationships

4.1.2 Customer-system-supplier model

At each level, an organization in charge of the development of a product has a customer and a supplier (see Figure 3), and the product under its responsibility is called a system. Within this Standard, the customer is located at the "next upper level", whereas the supplier is located at the "next lower level".

NOTE The model in Figure 3 is the implementation of the customer-supplier model as described in ECSS-M-00B. In this model, the organization in charge of the development of a product is simultaneously a supplier w.r.t. to its own customer (next upper level), and a customer w.r.t. its suppliers (next lower level).

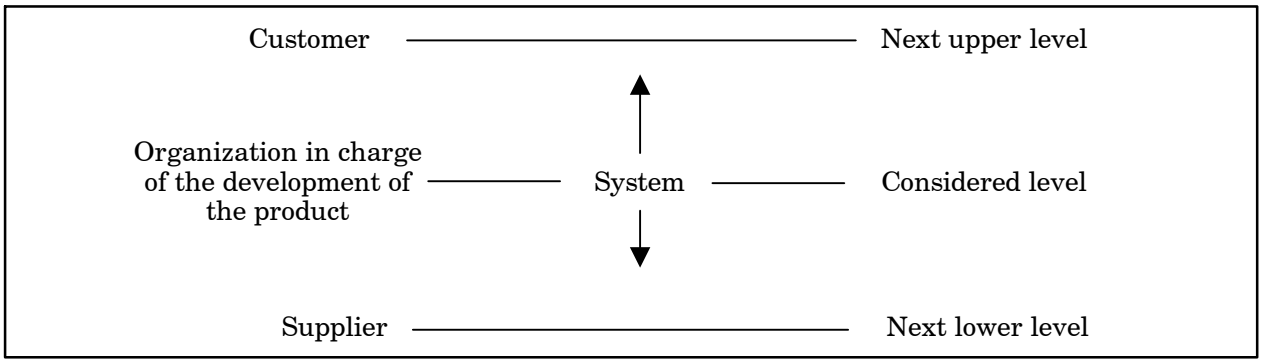


Figure 3: Customer-supplier net

The organization in charge of the development of the product has a system engineering (SE) organization that works under the responsibility of the respective project manager in charge of the development of the product. Usually, this organization also has a management, product assurance, engineering, production, and sometimes, an operations and logistics engineering organization. These are referred to in this Standard respectively as "management" (M), "product assurance" (Q), "engineering" (E), "production" (P), and "operations" (OPS).

NOTE The above scheme can be recursively and consistently applied to customer and supplier levels (where the roles of customer and supplier are as shown in Figure 3).

4.2 System engineering plan

a. The organization in charge of the system (the considered product, see Figure 3) shall produce a system engineering plan (SEP), which describes the approaches, techniques, tools, organization, planning and scheduling of the technical effort to accomplish the project objectives.

NOTE 1 The SEP demonstrates the implementation of the system engineering functions mentioned hereafter and the logic and consistency of the development activity planning.

NOTE 2 The requirements for the contents of the SEP are given in ECSS-E-10 Part 17A Annex E.

b. The SEP shall describe all anticipated contributions to the SE effort and be updated during the course of the project to reflect any evolution in the system engineering implementation.

c. The initial SEP and consolidated versions shall be submitted to the customer for approval.

d. Each supplier in charge of one element of the system decomposition shall establish its own SEP.

4.3 System engineering integration and control

4.3.1 Overview

System engineering integration and control ensures the integration of the various engineering disciplines and participants throughout all the project phases in order to optimize the total definition, realization and robustness of the system considering the whole life cycle and corresponding environments.

This includes, for example,

- electrical engineering,
- mechanical engineering,
- software engineering,
- communication engineering,
- control engineering,
- operations engineering,
- environmental engineering,
- logistics engineering,
- human factors engineering, and
- interfaces to management, product assurance, production, and operations following methodologies defined in the ECSS Standards.

4.3.2 Management of system engineering activities

System engineering integration and control, with the support of the engineering disciplines, shall be capable of the following.

a. Planning and managing a fully integrated technical effort that can achieve the general objectives of the system with a cost and risk acceptable to the customer.

b. Applying the system engineering process for each level of system decomposition during each phase of the project life cycle.

c. Monitoring and controlling the project progress through technical reviews, risk management, data management, interface management, configuration management and verification.

d. Making and implementing system design decisions by initiating and implementing:

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

e. Ensuring the availability of product and process data which enables the complete system to be produced, tested, delivered, operated, supported and properly disposed of.

f. Coordinating, integrating and harmonizing the planning, activities and products of all disciplines involved in space project engineering.

   NOTE For space engineering disciplines, see ECSS-E-00.

g. Ensuring that the methods and means (including software) for each activity are available and validated at the due time.

h. Ensuring that the experience gained in past and parallel activities is systematically considered in the process and in the design solutions.

4.3.3 Planning

System engineering integration and control shall:

a. ensure that the SEP conforms to the project master schedule;

b. provide inputs based on key events for each discipline to enable them to establish their own planning in a coordinated manner;

c. provide input to project management for planning purposes.

4.3.4 Engineering database

System engineering integration and control shall establish and control a database as a repository for engineering data from trade-offs, risk assessment, requirements, analysis, design, and verification.

NOTE For requirements on the database, see ECSS-E-10 Part 9.

4.3.5 Documentation and product data exchange

System engineering integration and control shall support the definition and the setting up of the documentation and data exchange system in order to facilitate the system engineering interdisciplinary work (e.g. interface management, and configuration control).

NOTE For engineering documentation requirements see ECSS-M-50, and for data exchange system requirements see ECSS-E-10 Part 7.

4.3.6 Interface management

4.3.6.1 Overview

System interfaces can be external (with other, contiguous systems) or internal (between functions within the system).

Both can be part of an original set of requirements (interface requirement document), or can be defined as outputs from functional studies. They are determined at the boundary between the functions of hardware or software assemblies implemented by engineering groups with different responsibilities, and are usually separately specified.

NOTE For interface requirement document see ECSS-E-10 Part 6.

4.3.6.2 Process

a. System engineering integration and control shall establish and maintain a positive control of interfaces supported by interface control documents (ICD).

b. Functional block diagrams and functional interface input and output shall be established in the start phase of the project and consolidated throughout its course.

NOTE For interface control document see ECSS-E-10 Part 4A Annex A.

4.3.7 Requirement engineering

a. System engineering integration and control shall ensure that each SE discipline contributes to the capture, the characterization and validation of the technical requirements.

b. With regard to system and product, only the set of technical requirements shall be considered, including product assurance technical requirements.

NOTE 1 Requirements for quality and management are excluded.

NOTE 2 This set can either be a functional specification or a technical specification.

4.3.8 Budget and margin approach

a. Technical budgets and associated approaches for design margins covering scatter and uncertainties shall be defined and controlled for each level.

b. During the development of a space system, margins shall be reduced depending on the maturity and degree of validation of the design, and related technical uncertainties, problems or potential development and mission risks.

c. For the physical parameters (e.g. mass, size and tolerance) a product-oriented element or component budget shall be identified.

d. There shall be a continuing comparison of anticipated and actual achievement for the technical parameters.

4.3.9 Technology

a. Systematic trade-offs of alternative technologies shall be made for attaining product performances, taking into account their availability and impact on the project.

b. The technologies considered for use shall be assessed in terms of availability, supportability and feasibility within the defined industrial organization cost and schedule.

NOTE This is particularly important during conceptual phases.

c. Any additional research or tests, or any investigation to reduce uncertainties and risks to an agreed level shall be conducted, and, where risks are higher than the agreed level, back-ups shall be envisaged.

NOTE For risk management, see ECSS-M-00-03.

d. Tracking of progress for the qualification shall be performed in a controlled manner in line with the overall schedule.

e. At the detailed definition stage, continuous monitoring of readiness and efficiency of the manufacturing processes and corresponding technologies shall be performed in order to detect any deviation from objectives.

4.3.10 Cost effectiveness

4.3.10.1 Overview

Cost effectiveness is a major driver in the programme decision process and design iteration.

4.3.10.2 Process

a. Cost effectiveness based on the product-system specific cost objective (e.g. recurring cost, operative cost or life cycle cost minimization) shall be considered as a product design parameter, along with, for example, technical requirements and availability.

b. Cost effectiveness may be applied to the system and each element of the system by allocation.

NOTE Value analysis is an adapted method to assess and ensure cost effectiveness. For value analysis, see ECSS-E-10 Part 8.

4.3.11 Risk management

a. System engineering shall contribute to the risk management process by specifically providing, and by assessing, the technical data involved in the risk management analyses, decision and implementation activities.

NOTE For risk management, refer to ECSS-M-00-03.

b. The contribution specified in a. above shall include support for the following:

1. analysis of the risk causes, consequences and acceptability;
2. quantification and categorisation of the risk;
3. definition and implementation of a risk management plan;
4. assessment of the effects of risk-reduction actions;
5. residual risk acceptance process.

c. System engineering shall consistently implement and control the selected reduction of risks, which are within engineering's responsibility.

4.3.12 Procurement

System engineering integration and control shall support the following:

a. the make or buy decision trade-off;

b. the preparation of the procurement specification, (e.g. by providing the technical specifications);

c. the procurement activities by coordinating engineering effort.

4.3.13 Change management

a. System engineering shall analyse the change impact on the technical elements.

NOTE For change control requirements establishment and maintenance, see ECSS-M-40.

b. When a change affects interfaces and involves parties on both sides of the interface, the upper level shall:

1. ensure the compatibility of newly defined interfaces,
2. make the decisions, taking into consideration the benefit for the whole.

4.3.14 System engineering capability assessment

a. The capability to perform system engineering tasks or an activity including system engineering studies should be demonstrated, as a minimum, with the following.

1. The evidence of adequate human resources, skills and experience, and the existence of an appropriate organization, able to execute the system engineering tasks.
2. Where subcontractor activities are carried out, the capacity to monitor, control and coordinate such subcontractor activities.

b. If a. above is not met, a system engineering capability assessment, carried out according to an approved procedure, shall be performed.

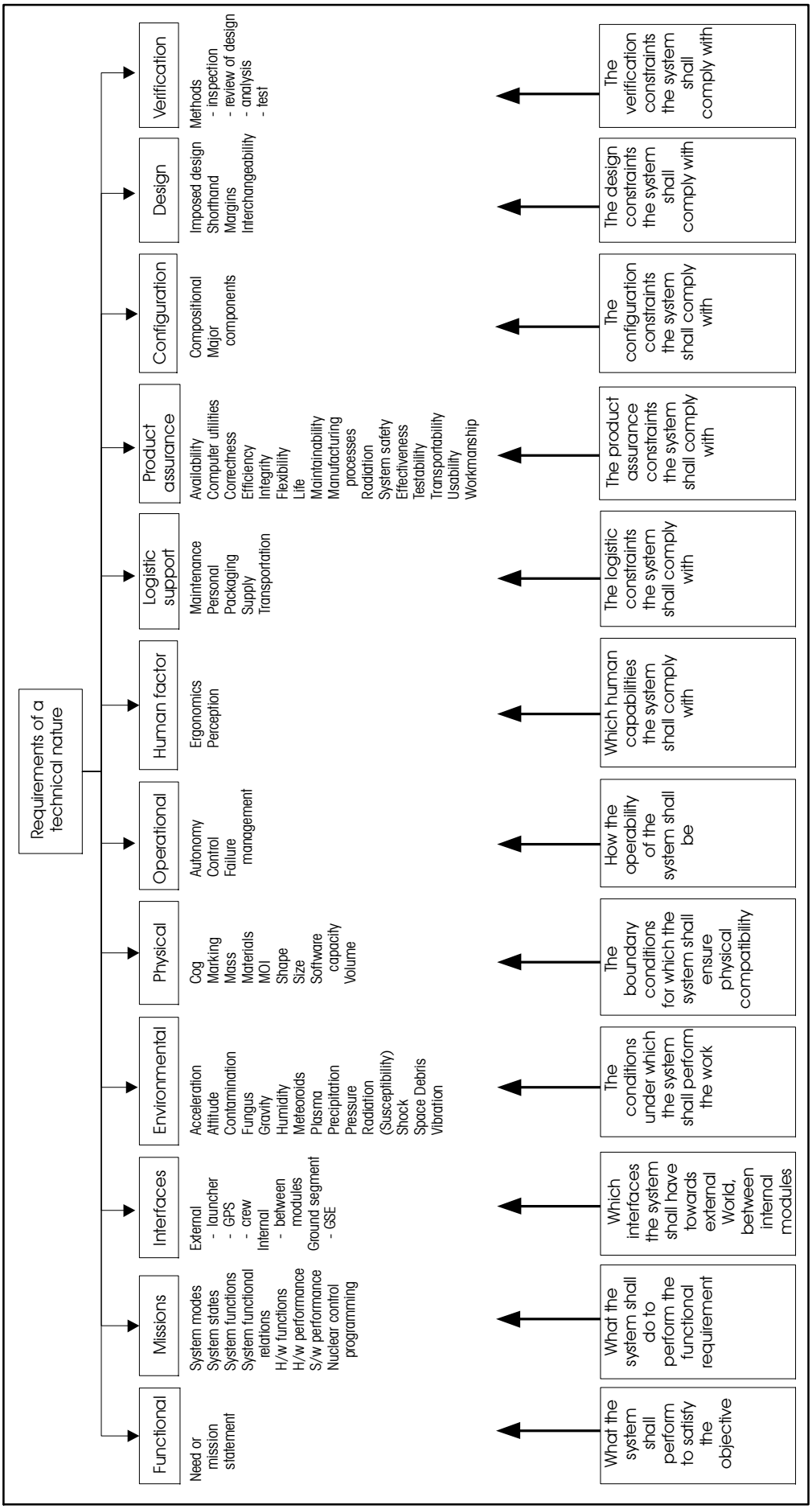


Figure 4: Space system requirement types

4.4 Requirement engineering

4.4.1 Objectives of requirement engineering

Requirement engineering shall ensure the following:

a. Proper interpretation of the customer needs and constraints concerning technical requirements for a product that satisfies the customer needs, produced, consolidated and agreed with the customer.

NOTE This can be done in interaction with the customer.

b. Generation, control and maintenance of a coherent and appropriate set of system and lower level specifications.

c. Full traceability of the requirements within the set of specifications stated in b. above, down to final verification close-out.

4.4.2 Requirement engineering elements

4.4.2.1 Overview

As specified in 4.4.2.2 to 4.4.2.6, for the purpose of performing requirement engineering, all requirements are

a. justified,

b. sorted by type,

c. possessing precise attributes,

d. assessed in terms of risk index,

e. traceable to the next upper level requirements.

NOTE See ECSS-E-10 Part 6 for details.

4.4.2.2 Requirement justification

Space system requirements shall be justified.

NOTE The objective is to avoid requirements without rationale or object, and to enable evaluation of requirement impact in case of non-conformity or requirement evolution.

4.4.2.3 Requirement classification

Space system requirements shall be identified, sorted and grouped on the basis of requirement classes in relationship to their objectives and sources.

NOTE The classification shown in Figure 4 is a guideline to structure the specification with the objective of facilitating checking of the completeness of the scope covered by the requirements.

4.4.2.4 Requirement attributes

In order to facilitate the system engineering process, in particular the verification activities, each requirement shall, as a minimum, have the attributes making it:

a. Traceable, e.g. either w.r.t. a higher-level requirement, an imposed constraint (e.g. an applicable standard), or an accepted lower level constraint.

b. Unique, and associated with an identifier (for example a document and paragraph number).

c. Single, and not a combination of several requirements.

d. Verifiable, using clearly identified verification methods.

e. Unambiguous (e.g. “no tbd’s”, no “should’s”).

f. Referenced to other requirements (with applicable document and paragraph identification).

g. Associated with a specific title.

4.4.2.5 Requirement criticality assessment

As each requirement differs in importance for the system development and operation in terms of impact on cost, schedule and risk, and, in order, to support the system engineering process vis-à-vis risk and cost minimization:

a. critical requirements shall be identified;

b. the sensitivity of the system to the critical requirements identified in a. above (i.e. the impact on implementation aspects due to modification of critical requirements) shall be evaluated;

c. an indicator of risk-severity and priority should be associated with each requirement identified in a. above, to support the requirement engineering activities.

NOTE For severity and criticality of a requirement see ECSS-E-10 Part 6.

4.4.2.6 Requirement traceability

4.4.2.6.1 Overview

Traceability is the ability to identify the relationship between:

a. requirements (e.g. a higher level requirement, an imposed constraint, applicable standard, or an accepted lower level constraint);

b. a decision and the affected requirements (e.g. within trade-off loops);

c. a requirement and its source (e.g. in the mission statement);

d. a verification result (e.g. test result) and the related requirement to be verified.

4.4.2.6.2 Process

The requirement engineering shall ensure implementation of the traceability, as defined in 4.4.2.6.1.

4.4.3 Requirement engineering process

4.4.3.1 Overview

The basic activities in the requirement engineering process (as specified in 4.4.3.2 to 4.4.3.5) are:

a. requirement capture,

b. requirement analysis and validation,

c. requirement allocation,

d. requirement maintenance.

4.4.3.2 Requirement capture

a. The customer's requirements (i.e. needs and objectives) shall be captured in order to achieve the following.

1. The understanding of the customer's expectations and agreement with the customer on a refined requirement baseline.
2. A synthesis of responsive products and services to the requirements (see 4.5.5).

b. To comply with a.1. above, potentially incomplete, ambiguous or contradictory requirements shall be identified and resolved with the customer representatives.

4.4.3.3 Requirement analysis and validation

Requirement analysis and validation shall include the following:

a. Assessment of different situations of the system during its life cycle from manufacturing to disposal with associated combinations of environmental conditions as well as the number of occurrences and their duration.

b. Identification of design, implementation, and the statutory and regulatory requirements specific to the product, not customer specified.

c. Identification of constraints (e.g. limits of applicability) related to each specific requirement.

d. Identification of operational scenarios of the system in all its modes.

e. Checking that the final set of requirements in the system and lower level specifications, is individually and globally consistent and non redundant (internal validation).

f. Gaining the acceptance by the customer of the final set of requirements in the system and lower level specifications (external validation).

4.4.3.4 Requirement allocation

a. The system requirements shall be allocated to the lower level products on the basis of system analyses and design and then to the requirements included in the specifications of these products.

b. The allocation process shall be iteratively carried out in parallel with functional, architectural, and design analyses.

c. The level of the requirements complexity (e.g. toward a single parameter requirement) shall be decreased by the requirement flow-down in order to achieve measurable detail or go, no-go criteria.

d. Existing specific requirements (e.g. some design or procurement constraints specified by the specification of the relevant product) shall be allocated to the applicable level.

4.4.3.5 Requirement maintenance

a. At all levels, requirements shall be maintained during the entire life cycle of the system down to final verification close-out.

b. Any change in requirements shall be processed and recorded in order to guarantee full visibility and traceability of the current requirement baseline.

NOTE For reporting of the actual requirement status, see ECSS-M-40.

4.4.4 Functional and technical specifications

a. Functional specifications and technical specifications of the system and of the different lower level products shall be organized in a comprehensive specification tree.

NOTE 1 A sample specifications tree is shown in Figure 5.

NOTE 2 For requirements applicable to specifications, see ECSS-E-10 Part 6.

NOTE 3 The functional and technical specifications are of different nature and depend on the characteristics of the configuration item to which they apply, and its level in the architecture.

b. Subsets (but logical integral parts) of the end item requirements specification (e.g. discipline requirements) may be the subject of dedicated support specifications.

c. Interface requirements, that are a logical integral part of the functional and technical specifications, may be the subject of stand-alone interface requirements documents.

4.4.5 Requirement management and tools

a. The requirement engineering approach shall be tailored and a requirements management tool shall be set up accordingly to ensure proper administration of the requirements.

b. Requirement management shall ensure the proper capture of the complete set of requirements in line with the criteria defined in 4.4.3.2.

c. Complete allocation of requirements to product tree elements shall be ensured, as well as to the related lower level requirements, and a corresponding traceability matrix shall be produced.

d. Requirements baselines shall be established as part of configuration baselines, change control shall be performed and the technical specifications shall be issued.

NOTE For requirements applicable to change control, see ECSS-M-40.

e. Requirement management shall ensure complete allocation of requirements to verification activities, and the production of a complete verification matrix.

NOTE For requirements applicable to the verification matrix, see ECSS-E-10 Part 2B Annex C.

f. Requirement management shall ensure the successful execution of all verification activities (i.e. verification close outs), and the complete verification control documents are produced, including lower levels.

NOTE For requirements applicable to the verification plan, see ECSS-E-10 Part 2B Annex D.

g. Requirements management (i.e. the administration of generation, allocation and maintenance of requirements) may be supported by computerized tools containing a requirement database and application software to support requirement control, traceability and reporting.

h. The tools detailed in a. to g. above should, when used, be linked to the verification control and configuration control tools.

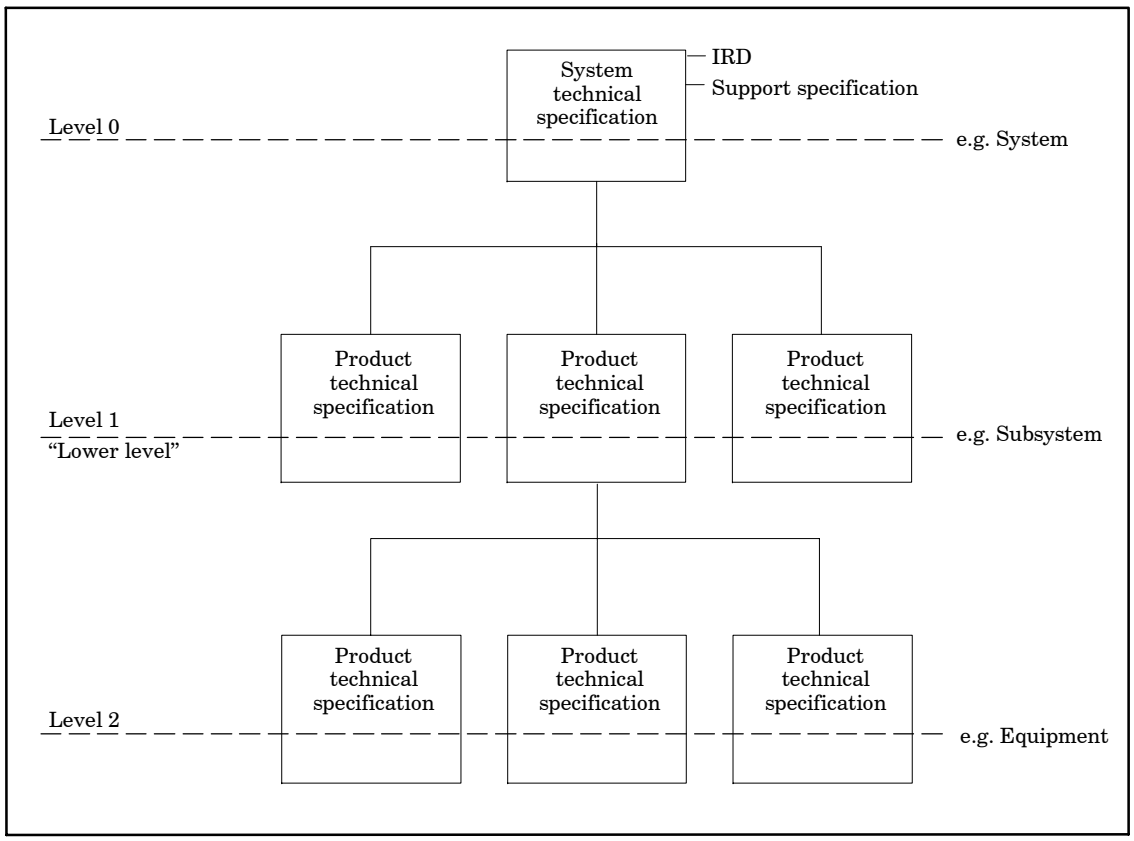
4.5 Analysis

4.5.1 Scope of analysis effort

4.5.1.1 Overview

System engineering analyses are performed at all levels and in all domains in order to:

- Resolve functional and performance requirements and constraint conflicts during requirement analysis.
- Decompose functional requirements and allocation performance requirements during functional analysis, and subsequently evaluate the effectiveness of alternative element solutions and select the best physical solution during synthesis.
- Assess system effectiveness, identify and analyse risk factors; select appropriate risk handling approaches; manage risk factors throughout the system engineering effort.
- Complement testing evaluation and provide trade studies for assessing effectiveness, risk, cost and planning.



IRD: Interface requirement document.
Support specification: Support specification document that presents formal general technical requirements which are applicable to different constituents through the related applicable specifications.

Figure 5: Sample specifications tree

4.5.1.2 Process

a. Analysis shall be performed in all domains at all levels and in all operation modes.

b. Analysis shall provide enough information and solutions to enable the decision maker to select the best available alternatives.

c. Analysis shall provide information for measuring progress, evaluating alternatives and documenting data and decisions used and generated.

d. Analysis shall include trade-offs, studies, effectiveness assessments, and design analyses to determine progress in satisfying technical requirements and programme objectives.

4.5.2 System analysis

a. System analysis shall be performed during all phases of the product life cycle.

b. System analysis shall integrate mission analysis, requirements analysis, functional analysis, physical analysis and performance analysis.

c. System analysis shall provide a rigorous quantitative basis for performance, functional and system assessments.

d. Cost and schedule shall be analyzed at each step of the product life cycle versus the system technical parameters.

e. Mission, requirements, design, operation and support shall be analyzed versus cost and schedule of the final product.

f. The analyst shall develop, document, implement, control and maintain a method to control analytic relationships and measures of effectiveness.

g. Critical measures of the effectiveness of technical performance should be identified to support the decision making.

h. System cost-effectiveness assessments shall be used to support risk assessment.

i. Margins and tolerances shall be assessed.

j. Budgets (e.g. mass, communication links, power, and on-board computer memory capacity) shall be assessed.

k. Time-line analysis shall be conducted to determine the time sequencing between two or more events and to define any resulting time requirements for assessing planning critical paths.

l. For each relevant life cycle event, environmental conditions shall be assessed and quantified from existing standards, existing environmental databases, laboratory tests, environmental models, or in-service measurement data.

m. Conformity between existing environmental databases and the project constraints shall be established.

n. Environment types and combinations occurring during the life cycle shall be considered on the basis of criticality with respect to system functions.

o. The influence of the environments during each life profile event on system function shall be assessed in terms of normal limit and extreme environmental conditions.

p. For each pair of system functions and environment conditions, the criteria for qualification and acceptance levels shall be defined.

q. The induced effects of design, such as mutual effects and dynamic interactions between system components or the system and its external environment, shall be taken into account.

r. Variability or statistical distribution of environmental factors shall be assessed and environmental factors applicable for design including margins for system robustness shall be derived.

s. Environment conditions shall be specified for verification, taking into account accuracy and limitations for modelling and test.

4.5.3 Trade-off studies

4.5.3.1 Overview

A trade-off study can be:

- Mental

  A selection based on the judgement of the analyst or designer, which does not demand the rigour of a more formal study, and for which the consequences are not too important (one alternative clearly outweighing the others) or time is not available for a more formal approach.

- Informal

  Following the same methodology as a formal trade study but is not formally documented since it is of less importance to the customer.

- Formal

  Formally conducted with results reviewed at technical reviews.

4.5.3.2 Process

a. The analyst shall conduct or consolidate synthesis trade-off studies in order to:
   1. Support decisions for new products and process developments versus non-developmental product and processes.
   2. Establish system and configuration items.
   3. Assist in selecting system concepts, designs and solutions (including people, parts and materials availability).
   4. Support material selection and make-or-buy, process, estimation and location decisions.
   5. Analyze planning critical paths and propose alternatives.
   6. Examine alternative technologies to satisfy functional and design requirements including alternatives for moderate to high-risk technologies.
   7. Evaluate environmental and cost impacts of materials and processes;
   8. Evaluate alternative physical architectures to select preferred products and processes.
   9. Select standard components, techniques, services and facilities that reduce system life-cycle cost and meet system effectiveness requirements.
   10. Assess the model philosophy demonstrating qualification objectives and verification goals as well as testability needs.
   11. Assess capacity of the design to evolve.

b. For the standard components referred to in a.9. above, agencies and commercial databases should be used to provide historical information for evaluation decisions.

4.5.4 Functional analysis

a. The analyst shall examine each primary system function in order to:
   1. Support the identification and definition of performance and functional requirements for the primary system functions to which system solutions are responsive.
   2. Support the selection of product and process design requirements that satisfy the performance and functional requirements, taking into account the project constraints.

b. From the requirements analyses a consolidated requirement baseline shall be established which is translated into a functional architecture.

   NOTE The functional architecture describes the functional arrangements and sequencing of sub-functions resulting from the breaking down of the set of system functions to their sub-functions, and is documented in the function tree.

c. Functional analysis shall identify product and subsystem solutions to the functional requirements that lead to an optimized functional architecture.

d. Functional analyses shall be conducted iteratively to analyze the functional requirements and to define the lower level functions that conform to the higher-level requirements.

e. Functional requirements shall be arranged so that lower level functional requirements are recognized as part of the higher level requirements.

f. Functional requirements shall be logically sequenced, with input, output and functional interface (internal and external) requirements defined, and be traceable from beginning to end conditions and across their interfaces.

4.5.5 Requirement allocation analysis

4.5.5.1 Overview

From each functional requirement and interface, performance requirements are established from the highest to the lowest level. If higher-level performance and functional requirements cannot be resolved to the lower level, the analyst determines performance requirements for lower level functions and evaluates alternative functional architecture.

4.5.5.2 Process

a. Allocable requirements shall be progressively divided down to lower levels.

b. Allocable requirements (e.g. time to perform or weight) shall be directly or indirectly allocated to sub-functions by partitioning the requirements directly allocable among sub-functions.

NOTE Requirements, that are not directly allocable, such as range, are translated into derived performance requirements such as fuel capacity, engine efficiency, and vehicle resistance, through specific techniques and analyses.

c. Non-allocable requirements shall be applied directly to all sub-functions (e.g. constraint, material or process standard).

d. The analyst shall document the allocation of system performance requirements to sub-functions in order to provide traceability and facilitate later changes.

e. Trade studies and risk analyses shall be performed to select a balanced set of sub-functions and to allocate performance requirements to sub-functions so that a balance of requirements is assured across sub-functions and to resolve conflicts among allocated performance requirements and non-allocable requirements.

f. The analyst shall examine each sub-function and aggregate of sub-functions to determine the responses (outputs) of the functions to stimuli (inputs).

g. Analyses shall be conducted as a means of understanding the functional behaviour of sub-functions under various conditions and checking the integrity of the functional arrangement logic.

h. Analyses should involve the simulation or stimulation of functional models, utilising operational scenarios, which expose the model to a variety of stressful and non-stressful situations, which reflect anticipated operational usage and environments.

4.5.6 Analysis tools and methods

4.5.6.1 Overview

Analysis tools are defined as all computer-supported tools used for the purpose of analysing a given design (e.g. tools for system simulation, for engineering design and performance assessment).

4.5.6.2 Process

a. The system engineering plan shall define the analysis tools and methods to be used during the product life cycle, as well as the model and data exchanges between the tools to be used.

b. Existing databases shall be used to evaluate the product (e.g. cost, technology, design, and test).

c. Analysis tools shall be validated, maintained, and operated by trained personnel, available for the lifetime of the project.

d. Analysis tools shall be capable of accepting reference data from the design tools via appropriate interfaces.

e. Analysis tools shall also be capable of exchanging engineering models and data to be used for the benefit of multi-disciplinary analysis, in a multi-tool and multi-site environment.

NOTE For requirements applicable to exchange of models and data by electronic means, see ECSS-E-10 Part 7.

f. Models produced by analysis tools shall be validated, and procedures and results shall be recorded.

g. Engineering tools that are computer-based shall be related to the engineering database of the programme to ensure data consistency and configuration control.

h. A digital or virtual model of the system should be developed, in order to:

1. analyze the aspects of the system that cannot be addressed by subsystem or discipline analysis (e.g. interaction between the AOCS and the power subsystem);
2. support trade-offs at system level (e.g. on-board architectures, and FDIR strategies);
3. analyze system operability issues (e.g. by executing intended mission profiles taking into account possible on-board and ground configurations);
4. assess engineering margins under realistic mission boundary conditions (e.g. as obtained from a mission simulation).

i. The system virtual model should focus on critical mission aspects at system level and be available early enough to support design decisions.

NOTE It can be based on subsystem models provided by the responsible suppliers.

j. The system virtual model should be able to provide a coherent and efficient simulation of the life cycle that is capable of evolving

1. from early system models used to support system and mission specification,
2. through models used to support different tasks during the design phase (e.g. compatibility of flight S/W with flight H/W, and FDIR concept and implementation) with increased fidelity,
3. to models to support the integration and test activities (e.g. as part of the EGSE), and the preparation and execution of operations.

k. The system virtual model should be coherent with subsystem and discipline analysis and design by:

1. incorporating subsystem and discipline specific models (e.g. AOCS model),
2. remaining consistent with subsystem and discipline design baseline and analysis results (e.g. thermal).

l. Analysis reporting shall include:

1. clear reference to the configuration item baseline assumed for the analysis,
2. identification of the analysis constraining assumptions (e.g. environmental),
3. explicit statement of basic assumptions and of analysis methods adopted,

4. description and justification of the mathematical models used.
5. conclusion providing the actual values, the expected values and the resulting margins.

4.6 Design and configuration

4.6.1 Design process

4.6.1.1 General

a. The design process shall result in a physical architecture and design (including software), from functional analysis and requirement allocation.

b. Synthesis shall be conducted interactively with analysis and verification to assess which design output best conforms to requirements.

c. In fulfilling tasks a. and b. above, design and configuration shall:
   1. Apply design simplicity concepts, evaluating alternatives with respect to such factors as ease of access, easy integration, common and non-complex tools, decreased part counts, modularity, producibility, standardization, and standardization of interfaces and cost.
   2. Demonstrate design consistency with results from risk reduction efforts.
   3. Identify critical parameters, and analyze their variability and solution sensitivity to the variability.
   4. Identify applicable process and material specifications.
   5. Define product and process alternatives iteratively as well as allowances for tolerances.
   6. Define tolerance methods that facilitate inspection.
   7. Adopt design solutions that facilitate fault detection, isolation and recovery (e.g. test points, modularity, built-in test software, and feedback loops).
   8. Define solutions to a level of detail that enables later verification that specified requirements are met.

4.6.1.2 Design trade-offs

4.6.1.2.1 Overview

Design is an iterative process whereby various concepts are evolved and evaluated against a set of design requirements, commensurate with cost, schedule, manufacturing constraints, performance and risk impacts.

4.6.1.2.2 Process

Design trade-off studies shall be conducted in order to, as a minimum, achieve the following objectives.

a. Evaluate alternative designs and processes (physical and software architectures) and associated risk to select possible solutions for products.

b. Select standard components, techniques, services and facilities that reduce system life cycle cost.

c. Evaluate environmental and cost impacts of materials and processes.

d. Examine alternative technologies, that can replace high-risk technologies.

e. Select materials and take make-or-buy decisions.

4.6.1.3 Budgets

As a part of the design and configuration activity:

a. All applicable system design budgets shall be generated and maintained, reflecting the as-designed status of the system.

b. Budget requirements for all system levels of decomposition shall be apportioned.

c. The margin policy defined as part of the activity in 4.3.8 shall be applied.

4.6.2 Configuration

4.6.2.1 Configuration content

a. The output of the design phase shall consist of the complete system functional, physical and software configuration, including the lower assembly levels, budgets, interfaces and relationships between external and internal items.

b. The level of detail of the description shall be a function of the programme phase, and shall include at all assembly levels the following output.

1. Baseline configuration definition and description throughout the life cycle phases (e.g. launch, deployed and end-of-life).
2. Technical input to the product tree and the configuration identification.
3. Life cycle resource requirements and physical characteristics (e.g. budgets: mass, inertia, COG, RF link, power, data rates, and propellant).
4. Project documentation, e.g. project drawings at all product detail levels (including studies, engineering drawings, assembly drawings, interface drawings, manufacturing drawings, and electrical architecture block-diagrams), technical specifications, design descriptions, interface control documents, and procedures.
5. Inputs to definition and implementation of the operation concepts (e.g. time lines).

NOTE For requirements applicable to configuration management, see ECSS-M-40

4.6.2.2 Product tree

4.6.2.2.1 Overview

The product tree describes the hierarchical breakdown of a complex system into lower level to fully define the system.

4.6.2.2.2 Process

a. The product tree shall be structured as a natural breakdown of the system taking into account production issues.

b. The product tree shall be strictly product oriented.

NOTE Product oriented means that there is a systematic subdivision of the product into discrete and related elements of the product to be provided.

c. The product tree shall provide a complete overview of the entire system by its defined product items and their relationships.

4.6.2.3 Configuration baseline

a. A system configuration baseline shall be established and placed under control at defined programme points.

b. The baseline specified in a. above shall record the design, data (for example drawings and budgets), text description and other information, decisions, and clarifications made to system requirements.

4.6.2.4 Assembly relationships

The supplier shall control and document the hierarchical and assembly relationship of the system elements with the physical architecture.

NOTE This can be implemented in various ways, for example with a drawing tree or bill of material.

4.6.2.5 Design definition file

The designer shall maintain a file that includes all design documents and drawings providing a detailed description (e.g. functions, interfaces and architectures) and the functional and operational characteristics of the product.

NOTE 1 The design definition file is frozen (i.e. formal configuration control) once the qualification of the product has been achieved.

NOTE 2 This file is used for development, production and maintenance, and parts of it contribute to the user manual.

NOTE 3 The file usually consists of a collection of technical documentation, and other descriptive materials as a contribution from all engineering disciplines. The discipline related ECSS engineering standards detail the major document requirement definitions (DRDs).

4.6.2.6 Design justification file

a. A file shall be established consisting of an assembly of justification evidence to prove that the design is optimized for the requirements expressed in the technical specification.

b. The file shall identify technical risks, and provide evidence supporting their acceptability.

NOTE 1 The design justification file is frozen (i.e. formal configuration control) once the product has been qualified.

NOTE 2 This file is used for development, production and maintenance, and parts of it contribute to the user manual.

NOTE 3 The file usually consists of a collection of technical documentation, and other related materials such as contributions from all engineering disciplines. The discipline related ECSS engineering standards include the major document requirement definitions (DRDs).

4.6.3 Design tools

4.6.3.1 Overview

Design tools are defined as all computer-supported tools used for the purpose of design, i.e. derivation of a physical architecture including software (e.g. CAD and CAE).

4.6.3.2 Process

a. All design models shall refer to a common reference coordinate system. (See ECSS-E-10 Part 12.)

b. The system engineering plan shall define the design tools and methods to be used during the product life cycle.

c. Existing databases shall be used for the design of the product (e.g. part assembly and process, technology and design re-use).

d. Design tools shall be validated, maintained, operated by trained personnel, and available for the lifetime of the project.

e. Design tools shall enable the exchange of data between different locations by electronic means.

NOTE See ECSS-E-10 Part 7.

f. Models produced by design tools shall be validated.

g. Design tools shall provide reference data to the analysis tools, by offering interfaces.

NOTE This enables design iterations to be optimised in the system engineering process and minimize cost.

h. Design tools shall be correlated to the engineering database to ensure data consistency and configuration control.

i. Design tools shall contribute to the establishment of the system virtual model, as given in 4.5.6, and implement all multi-disciplinary aspects of it.

j. The virtual model shall be the master reference for the system configuration and all related analyses.

4.7 Verification

4.7.1 Verification process

4.7.1.1 Overview

Verification demonstrates, through a dedicated process, that the deliverable system meets the specified requirements and is capable of sustaining its operational role during the project life cycle.

NOTE Assembly, integration and test (AIT) activities considered by this Standard are related to the verification process for a given product (e.g. product qualification, and product acceptance).

They do not include any AIT type activities performed for the sole purpose of the production process and production quality assurance (e.g. process control, assembling operations, quality control, and facility operations), as well as the AIT activities for the production of off-the-shelf products (not produced as a direct response to a customer specification).

4.7.1.2 Verification process content

4.7.1.2.1 Overview

The verification process addresses all constituents of the system and is incrementally performed applying a coherent building block approach by

- establishing verification criteria against specified requirements,
- deriving the planning for the associated verification activities,

- monitoring the implementation and the execution of all verification activities at all levels in all phases,
- preparing the verification close-out documentation.

4.7.1.2.2 Stages

The verification process usually comprises the following stages:

- development,
- qualification (which can include in-orbit or in flight qualification),
- acceptance (which can include in-orbit or in flight acceptance),
- pre-launch readiness, and
- post-landing verification.

4.7.1.2.3 Verification objectives

The objectives of the verification process are as follows.

- To demonstrate the qualification of design and performance, as meeting all specified requirements (including time-lines) at all necessary levels.
- To ensure that the flight hardware and software are free from workmanship defects and acceptable for flight.
- To validate tools, procedures and personnel necessary to support the system ground and flight operations.
- To confirm system integrity and quality of performance after certain stages in the project life cycle.

Even though they are not strictly verification activities, payload related activities, such as instrument calibration, magnetic residual characterization, and payload calibration, are usually considered part of the verification process.

4.7.1.3 Verification approach

a. A verification approach shall be selected during each phase of the project including Phase 0, where relevant (see Clause 5), by
   1. analyzing the requirements to be verified taking into account design constraints and the qualification status of candidate solutions;
   2. considering the availability and maturity of the verification tools;
   3. considering the test and verification methodologies;
   4. examining the programmatic constraints;
   5. considering the cost and schedule.

b. The approach specified in a. above shall be derived through an iteration process to identify:
   1. “Which” requirements to verify;
   2. “How” to verify them;
   3. “When” to implement the verification steps in the development process.

   NOTE See Figure 6.

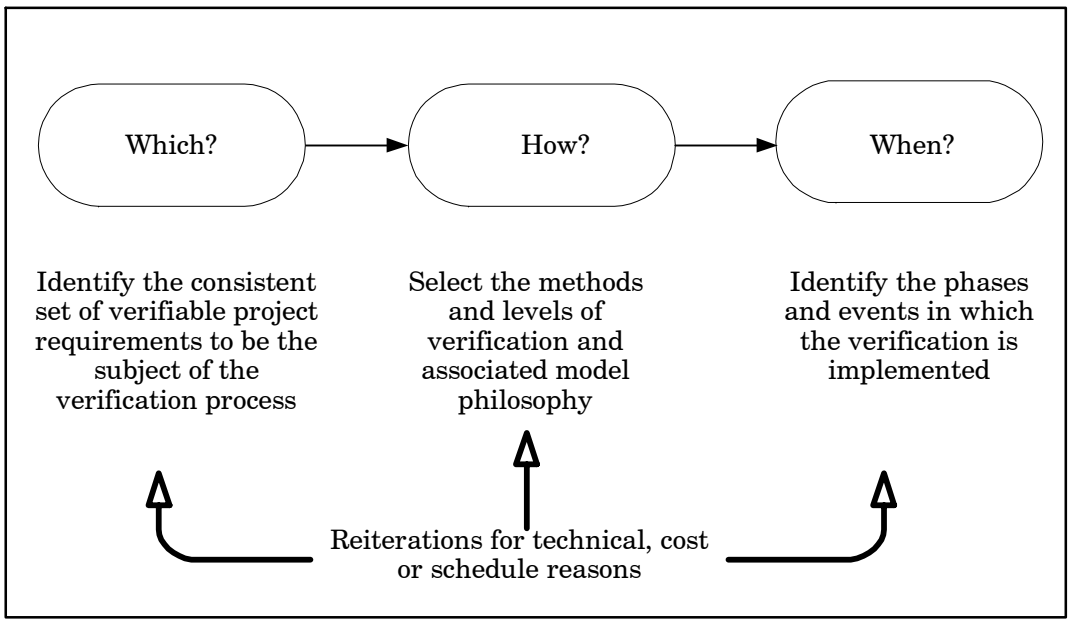


Figure 6: basic verification approach

c. The system and lower level requirements shall be verified by one or more of the following methods:
   1. test (including demonstration);
   2. analysis;
   3. review of design;
   4. inspection.

d. The verification method shall be selected according to the type and criticality of the requirement, and with the cost effectiveness of the method in mind.

e. For each verification event, acceptance and rejection criteria shall be defined and expressed in unambiguous, measurable terms.

4.7.1.4 Verification levels

a. The requirement verification shall be performed incrementally at different verification levels in relation to the product tree.

   NOTE Verification levels usually include
   - equipment,
   - subsystem, and
   - system.

b. Formal close-out of qualification or acceptance at lower levels shall be performed prior to close-out at higher level.

c. The resulting organized data shall support the formal declaration of the system verification achieved.

4.7.1.5 Model philosophy

a. The model philosophy shall be justified in the system engineering plan.

b. A trade-off of the number of models (from system to lower assembly levels) shall be made in order to achieve a high confidence in the product verification with the shortest planning and a suitable weighting of cost and risk.

c. The model philosophy definition shall combine programmatic constraints, verification strategies, integration and test program aspects, availability of

verification facilities and the development status of the candidate design solution as shown in Figure 7.

NOTE Examples of model philosophies are prototype, protoflight or a mix of the two, called a hybrid philosophy.

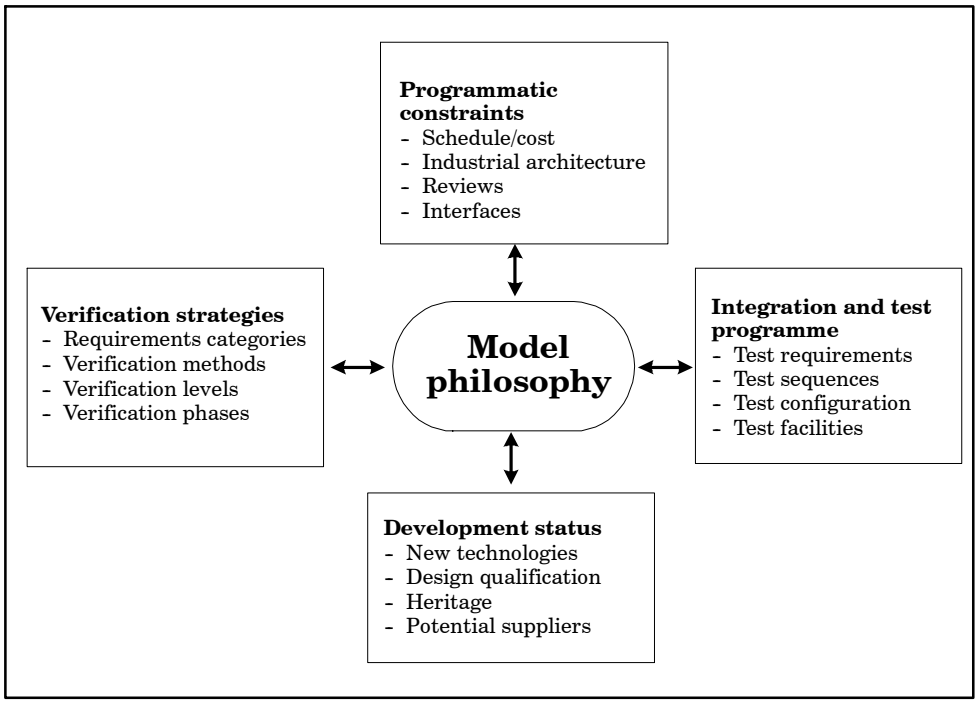


Figure 7: Parameters for model philosophy definition

4.7.2 Verification strategy

4.7.2.1 Overview

The process for deriving a verification strategy is shown in Figure 8.

4.7.2.2 Strategy

a. Verification shall be strictly connected to the requirements, which represent the start and the end point of the process.

b. A coherent verification strategy shall be defined for each class of requirement (see 4.4.2.3) combining the selected verification methods at each level of verification to be applied at the different verification stages in order to ensure consistency between verification activities, and to avoid duplications or gaps in the entire verification process.

c. The verification process shall include a combination of the functional tests during integration and environmental tests.

d. Each requirement shall have a corresponding entry in the verification control document.

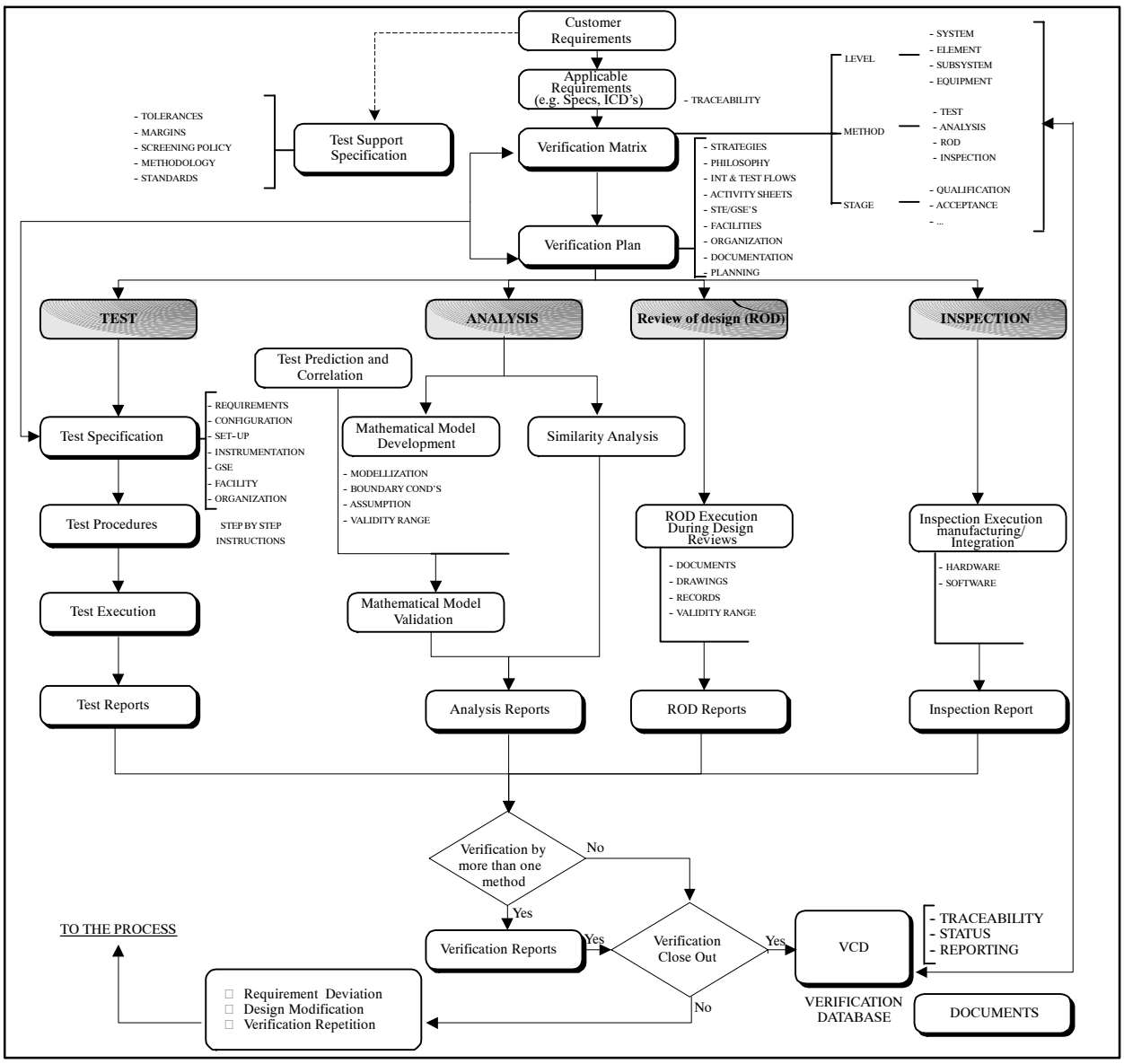


Figure 8: Documentation associated to the verification strategy derivation

4.7.2.3 Environmental verification

4.7.2.3.1 Overview

Verification of the environmental requirements to be applied in qualification and acceptance represents an important subset of the verification process.

4.7.2.3.2 Process

The environmental verification strategy shall be based on the most efficient combination of prediction of the response to the environment by models and environmental tests.

4.7.2.4 Testing

a. The tests to be performed on the defined models at the applicable levels in the different stages shall be selected in agreement with the chosen verification strategy.

b. Tests shall be selected based on their effectiveness in covering the specified requirements.

c. An assessment of the effectiveness of a test (e.g. specific, non-common, new, or multiple test methods) shall be made in order to define the most appropriate test strategy and evaluated on the basis of statistical data from past projects.

d. The methodologies applied for testing shall be the subject of trade-offs taking into consideration the state-of-the-art test methods and other available techniques (e.g. infrared versus solar simulation in thermal balance test).

e. The severities of tests (i.e. levels and durations) shall

   1. be tailored in accordance with requirements, design approach and verification strategy,
   2. take into account test conditions (e.g. tolerances).

f. If testing includes demonstration, the demonstration shall be conducted through observation with or without special test equipment or instrumentation, to verify qualitative characteristics such as human-factor engineering features, services, access features, and transportability.

4.7.2.5 Analysis

4.7.2.5.1 Overview

Analysis is used in the qualification phase very often in combination with testing.

4.7.2.5.2 Process

a. Analysis methods (for example, mathematical modelling, similarity analysis, and simulation) shall be selected on the basis of technical success and cost effectiveness, in line with the defined verification strategies.

b. Similarity analysis with an identical or similar product shall

   1. provide evidence that new application characteristics and performances are within the limits of the precursor qualified design,
   2. define any difference that can dictate complementary verification stages.

4.7.2.6 Review of design (ROD)

a. The review of design shall consist of reviewing a document or drawing for conformance to a specific requirement.

b. The activity should be carried out simultaneously with the product design review.

c. The method shall be selected in line with the verification strategies.

d. Establishment of conformance to the design baseline shall be documented by a review of design report.

   NOTE For requirements on review of design reports, see ECSS-E-10 Part 2B Annex K.

4.7.2.7 Inspection

a. Inspection shall consist of inspecting hardware and software for conformance to applicable documentation.

   NOTE Inspection can be complementary to review of design.

b. The activity should be carried out together with quality assurance tasks during development and production.

c. The method shall be selected in line with the verification strategies.

d. Establishment of compliance with the design baseline shall be documented by an inspection report

   NOTE For requirements on inspection report, see ECSS-E-10 Part 2B Annex L.

4.7.3 Verification tools

a. The verification process shall be implemented with the support of appropriate verification tools (for example, ground support equipment, simulators, analytical tools, AIT tools, and test facilities).

b. The supplier shall be capable of demonstrating that the design and validation of these tools are in accordance with the best current engineering practices for the space domain in line with references or documents submitted by him.

NOTE Maximum care is devoted to the design and verification of these tools because verification results strictly depend on their quality.

c. Verification tools shall strive to improve commonality and re-usability at different levels and across the different phases of a project.

d. The system verification shall be supported by tools that maximize efficiency, thereby ensuring that the verification objectives are met while mitigating risk and preserving costs and schedule.

e. The system verification tools shall enable a coherent and efficient approach to the life cycle and be capable of:

1. Integrating and making use of virtual system models developed to support the design phases (see 4.5.6).

NOTE The system virtual model can be used to debug the test procedures in advance of the hardware integration, to replace missing hardware components, and to provide the environmental simulation for closed-loop tests.

2. Evolving to support of an efficient preparation of mission operations, including the validation of the operational procedures.

NOTE This can be facilitated by using the same environment for testing and for mission operations.

f. The verification tools shall enable coherence between system verification activities and next lower level verification activities.

g. The verification tools should enable optimization of the development process by:

(a) ensuring compatibility between system and lower level verification activities, so that system activities can be built upon the next lower level activities (e.g. re-use of test procedures);

(b) enabling re-usability of modules from the next lower level AIT benches for system AIT benches (e.g. front-end equipment).

4.7.4 Verification implementation

a. The verification process shall be implemented through the following major steps.

1. Definition of the overall verification philosophy.
2. Generation of verification requirements and associated verification planning, including consideration of next lower level.
3. Contribution to the AIT planning in line with the verification philosophy, including consideration of next lower level.
4. Bottom-up execution of review of design-analysis-test-inspection.
5. Verification control and reporting.

b. Implementation of the verification process shall be documented.

NOTE 1 The basic set of documents to assure proper implementation of the verification process includes, for example:

1. system and lower level verification plans, part of SEP,
2. verification control documents,
3. system and lower level AIT plans,
4. test specifications and procedures, and
5. test report, analysis report, review of design report, inspection report, and verification reports.

NOTE 2 The principle is that from SEP either a verification plan, or an AIT plan, or both, are rolled out (without overlap), or an AIV plan combining the two is rolled out, whenever appropriate for the programme (see Figure 9).

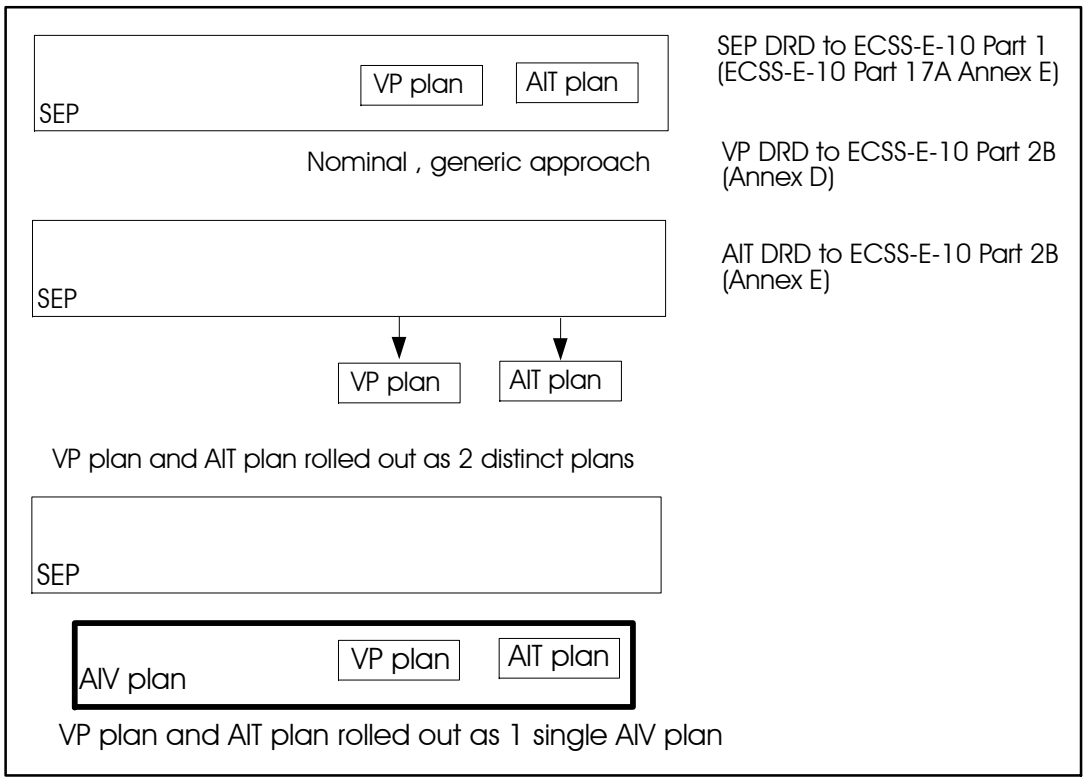


Figure 9: VP plan and AIV plan roll out

c. The verification process shall be tightly controlled in order to prevent potential problems, reduce risks of cost increase and schedule slip, and give visibility of the verification process to the customer.

d. A verification database, linked with the requirement database, should be used.

NOTE The objective is to minimize repetitive work with the possibility of errors, and improve the effectiveness of the overall process.

e. Traceability to requirements shall be used to ensure a nominal verification control activity.

NOTE The results of the verification implementation are documented in the design justification file up to completion of the

qualification of the product. Further verification activities are documented in the production master file.

4.8 System engineering interfaces

4.8.1 General

Interfaces between the system engineering process and other processes and the engineering disciplines are shown in Figure 10. Exchanges through these interfaces are identified in Clause 5 in the description of the system engineering process through all phases of a project.

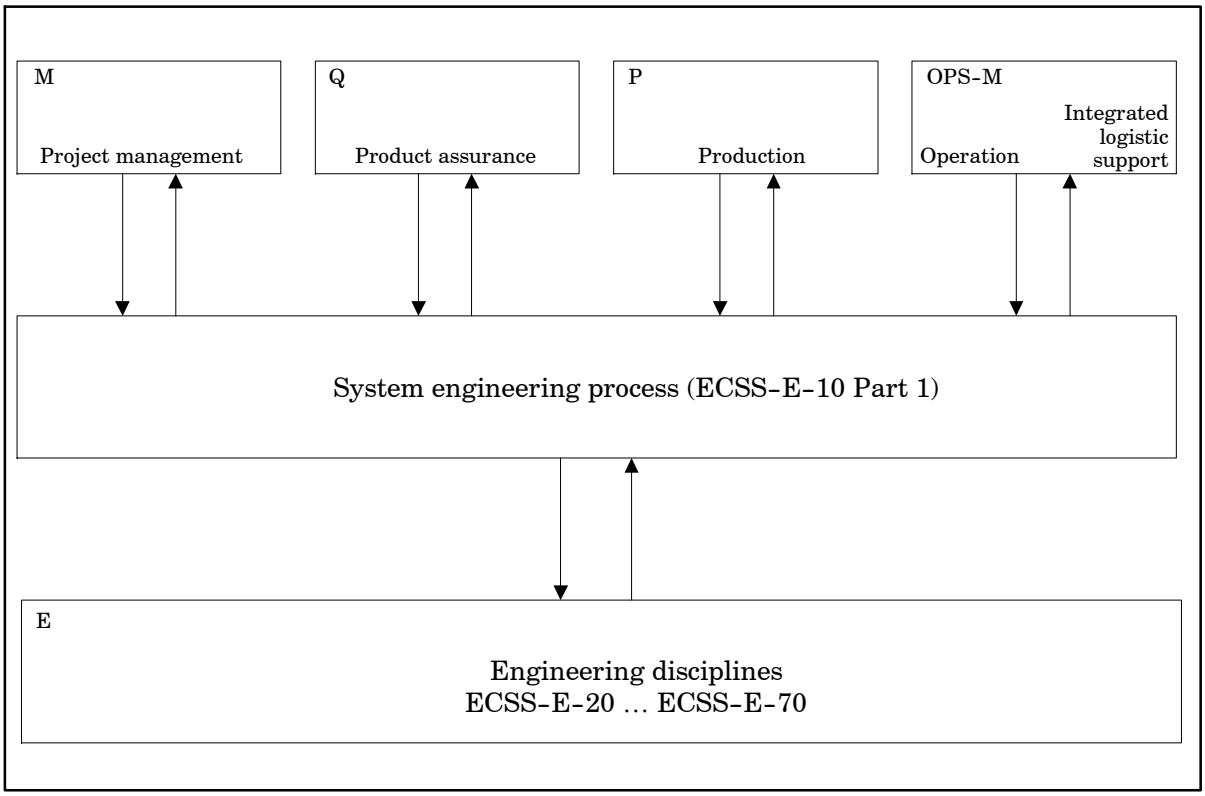


Figure 10: System engineering process interfaces

4.8.2 Management

a. System engineering management as described in 4.3.2 shall exchange inputs and outputs with project management in order to provide to and receive from the project management all technical data used for the decision process at system level.

b. System engineering shall interface with management for the following issues.

   1. Planning (see 4.3.3): with reference to project planning and phasing data and associated detailed plans to assess, define and control the phasing of activities and monitor milestone events and forecasts.
   2. Cost: to supply estimates of activities-resources and monitor accounted activities and trends.
   3. Configuration control: to support finalization and maintenance of technical baselines (e.g. requirements, design, and verification) through configuration control boards and implement configuration management procedures for product identification, control and accounting.

4. Procurement (see 4.3.12): to assure availability of technical data for items to be produced, technical monitoring and control of supplier's activities and products and definition of acceptance procedures.
5. Change management (see 4.3.13): to coordinate each change proposal, define technical implications, support planning and budgeting of change and commit to finalize released proposal.
6. Risk management (see 4.3.11): to enable risk assessments and the risk management policy selection and implementation.

   NOTE For risk management policy, refer to ECSS-M-00.

4.8.3 Product assurance

Product assurance (PA) and systems engineering activities shall be interfaced in such a way as to ensure reciprocal timely availability of inputs, especially w.r.t. the following:

a. Coordination of SEP and product assurance plan.
b. The implementation of the PA requirements in the technical specifications (e.g. dependability and safety, EEE parts, materials and processes).
c. Verification requirements.
d. Requirement traceability.
e. Assessment of the proposed design solutions, e.g.
   1. system architecture,
   2. functional architecture,
   3. technology trade-offs,
   4. materials, parts and processes,
   5. safety features.
f. The conduct of
   1. risk assessment studies,
   2. dependability analyses (hardware and software),
   3. materials and critical process qualification assessments,
   4. evaluation of hardware and software verification process-status,
   5. evaluation and qualification of material and processes,
   6. nonconformance treatment,
   7. assessment of failures.

4.8.4 Production

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

NOTE 1 This relates to, for example:

- Incorporation of design and verification inputs into manufacturing, AIT documents.
- Involvement of production in evaluations of the design solutions for producibility, testability and cost trade-offs.
- Preparation, execution and evaluation of development tests, i.e. tests supporting a prototype design improvement process based on iterative loops of manufacture, test and evaluation when theoretical design work and simulation are not sufficient.

- Development and qualification of manufacturing process.
- Holding test readiness reviews and test review boards.
- Adjustment and validation of assembly and handling procedures.
- Non-conformance evaluation and disposition (hardware and software).
- Agreement between system engineering and production, on, for example, the:
  - manufacturing plan,
  - work orders,
  - integration records,
  - test report,
  - integration and test procedures,
  - test support tools,
  - assembly, integration and test plan,
  - verification plan,
  - test specifications,
  - manufacturing drawings.

NOTE 2 Verification of requirements is the responsibility of system engineering: this is done by monitoring the test activity performed by production. In particular:

- System engineering and production agree on an AIT plan (on the basis of the verification plan from which an initial AIT concept is derived by system engineering) and participate jointly in test readiness reviews and test review boards.
- System engineering produces test specifications and test reports.
- The test procedure, the execution of the test themselves, and test result documents (containing raw test data) are the responsibility of production.
- For recurrent products, the above activity is tailored by production (see 5.7.2.9).

NOTE 3 For production interfaces, refer to ECSS-E-10 Part 15.

4.8.5 Operations and logistics

4.8.5.1 Operations engineering

The system engineering process shall ensure that all points of interface with operations and logistics are duly supported by communication, cooperation and provision of inputs between the organizations.

NOTE 1 This relates in particular to:

- design feedback and implementation policy associated with operations requirements;
- correlation between system performance and operations requirements;
- command and measurement characteristics associated with system equipment;
- deployment and installation scenarios, methods and procedures;

- engineering (design, interfaces, and configuration) requirements and constraints to be satisfied by the operations plans and procedures;
- operations and maintenance scenarios, objectives and requirements, including disposal, for implementation in system design;
- master measurement and command list;
- operations feedback and implementation policy associated with engineering requirements and constraints to be satisfied by the operations and ILS plans and procedures;
- contribution to user manual and training aspects.

NOTE 2 For system operation engineering refer to ECSS-E-10 Part 16, and for logistics engineering refers to ECSS-E-10 Part 10.

4.8.5.2 Operations verification

Interface activities in operations verification shall be supported by system engineering w.r.t:

a. Establishment of operations verification requirements.

b. Qualification and acceptance of operations activities, in terms of functional verification, procedures (including time-lines) and operational data verification, integrated mission simulation.

4.8.5.3 Operations documentation

System engineering shall interface with operations documentation by supporting them with the following:

a. Preparation of user manuals.

NOTE This is usually under the control of operations but includes sections and data provided by system engineering.

b. Preparation of accommodation handbooks.

NOTE This is usually under the control of system engineering but includes section and data provided by operations.

4.8.5.4 Integrated logistics support (ILS)

4.8.5.4.1 Overview

ILS, within the system engineering process, is a disciplined, unified and iterative approach to the management and technical activities performed in order to

- integrate support considerations into system and equipment design,
- develop support requirements that are related to supportability and readiness objectives and to design,
- provide such support.

4.8.5.4.2 Process

System engineering shall take into account and process the inputs and requirements generated by the integrated logistics support (ILS).

NOTE For requirements applicable to ILS, see ECSS-M-70.

4.8.5.5 Logistic analyses

a. Logistic analyses, by which the logistics support for a new system is identified and evaluated during the development phase, shall be conducted at system engineering level.

b. Logistic support analysis shall be performed to cover, as a minimum, the following.

1. The initial determination and establishment of logistics criteria as an input to system design.
2. The evaluation of various design and support alternatives.
3. The identification and generation of logistics source data for the development and provisioning of logistics support elements.
4. The establishment of a reference database of logistics data (LSA record system).

NOTE LSA activities are supported and complemented by a set of different analytical methodologies such as:

- maintenance analysis,
- reliability centred maintenance analysis,
- level of repair analysis,
- logistic modelling,
- supply support analysis, and
- packaging, handling, shipment and transportation analysis.

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5

System engineering process

5.1 Introduction

5.1.1 Purpose

This Clause defines a generic SE process for all space products. This SE process is defined for each phase in accordance with ECSS-M-30.

5.1.2 Methodology

Each phase starts with a kick-off event and ends with a review and closing of the related actions.

For each phase the process is described with an objective, flowchart, text and table as follows:

- The objective is expressed as defined in ECSS-M-30.
- The flowchart shows the different tasks and their relationships.
- The text is in the form of numbered lists. List item a. states the task to be performed as a requirement. Subsequent bullets describe recommended activities to fulfil the task specified in a., and the expected outputs.
- The table lists, for each task, the input information (input from), the documents to be delivered (output to), the SE functions to be performed and the contribution of other actors.

For each phase the process comprises the starting conditions (kick-off), the sequence of tasks to be performed, and the closing event (review).

If in the description of the process (e.g. in the flowchart) it is shown that different tasks are executed in parallel or in series, in practice iterations between them are performed and encouraged. These iterations are not described in this Clause.

Two types of documents are identified at the end of each task and phase: formal documents (ECSS standards and DRDs to the different parts of ECSS-E-10) and informal documents. The latter can be part of a formal document or “standalone” document useful for the internal needs of the project.

5.1.3 Conventions

Documents that are considered to be the output of a phase in accordance with ECSS-M-30 are identified in the text with the statement “see ECSS-M-30”.

ECSS standards and DRDs references are given when they are first used in the tables and in the text. However, the complete reference is only specified in the text.

In the tables, to indicate which actors and disciplines are involved in a task, the following notation is used:

- Cus customer-consumer
- M company management or project management
- Q product assurance
- E engineering discipline
- Ops operations
- P production

To indicate the nature of the contributions of the different actors and disciplines, the following notation is used in tables:

- (R) responsible for doing a task
- (Ag) agreement, with the signification of acceptance (see ECSS-P-001)
- (Ap) approval (see ECSS-P-001)
- (C) contributing to a task
- (I) for information

To indicate which SE function is in charge of a task the following notation is used:

- An analysis
- DC design and configuration
- IC integration-control
- RE requirement engineering
- V verification

For each task, only the leading SE function is given.

In the flowcharts, tasks shared with other disciplines and performed under the responsibility of the other disciplines appear in boxes with rounded corners and dotted borders.

Task “i” of a flowchart is detailed under sub-section “i” of the “Description of activities” and under ID “i” in the table of that phase.

The concept GSE includes MGSE, EGSE, OGSE and FGSE.

5.1.4 Customer–supplier model and responsibilities

The customer-supplier model on which this Standard is based is defined in 4.1.2.

The links to be established by the SE organization with management, product assurance, engineering, production and operations, are identified in the tables in the columns “Input from”, “Other actors” and “Output to”. They concern e.g. the management, product assurance and operations of the organization to which the SE organization belongs, in line with 4.1.2.

Successive configuration baselines are established and placed under the relevant responsibilities of the customer or of the organization to which SE belongs, as follows:

- Internal configuration control: the related activities are the responsibility of the organization to which SE belongs.
- Formal configuration control: the related activities are subject to the approval or agreement of both the customer and the organization to which SE belongs.

5.1.5 Approval and agreement

In this Clause, the concept agreement has the same meaning as acceptance, as defined in ECSS-P-001, “act of an authorized representative of the customer by which the customer assumes for itself, or as an agent of another party, ownership of existing and specified products tendered, or confirms satisfactory performance of specific services, as partial or complete performance of the contract on the part of the supplier”.

The concept approval has the meaning defined in ECSS-P-001, “formal agreement to use or apply an item”.

5.1.6 Generic and practical implementation aspects of the SE process

This generic process describes the phases and the activities to be performed to obtain a product and to satisfy the mission statement or an intended need. It is applied for each element of the architectural decomposition, i.e. each white bar in the Figures 11 to 14.

The terminology used is intentionally kept generic.

Figure 11 to Figure 14 show, generically, the SE life cycle. This life cycle is repeated, with various degrees of tailoring, in all lower level elements of the system decomposition.

Figure 11 shows a full three-level life cycle, e.g. the system procures subsystems which themselves procure equipment units. It is assumed that Phase 0 or A is not needed below system level (no new technology used).

Figure 12 shows a tailored example that is called a two-step approach, where, for example, the system procures equipment units directly (no subsystem concept). It is assumed that Phase 0 or A is not needed below system level.

Figure 13 shows the tailored example of Figure 11, showing the relationship between two levels when using recurring products.

Figure 14 presents a tailored example showing the logic when new technology elements are used (Phase A at subsystem and equipment unit levels).

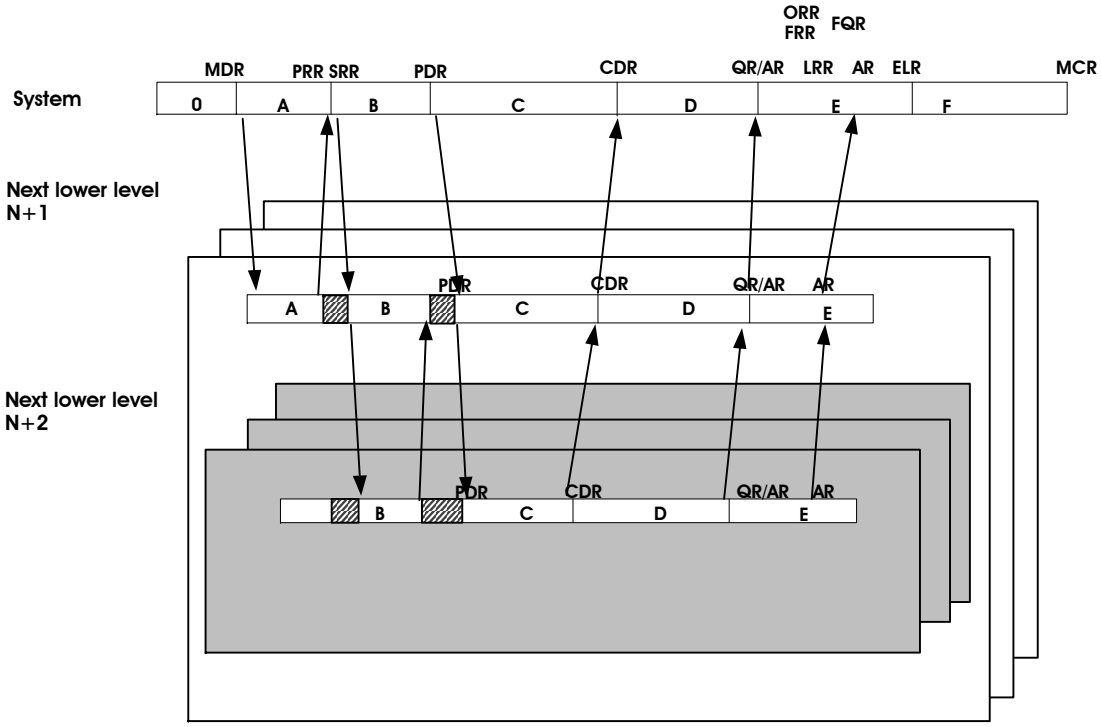

Figure 11: Three-level life cycle

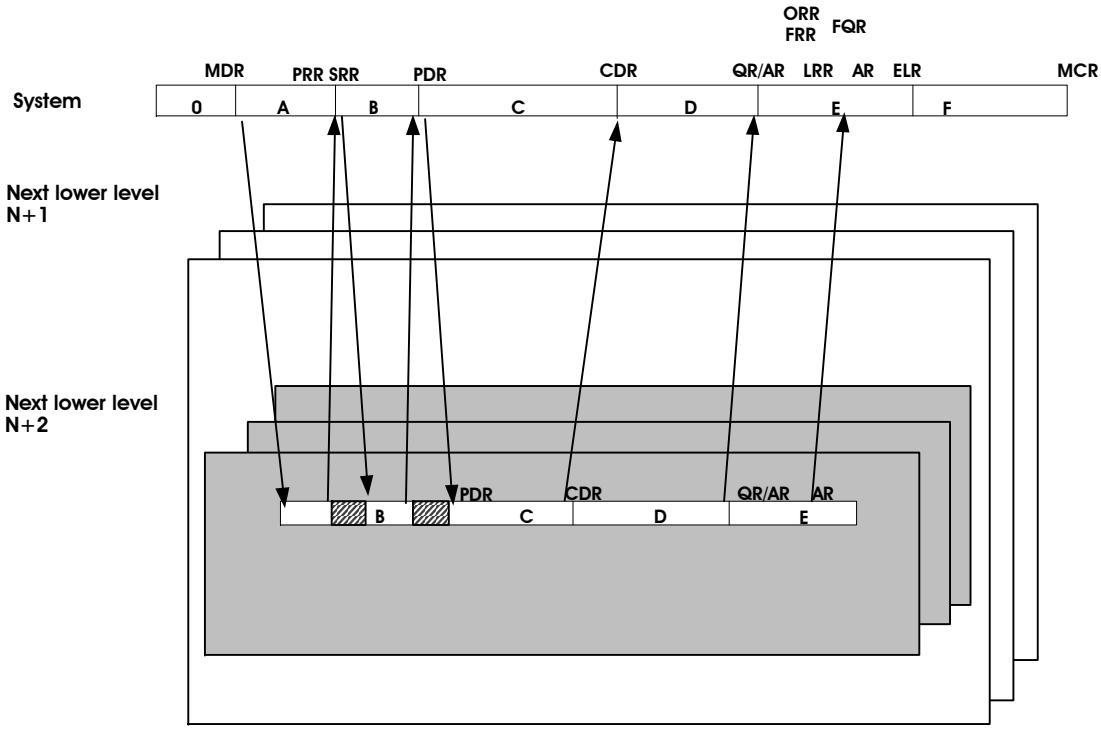

Figure 12: Two-step approach

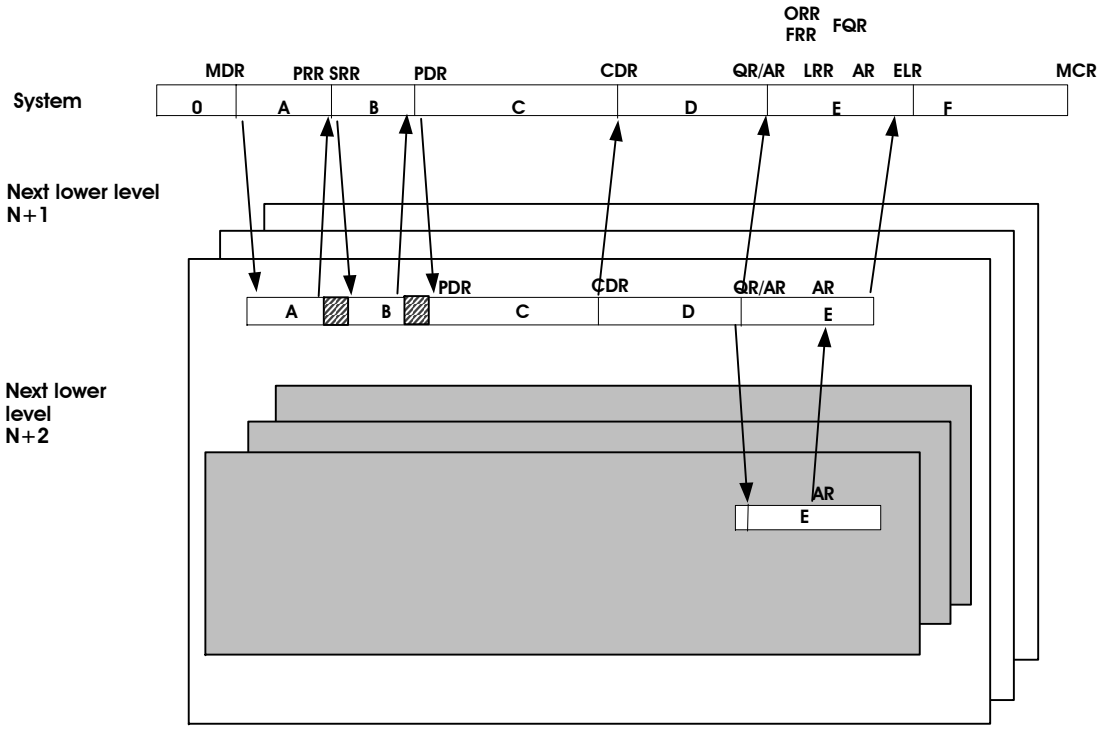

Figure 13: Process with recurring product

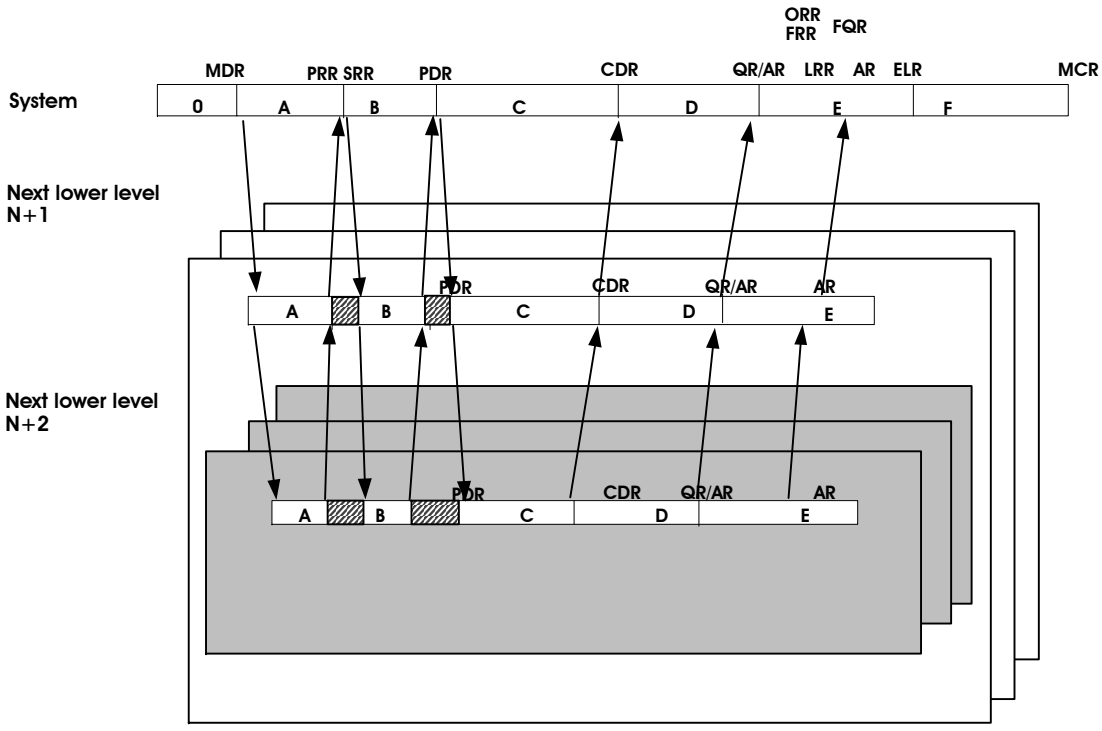

Figure 14: Process with new technology element

According to ECSS-M-30 and ECSS-M-30-01, the following reviews are considered:

AR acceptance review
CDR critical design review
ELR end-of-life review
FRR flight readiness review
FQR flight qualification review
IOOR in orbit operation review
LRR launch readiness review
MCR mission close-out review
MDR mission definition review
ORR operational readiness review
PDR preliminary design review
PRR preliminary requirements review
QR qualification review
SRR system requirements review

The examples shown in Figure 11 to Figure 14 present reviews, which are specific to the highest level (this includes the mission definition). They are applicable to reviews at other levels after the corresponding tailoring.

In practice:

- A combination of different degrees of tailoring can be expected, driven by the existence of, for example, recurring elements and new technology elements.
- The SE process can be adapted according to objectives (e.g. one off, multiples and series) and the model philosophy (i.e. QM and PFM).
- The production of the recurring product (FM2) can be performed during Phase E in conformity with the design definition file, which is qualified at the end of Phase D.
- Procurement of materials and components is in general performed during Phase D and manufacturing of the parts also begins during Phase D.
- Since the phase activities of one supplier are performed through different phase contracts (A, B, A-B, B-C-D,C-D) a lot of work can already be done in the preparation of the proposal for the subsequent phases. For example, a supplier can perform Phase A activities in preparation of the proposal relating to the Phase B-C-D.

For the system engineering process of a generic project, the relationship between the following four key documents is shown in Figure 15:

- Mission statement as input document.
- Functional specification, as defined in A.2.3.1.a. and in ECSS-E-10 Part 6.
- Mission description document, as defined in A.2.1.2.a. and in ECSS-E-10 Part 17A Annex C.
- Technical specification, as defined in A.2.3.1.b. and in ECSS-E-10 Part 6.

While in this model iterations are considered during Phase 0 to establish concepts (reported in the corresponding mission description documents), trade-offs are performed to select the concept proposed for Phase A, and consolidated during Phase A, as described in detail in 5.2 and 5.3.

As mentioned above, in practice, a combination of different degrees of tailoring is expected driven by the actual project implementation aspects.

Finally, one important consideration is that the practical implementation of a project in phases which can be executed by different organizational entities (e.g. macro-phases such as Phases 0 and A, followed by Phases B to F) results in a project specific tailoring of the ECSS system engineering process which is not described in the generic process presented here, but which is compliant with it by the virtue of coherent tailoring.

As a consequence, some documents not present in the generic ECSS documentation model are generated in these tailored cases to initiate the second macro-phase, such as, for the example given, the system requirements document (SRD) which can result from merging relevant elements of the output documents of Phase A, e.g. the mission statement, the preliminary system technical specification, with additional requirements introduced at that point in time.

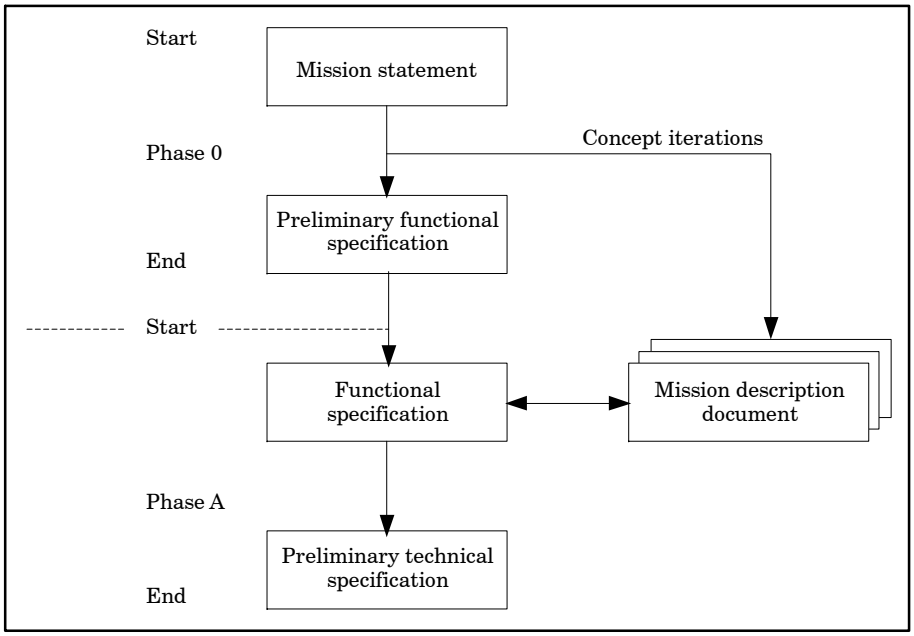

Figure 15: Relationship between key documents

5.1.7 Interfaces

The SE organization produces data, which are used by management, product assurance, production and operations.

The SE organization has the technical responsibility for technical documentation, e.g. DDF and DJF, but their configuration management is the responsibility of project management.

Thus, the SE organization defines the verification and test objectives according to the assembly, integration and test process and produces inputs for the implementation by producing the different verification and test processes.

The SE organization only contributes to the establishment of the production master file by defining the verification process for the recurring products.

5.1.8 Organization and methods

The SE process only describes activities to be performed and it does not imply a specific team or organization. However, the tasks of one phase can be performed following a logic as described by the flow (see 5.1.2) if an impenetrable barrier between disciplines does not exist, and activities are performed on an iterative basis.

The minimization of contractual levels and visibility provided by an integrated team approach has advantages in the area of cost, risk and schedule.

The SE process described in 5.2 to 5.8 is the overall technical process that includes aspects of all technical disciplines, e.g. as per ECSS-E-20 to ECSS-E-70. The level of detail to be considered depends on the level of decomposition of the system (e.g. make, buy, or re-use of equipment units) and the technical contents.

To obtain the best compromise between design and production (including assembly and integration), methods such as value analysis, and design for manufacturing and assembly, are used.

5.2 Mission analysis-needs identification: Phase 0

5.2.1 Objective and process flow: Phase 0

At the end of this phase a mission should be defined and possible associated system concepts proposed.

NOTE The flow of the generic SE tasks in Phase 0 is described in Figure 16.

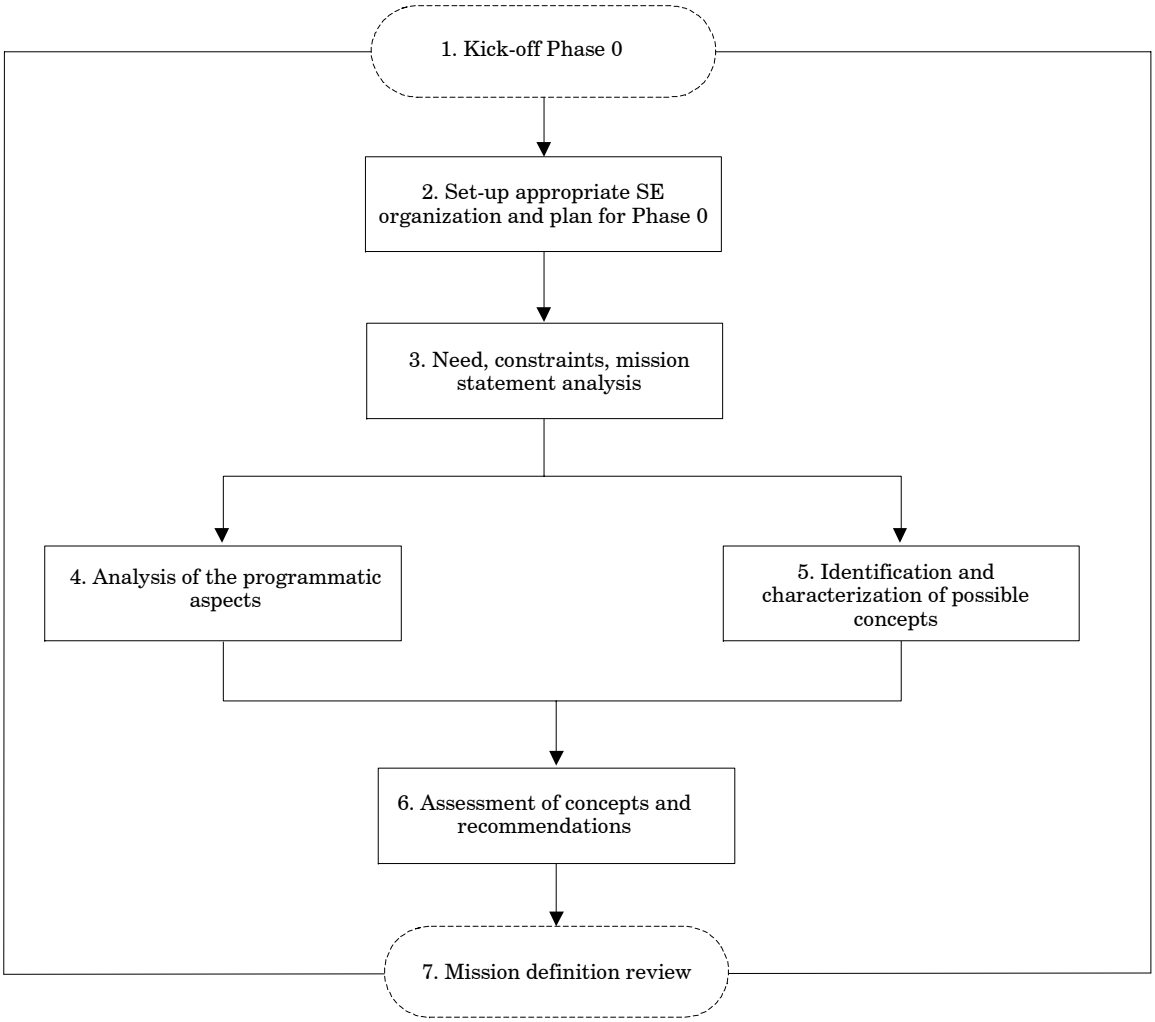

Figure 16: Phase 0 flow chart

5.2.2 Description of activities and documents

5.2.2.1 Kick-off Phase 0

a. The SE organization shall support the kick-off (KO) meeting of Phase 0.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *An agreed technical assumption provided by the supplier.*

5.2.2.2 Set-up appropriate SE organization and plan for Phase 0

a. The SE organization shall define the specific organization, the technical skills, and the study logic appropriate to the anticipated activities and present them in the system engineering plan (SEP), and contribute to their implementation.

b. Task a. should include the following activities.

1. Prepare the SEP by tailoring

   NOTE For the SEP, see ECSS-E-10 Part 17A Annex E.

2. Implement the specific SE organization, subject to management approval.

EXPECTED OUTPUT: *SEP, which covers the full scope and detail Phase 0 activities.*

5.2.2.3 Needs-constraints-mission statement analysis

a. The SE organization shall establish the first issue of the system functional specification (FS).

b. Task a. above should include the following activities.

1. Review of the mission statement and business agreement documents to identify and comprehend the needs and constraints, and derive technical requirements (e.g. functional, configuration, interface, environmental, and operational requirements).

   NOTE For this activity, see ECSS-E-10 Part 6.

2. Prepare the first issue of the system FS and obtain the agreement (Ag) of the management and the customer to avoid any misunderstanding and clarify the major concept driving the expressed needs.

3. Justify the technical requirements and refine the mission statement by iterating the needs-requirement identification loop with support of the customer.

EXPECTED OUTPUT: *System functional specification, first issue (see ECSS-E-10 Part 6).*

5.2.2.4 Analysis of the programmatic aspects

a. The SE organization shall identify the programmatic aspects and their consequences.

b. Task a. above should include the following activities.

1. Review the business agreement documents and take into account management instructions to identify and understand the driving programmatic aspects and constraints (e.g. strategic launcher, industrial policy, cooperation commitments, organization, cost and schedule).

2. Prepare a synthesis of the programmatic aspects, and obtain the agreement (Ag) of the management.

3. Refine the mission statement by iterating the needs, constraints and programmatic aspects identification loop with support of customer taking into account task 5.2.2.3.

EXPECTED OUTPUT: *Synthesis of programmatic aspects.*

5.2.2.5 Identification and characterization of possible concepts

a. The SE organization shall identify and characterize a set of concepts able to fulfil the technical requirements expressed in the first issue of the system functional specification.

b. Task a. above should include the following activities.

1. Gather information, which can lead to concept definition, e.g. previous experience, R&D output, lessons learned, databases.
2. Define and characterize possible concepts, e.g. technology status and capability, risk analysis.
3. Evaluate roughly the concepts against the main FS requirements, e.g. performance, critical areas.
4. Identify a set of possible concepts.

EXPECTED OUTPUT: *Set of possible concepts: Informal synthesis of the output from identification and characterization of possible concepts.*

5.2.2.6 Assessment of concepts and recommendations

a. The SE organization shall establish a preliminary system FS and preliminary mission description document (MDD) and propose a reduced set of recommended system concepts compliant with the mission statement.

NOTE 1 For the MDD, see ECSS-E-10 Part 17A Annex C.

NOTE 2 The mission description document is only a system level document and is established for each possible concept.

b. Task a. above should include the following activities:

1. Compare the possible concepts regarding objective and constraints.
2. To rank the possible concepts.

c. Task a. above should also include the production of a requirement justification file (RJF), on one side to check that all requirements are duly justified, on the other side to be used for the assessment of inputs of requirement changes.

EXPECTED OUTPUT:

a. Preliminary system functional specification.

b. Preliminary mission description document.

c. System concept report (see ECSS-E-10 Part 17A Annex D).

d. Requirement justification file (see E-10 Part 6).

e. SEP for next phases.

f. Project phasing and planning requirements document (PPPR).

g. Trade-off report (see ECSS-E-10 Part 17A Annex M).

5.2.2.7 Mission definition review (MDR)

a. The SE organization shall support the MDR process to ensure its successful completion.

NOTE For the MDR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities.

1. Ensure availability of the following SE documentation according to the MDR review plan:
   (a) preliminary system functional specification;
   (b) preliminary mission description document;
   (c) requirement justification file;

(d) system concept report;

(e) SEP.

2. Ensure execution of all SE activities for successful completion of the MDR (e.g. provision of clarifications, reply to RIDs, closure of actions).
3. Update the system concept report and related documentation according to the customer and management jointly approved baseline after MDR.

EXPECTED OUTPUT: *Consolidated documents such as:*

a. approved preliminary system functional specification (internal configuration control, see ECSS-M-30);

b. agreed preliminary mission description document;

c. approved requirement justification file;

d. consolidated system concept report.

5.2.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.2.2 are summarized in Table 1, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 1: Phase 0

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
1	Kick-off Phase 0			(C)	(C)	(Ag)					M	Agreed technical assumptions
2	Set-up appropriate SE organization and plan for Phase 0	Cus	Mission statement	IC(R)	(C)			(C)			SE M(Ag)	SEP (ECSS-E-10 Part 17A Annex E) for Phase 0
		STD	SEP (see ECSS-E-10 Part 17 Annex E)									
3	Need, constraints, mission statement analysis	Cus	Mission statement	An(R)	(C)			(C)		(C)	M(Ag) Cus(Ag) SE	First issue of the system functional specification (see ECSS-E-10 Part 6)
		Cus	Business agreement (e.g. SOW)									
4	Analysis of the programmatic aspects	Cus	Mission statement	An(R)	(C)	(C)					M(Ag) SE	Synthesis of programmatic aspects
		Cus	Business agreement									
		M	Management instructions									
5	Identification and characterization of possible concepts	SE	First issue of the system functional specification	An(R)			(C)	(C)	(C)	(C)	SE	Set of possible concepts including associated risk assessment

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 1: Phase 0 *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
6	Assessment of concepts and recommendations	SE	First issue of the system functional specification	An(R)			(C)	(C)	(C)	(C)	SE M(Ag) SE	Preliminary system functional specification
		SE	- Synthesis of programmatic aspects - Set of possible concepts								SE M(Ag)	System concept report (see ECSS-E-10 Part 17A Annex D)
											SE M(Ag)	Requirements justification file (RJF) (see ECSS-E-10 Part 6)
											M(Ap) SE	Preliminary mission description document (see ECSS-E-10 Part 17A Annex C)
											SE M(Ag)	SEP for next phases
											SE M(Ag)	Project phasing and planning requirement document (PPPR) for next phases
											SE M	Trade-off report (see ECSS-E-10 Part 17A Annex M)

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 1: Phase 0 *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
7	Mission definition review	M	MDR review plan	IC(R)	A	(C)	(C)	(C)	(C)	(C)	Consolidated documents, as a minimum:	
		M	MDR review data package								M,SE Cus(Ap)	Preliminary system functional specification
											Cus(Ag) M,SE	Preliminary mission description document
											Cus(Ap) M,SE	Requirement justification file
											M,SE	System concept report

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.3 Feasibility: Phase A

5.3.1 Objective and process flow: Phase A

The feasibility phase should result in finalising the expression of needs identified in Phase 0 and proposing solutions to meet the perceived needs.

NOTE The flow of the generic SE tasks in Phase A is described in Figure 17.

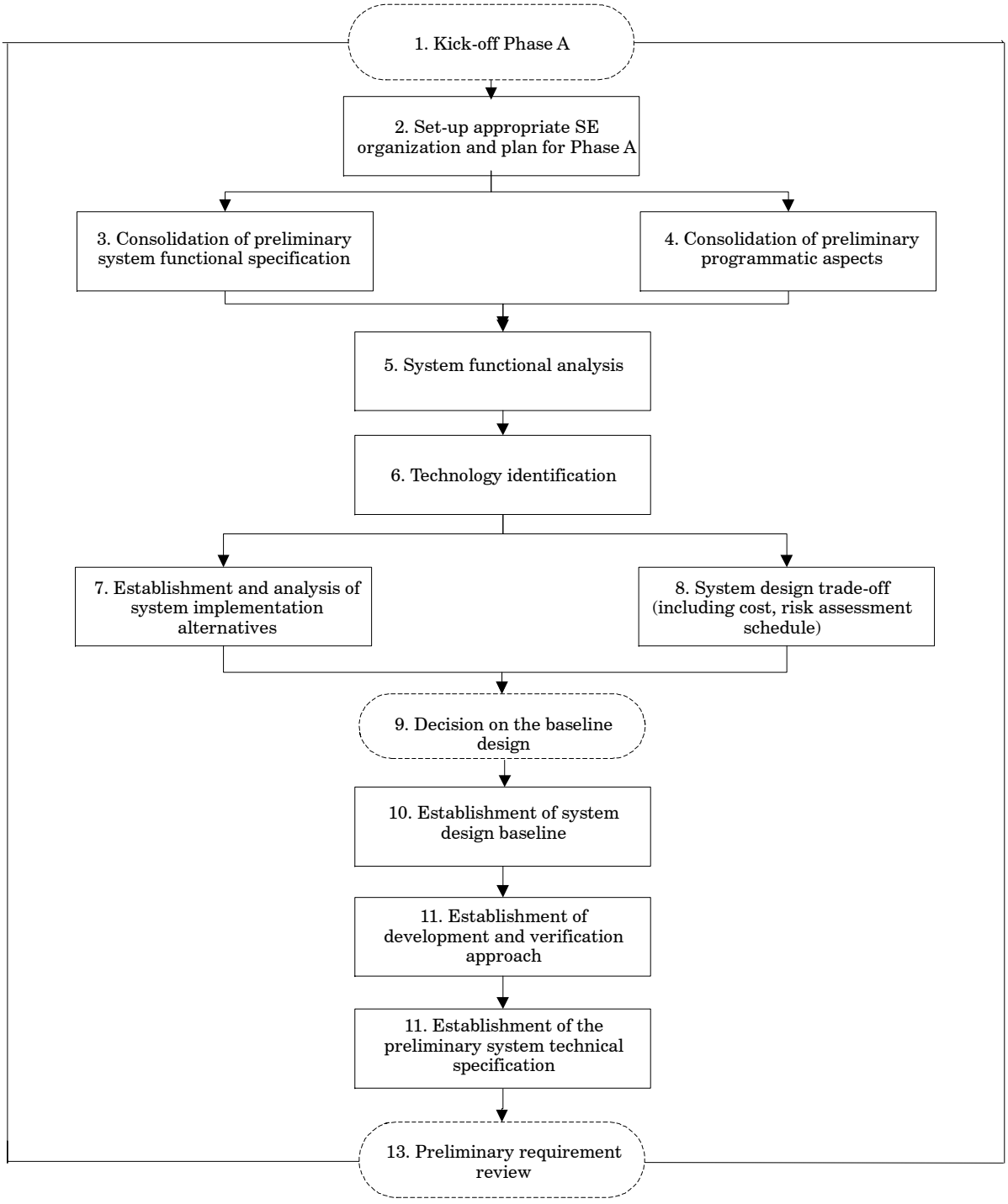

Figure 17: Phase A flow chart

5.3.2 Description of activities and documents

5.3.2.1 Kick-off Phase A

a. The SE organization shall support the KO meeting of Phase A.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *Agreed technical assumptions.*

5.3.2.2 Set up appropriate SE organization and plan for Phase A

a. The SE organization shall put in place the specific organization, the technical skills, and the study logic appropriate to the anticipated activities and contribute to their implementation.

b. Task a. above should include the following activities.

1. Prepare the SEP by tailoring.
2. The SEP, covering the full scope of the project and details of how it is covered within Phase A activities.

EXPECTED OUTPUT: *SEP, which covers the full scope of the project, detailing Phase A activities.*

5.3.2.3 Consolidation of preliminary system functional specification

a. The SE organization shall consolidate the preliminary system functional specification on the basis of all updates and clarifications provided by the customer to the supplier during the kick-off meeting.

b. Task a. above should include the following activities:

1. Review the preliminary system functional specification in order to confirm, clarify or extend the technical requirements and related DRDs (e.g. functional, configuration, interface, environmental, and operational requirements).

   NOTE For this activity, see ECSS-E-10 Part 6.

2. Issue the consolidated preliminary system functional specification and obtain the agreement (Ag) of his management and of the customer to avoid any misunderstanding.

EXPECTED OUTPUT: *a. Preliminary system functional specification (consolidated issue).*

b. Requirement justification file (consolidated issue).

5.3.2.4 Consolidation of programmatic aspects

a. The SE organization shall provide input to consolidate the programmatic aspects and their consequences on the basis of all updates and clarifications provided by the customer to the supplier during the kick-off meeting, management instructions.

b. Task a. above should include the following activities:

1. Review the synthesis of programmatic aspects in order to confirm, clarify or extend the programmatic aspects and constraints (e.g. strategy w.r.t. launcher, industrial policy, cooperation commitments, organization, cost, schedule and risk aspects);
2. Issue the consolidated synthesis of programmatic aspects and obtain the agreement (Ag) of the management.

EXPECTED OUTPUT: *Synthesis of programmatic aspects (consolidated issue).*

5.3.2.5 System functional analysis

a. The SE organization shall define one or more functional architectures (logical solution representations) that conform to the technical requirements of the consolidated issue of the preliminary system functional specification.

b. This should include the following activities:

1. Select and implement one or more approaches to provide an abstract definition of the solutions by appropriated methods (e.g. simulation).
2. Establish system functional architectures (logical solution representations) by application of the selected approaches.
3. Allocate system technical requirements to the various logical elements of the functional architectures and identify and define lower level technical requirements.
4. Ensure that each system functional architecture agrees with the technical requirements of the consolidated issue of the preliminary system functional specification.
5. Issue the functional architectures and function trees.

NOTE See ECSS-E-10 Part 17A Annex I.

EXPECTED OUTPUT: *Functional architecture and function tree.*

5.3.2.6 Technology identification

a. The SE organization shall identify and characterize concepts and related physical elements (hardware and software) capable of implementing individual functions and conforming to the associated technical requirements for the functional architectures.

b. Task a. above should include the following activities.

1. Identify alternative implementation concepts for the individual system functions (e.g. power generation, communication, navigation, and payload pointing) defined in the functional architecture.
2. Identify elements enabling the implementation of these concepts.
3. Provide qualitative assessment of technologies for individual design options, with respect to maturity, availability and development uncertainty and risk.

NOTE Emphasis is put on single functions without considering overall system design optimization. These tasks are performed in a creative manner considering COTS, preferred parts list (PPL), proven and novel technologies.

EXPECTED OUTPUT: *A preliminary technology matrix (see ECSS-E-10 Part 17A Annex G) summarizing candidate technologies and COTS items per individual function.*

5.3.2.7 Establishment and analysis of system implementation alternatives

a. The SE organization shall establish and analyse a set of system implementation alternatives on the basis of identified concepts, technologies and related elements, and prepare the data for their trade-off.

b. Task a. above should include the following activities:

1. Establish feasible overall system implementation alternatives on the basis of the functional architecture alternatives.
2. Detail the system implementation alternatives down to the next lower level to achieve overall system optimization (this may be performed either by a sequential-iterative approach, by a concurrent engineering approach, or by any combination of both).

3. Define an appropriate and consistent margin philosophy for technical budgeting purposes.
4. Establish all major system budgets (e.g. cost, mass, power, link performance), and identify and assess any development and procurement risk (performance, schedule, cost), in cooperation with product assurance, management (ILS).
5. Establish the compliance matrix with respect to the consolidated issue of the preliminary system functional specification for each candidate system, together with an assessment of the robustness of the implementation alternatives with respect to changes of requirements in the consolidated preliminary system functional specification.

NOTE 1 Adapted analytical mathematical models and simulation models can be used to support the function and the analysis of the requirements.

NOTE 2 Value analysis can be used to perform the best performance-cost trade-off (see ECSS-E-10 Part 8).

EXPECTED OUTPUT: *Technical reports such as:*

a. set of system implementation alternative reports;

b. compliance matrices for the alternatives;

c. technical inputs to risk assessment, to cost and schedule assessment.

5.3.2.8 System design trade-off

a. The SE organization shall perform comparison and ranking of the system implementation alternatives; the system design baseline and options shall be identified; and recommendations shall be made to management to
   1. evaluate system alternatives, and
   2. predict system performance.

b. Task a. above should include the following activities:
   1. Define ranking criteria (technical, financial and programmatic) and weighting factors.
   2. Perform evaluation of criteria and compare the system implementation alternatives.
   3. Establish recommendations.
   4. Document the system implementation alternatives and the comparison in the trade-off report.

EXPECTED OUTPUT: *Trade-off report.*

NOTE The system design trade-off includes, for example, cost, risk assessment and schedule.

5.3.2.9 Decision on the design baseline

a. Management shall decide on the baseline on the basis of the trade-off report.

b. The SE organization should contribute to task a. above with the following activity:
   SE support to the management.

EXPECTED OUTPUT: *Technical documents to support decision.*

5.3.2.10 Establishment of system design baseline

a. The SE organization shall define and refine the design of the selected baseline.

b. Task a. above should include the following activities:

1. Refine the design baseline down to next lower level, in terms of functional architecture, function tree, physical configuration, product tree, budgets and appropriate margin philosophy, production, operations (on board and ground) and logistics, for the system and the support equipment, taking into account management (e.g. industrial policy) aspects.
2. Perform the specified analyses, and consider relevant analysis from product assurance (e.g. FMECA).
3. Issue the preliminary design definition file (DDF), design justification file (DJF) and compliance matrix.

EXPECTED OUTPUT:

a. *System functional specification.*
b. *Requirement justification file.*
c. *Preliminary design definition file (DDF) (see ECSS-E-10 Part 17A Annex H), including technical budget (see ECSS-E-10 Part 17A Annex J).*
d. *Design justification file (DJF) (see ECSS-E-10 Part 17A Annex L).*
e. *Function tree (see ECSS-E-10 Part 17A Annex I) and preliminary product trees (see ECSS-M-40B Annex B).*
f. *Consolidated mission description document.*
g. *Requirement traceability matrix (see ECSS-E-10 Part 6).*

5.3.2.11 Establishment of development and verification approach

a. SE shall establish the development and verification approach down to the next level.

b. Task a. above should include the following activities:

1. Establish the preliminary SE process and the related methods and tools (e.g. data exchange requirements, analysis tools).
2. Define an appropriate model philosophy based on assessment of the qualification status of existing H/W (hardware matrix) and on the criticality of the technology used (technology matrix and plan) with respect to mission reliability and availability.
3. Establish the corresponding verification strategies and related methods including the product acceptance approach.
4. Identify the needs for control plans as appropriate (e.g. fracture and contamination control).
5. Implement management (e.g. industrial policy) aspects.
6. Provide input to project phasing and planning requirements document (PPPR) for next phases.

EXPECTED OUTPUT: *SEP, including technology plan (see ECSS-E-10 Part 17A Annex F), preliminary system verification plan, and assembly, integration and test plan (see ECSS-E-10 Part 2B Annex E), fracture plan, contamination plan, control plans, frequencies plan and calibration plan as appropriate.*

5.3.2.12 Establishment of the preliminary system technical specification

a. The SE organization shall establish the preliminary system technical specification for the system design baseline.

b. Task a. above should include the following activities:

1. Produce the preliminary system technical specification on the basis of system preliminary design baseline, derived from the system functional specification, and the resulting business negotiation process (it is the baseline for the development).
2. Produce inputs for the preliminary traceability matrix, including the requirement justification (e.g. for requirements which are critical for the project).

EXPECTED OUTPUT:

a. *Preliminary system technical specification (see ECSS-E-10 Part 6).*
b. *Review preliminary requirement traceability matrix.*
c. *Requirement justification file.*

5.3.2.13 Preliminary requirement review (PRR)

a. The SE organization shall support the PRR process to ensure its successful completion.

NOTE For the PRR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities:

1. Ensure availability of the following SE documentation according to the PRR review plan:
   (a) system functional specification;
   (b) preliminary system technical specification;
   (c) requirement justification file;
   (d) preliminary system design definition file;
   (e) technical budget;
   (f) function tree down to the lower levels;
   (g) product tree down to the next lower level;
   (h) preliminary technology matrix;
   (i) preliminary system design justification file;
   (j) preliminary requirement traceability matrix;
   (k) consolidated mission description document;
   (l) preliminary verification matrix;
   (m) SEP.
2. Ensure execution of all SE activities for successful completion of the PRR (e.g. provision of clarifications, reply to RIDs, and closure of actions).
3. Update system design baseline and related documentation according to customer and management jointly approved baseline after PRR.

EXPECTED OUTPUT: *Data package documents, consolidated according to customer and management jointly accepted baseline after PRR, including:*

a. *approved system functional specification (see ECSS-M-30)*
b. *preliminary system technical specification (see ECSS-M-30)*
c. *approved requirement justification file.*

5.3.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.3.2 are summarized in Table 2, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 2: Phase A

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
1	Kick-off Phase A			(C)	(C)	(Ag)					M	Agreed technical assumptions
2	Set-up appropriate SE organization-plan for Phase A	Cus	Business agreement	IC(R)	(C)	(C)		(C)			SE M(Ag)	SEP
		Cus	Mission statement									
		SE	Phase 0 output									
		STD	SEP									
		M	Project management plan and management instructions									
3	Consolidation of preliminary system functional specification	SE	Preliminary system functional specification	An(R)	(C)			(C)		(C)	SE Cus(Ag) M(Ag)	Consolidated issue of preliminary system functional specification
		SE	Preliminary mission description document									
		Cus	Consolidated mission statement								M(Ag) SE	Requirement justification file
		Cus	Consolidated business agreement									
		STD	Space environment									
		STD	Human factors for space systems									
4	Consolidation of programmatic aspects	SE	Synthesis of programmatic aspects	IC(R)	(C)	(C)		(C)		(C)	SE M(Ag)	Consolidated synthesis of programmatic aspects
		Cus	Consolidated mission statement									
		Cus	Consolidated business agreement									
		M	Project management plan and management instructions									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 2: Phase A *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
5	System functional analysis	SE	System concept report	An(R)			C	C	C	C	SE	Functional architectures (logical solution representations)
		SE	Consolidated issue of preliminary system functional specification									
		SE	Preliminary mission description document								SE	Function trees (ECSS-E-10 Part 17A Annex I)
6	Technology identification	SE	Functional architecture	IC(R)				C	C	C	SE	Preliminary technology matrix (ECSS-E-10 Part 17A Annex G)
		SE	Database									
		M	COTS									
		Q	Preferred parts list									
7	Establishment and analysis of system implementation alternatives	SE	Functional architecture	DC(R)		C	C	C	C	C	SE, M	Set of system implementation alternatives reports
		SE	Preliminary technology matrix								SE,M	Compliance matrices for the alternatives
		SE	Preliminary system functional specification								Q	Technical input to risk assessment
		SE	Preliminary mission description document								M	Technical input to cost and schedule assessment

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 2: Phase A *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
8	System design trade-off (including cost, risk assessment, schedule)	SE	Preliminary system functional specification	IC(R)		C	C	C	C	C	SE, M	Trade-off report (including recommendations)
		SE	Set of system implement alternatives									
		SE	Compliance matrices for the alternatives									
		SE	Consolidated synthesis of programmatic aspects									
		Q	PA related to risk assessment									
		M	Cost and schedule assessment									
		M	Trade-off instructions									
9	Decision on the baseline design	SE	Trade-off report	IC(C)							M,SE	Technical documents to support decision

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 2: Phase A *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
10	Establishment of system design baseline	M	Management decision	IC(R)		(C)		(C)	(C)	(C)	Cus M(Ap) SE	System functional specification
		SE	Trade-off report								Cus, M, SE	Requirement justification file
		SE	Preliminary system functional specification								Cus, M SE	Preliminary system baseline definition (DDF, DJF) (see ECSS-E-10 Part 17A Annexes H and L)
		Q	Preliminary FMECA								Cus, M, SE	Requirement traceability matrix
											Cus, M, SE	Function tree
											Cus M, SE	Preliminary product tree (see ECSS-M-40B Annex B)
											SE, Cus,M	Mission description document
11	Establishment of development and verification approach	M	Programmatic and industrial policy information								SE	SEP for next phases, including technology plan and models approach
											SE M(Ag)	Preliminary system VP and AIT plan, (see ECSS-E-10 Part 2B Annex D and E)
											SE M(Ap)	Input to project phasing and planning requirements document (PPPR) for next phases

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 2: Phase A *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
12	Establishment of the preliminary system technical specification	SE	Agreed system functional specification	(IC)	(C)	(C)	(C)			(C)	SE, M, Cus	Preliminary system technical specification (see ECSS-E-10 Part 6A Annex B)
											Cus M,SE	Requirements justification file
		SE	Inputs from activities 10 and 11								SE, M	Requirements traceability matrix
13	Preliminary requirement review	M	PRR review plan	IC(C)	A	(C)	(C)	(C)	(C)	(C)	Cus(Ap), M, SE	Consolidated design and related documents, for approval
		M	PRR review data package									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.4 Preliminary definition (project and product): Phase B

5.4.1 Objective and process flow: Phase B

At the end of the preliminary definition phase:

a. a system technical specification shall be established as a system baseline development and lower level elements technical specifications;

b. the selected solution shall be evaluated and it shall have been demonstrated that it can meet the technical requirements according with the schedule, the budget, the target cost and the organization requirements.

NOTE The flow of the generic SE tasks in Phase B is described in Figure 18.

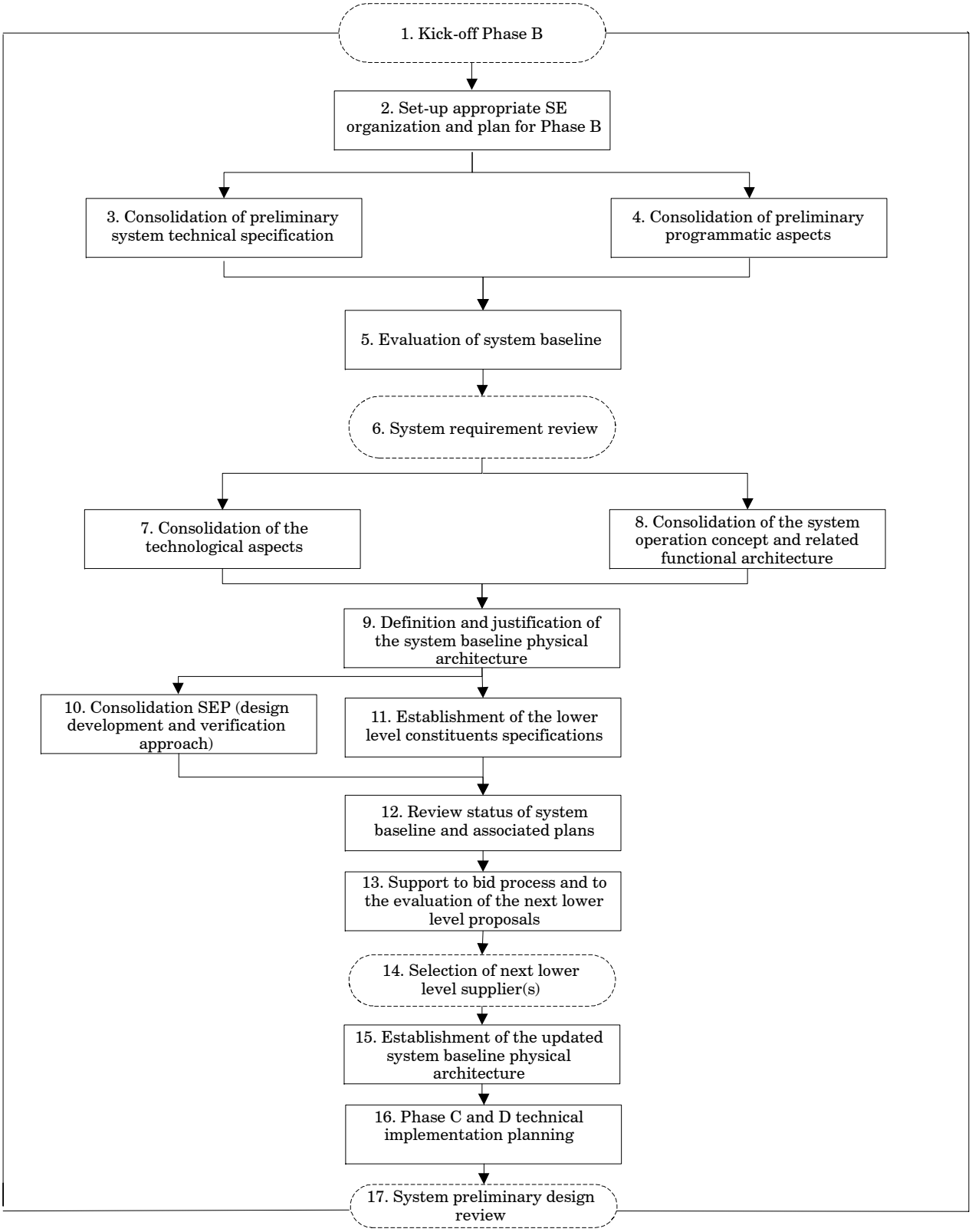

Figure 18: Phase B flow chart

5.4.2 Description of objectives, activities and clarifications on documents

5.4.2.1 Kick-off Phase B

a. The SE organization shall support the kick-off (KO) meeting for Phase B.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *Agreed technical assumptions.*

5.4.2.2 Set up appropriate SE organization and plan for Phase B

a. The SE organization shall define the specific organization, the technical skills, the study logic appropriate to the anticipated activities, present them in the SEP, and contribute to their implementation.

b. Task a. above should include the following activities:

1. Prepare the SEP by tailoring.
2. Implement the SE organization, subject to management approval.

EXPECTED OUTPUT: *SEP, which covers the full scope of the project with detailed Phase B activities.*

5.4.2.3 Consolidation of preliminary system Technical Specification

a. The SE organization shall consolidate the preliminary system technical specification on the basis of all updates and clarifications provided by the customer to the supplier during the kick-off meeting.

b. Task a. above should include the following activities:

1. Review the preliminary system technical specification in order to confirm, clarify or extend the technical requirements and related DRDs (e.g. functional, configuration, interface, environmental, and operational requirements), including, for example, disposition, complementation and classification (e.g. with respect to priorities), resolution of ambiguities and combined requirements, and establishment of traceability with respect to original requirements.

   NOTE For this activity, see ECSS-E-10 Part 6.

2. Issue the consolidated preliminary system technical specification and obtain the agreement (Ag) of the management.

   NOTE It is good practice to consult the customer to avoid any misunderstanding.

EXPECTED OUTPUT:
a. *Consolidated issue of preliminary system technical specification.*
b. *Requirement justification file.*
c. *Associated interface requirement document (see ECSS-E-10 Part 6).*

5.4.2.4 Consolidation of programmatic aspects

a. The SE organization shall provide input to consolidate the programmatic aspects and their consequences on the basis of all updates and clarifications provided by the customer to the supplier during the kick-off meeting, management instructions.

b. Task a. above should include the following activities:

1. Review the synthesis of programmatic aspects in order to confirm, clarify or extend the programmatic aspects and constraints (e.g. strategy with respect to launcher, industrial policy and cooperation commitments, organizational, cost, risk, and schedule aspects).

2. Issue the consolidated synthesis of programmatic aspects and obtain the agreement (Ag) of the management.

EXPECTED OUTPUT: *Synthesis of programmatic aspects (consolidated issue).*

5.4.2.5 Evaluation of system baseline

a. The SE organization shall evaluate the performance of the system on the basis of all updates and clarifications provided by the customer to the supplier and by the management.

b. Task a. above should include the following activities:

1. Review the preliminary system baseline definition (preliminary operations, functional, and physical architectures) and ensure that it conforms to all technical requirements of the system technical specification (interfaces with other systems included).
2. Allocate internal technical requirements to the different elements of the function tree taking in account the technology matrix.
3. Verify the consistency of the allocated technical requirements.
4. Identify critical items, and assess the feasibility of the lower level elements.

   NOTE This activity can constitute a Phase A for lower levels of the system decomposition.
5. Activate engineering, production and operations to produce the analyses in support to the SE system performance evaluation (e.g. for critical aspects).
6. Prepare system verification.

EXPECTED OUTPUT: *a. Consolidated requirement traceability matrix.*

b. Preliminary verification matrix (see ECSS-E-10 Part 2B Annex C).

5.4.2.6 System requirement review (SRR)

a. The SE organization shall support the SRR process to ensure its successful completion.

   NOTE For the SRR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities:

1. Ensure availability of the following SE documentation according to the SRR review plan:
   (a) system functional specification;
   (b) consolidated preliminary system technical specification;
   (c) requirement justification file;
   (d) preliminary system design definition file;
   (e) technical budget;
   (f) function tree down to the next lower level;
   (g) product tree down to the next lower level;
   (h) preliminary technology matrix;
   (i) preliminary system design justification file;
   (j) preliminary requirement traceability matrix;
   (k) consolidated mission description document;
   (l) preliminary verification matrix;
   (m) SEP;
   (n) interface requirement document.

2. Ensure execution of the SE activities for successful completion of the SRR (e.g. provision of clarifications, reply to RIDs, and closure of actions).
3. Update system design baseline and related documentation.

EXPECTED OUTPUT:
a. *Data package documents consolidated.*
b. *Agreed system technical specification (internal configuration control).*

5.4.2.7 Consolidation of the technological aspects

a. The SE organization shall consolidate the technology aspects and establish a list of selected technology.
b. Task a. above should include the following activities:
   1. Characterize the capabilities of the different critical technologies regarding technical requirements and determine their status.
   2. Perform the verifications to demonstrate the capabilities of the critical technologies by using appropriate model breadboards (digital, hardware, and software).
   3. Perform sensitivity analysis to establish design margins.
   4. Assess critical technologies, including process aspects.
   5. Identify the risk associated with the introduction of new or advanced technologies to meet technical requirements, and identify alternative lower-risk technologies that can replace higher risk technologies that are identified and assessed as unacceptable.
   6. Identify the change in technical requirements for implementation of a certain technology.
   7. Select technologies, COTS, end-products in accordance with the technical requirements, the risk, the cost, and the make or buy policy.

EXPECTED OUTPUT:
a. *Consolidated technology plan, which is part of SEP.*
b. *Consolidated technology matrix summarising selected technologies, COTS items per individual function.*
c. *Technical input for risk assessment.*

5.4.2.8 Consolidation of the system operation concept and related functional architecture

a. The SE organization shall refine the operational concepts for the system and update the related system baseline functional architecture accordingly.
b. Task a. above should include the following activities:
   1. Characterize the operations scenario including timeline definition.
   2. Refine the operational concept and related operational technical requirements (e.g. all hierarchical modes and transitions, FDIR concepts, and autonomy concept).
   3. Establish a detailed timeline for critical operations.
   4. Incorporate the operational technical requirement in the functional architecture and ensure traceability down to the specified level. This includes apportioning of the functions, technical budgets to the elements of the system, and the technical management thereof.
   5. Validate the system baseline according to the consolidated system technical specification (e.g. by simulation or modelling) to ensure the adequacy of the operational concept and the internal functional coherency.

      NOTE Consolidated analytical mathematical models and simulation models are used to

- support the definition and analysis of the system requirements,
- evaluate the system design,
- predict performances.

EXPECTED OUTPUT: *a. Consolidated operational concept.*

b. Consolidated functional architecture.

c. Consolidated requirement traceability matrix.

5.4.2.9 Definition and justification of the system baseline physical architecture

a. The SE organization shall define the system baseline physical architecture (an implementation solution of the functional architecture).

b. Task a. above should include the following activities:

1. Define the baseline system physical architecture:
   (a) establish implementation concepts for all functions;
   (b) identify the next lower level elements and allocate functions;
   (c) define the element interfaces;
   (d) confirm external system interfaces;
   (e) prepare system block diagrams and associated descriptions;
   (f) define overall mechanical accommodation including e.g. initial routing of harness and pipes;
   (g) describe the implementation concepts and demonstrate its feasibility;
   (h) establish traceability with respect to higher-level requirements and prepare traceability matrix.
2. Perform value analysis.
3. Justify the baseline system physical architecture, which includes the following:
   (a) identify detailed engineering and PA analyses, which confirm that the design conforms to all requirements;
   (b) perform technical trades and configuration trades with respect to technical performance, reliability, lifetime, and cost taking into account the engineering and PA analysis results;
   (c) refine the operational concept with respect to constraints introduced by the chosen design solution;
   (d) assess the AIT aspects for the realization and the development of the system, and the availability aspects of next lower level constituents;
   (e) on lower levels of system decomposition, consider production aspects and identify potential long lead items (LLI);
   (f) evaluate the compatibility between system baseline solution and cost schedule constraints;
   (g) define and consolidate detailed environment parameters (e.g. thermal, mechanical, electrical, and chemical) on the basis of the analysis results;
   (h) perform design validation using the mathematical models and simulation.
4. Provide technical input for risk assessment.

EXPECTED OUTPUT:

a. *Consolidated mission description document.*

b. *Preliminary system user manual (see ECSS-E-10 Part 17A Annex E) at system level.*

c. *Consolidated preliminary DDF, including product tree, interface control document (see ECSS-M-40B Annex B) and technical budget.*

d. *Consolidated preliminary DJF.*

e. *Technical inputs to cost assessment, schedule assessment, ILS assessment, and risk assessment.*

5.4.2.10 Establishment of lower level constituents specifications

a. The SE organization shall establish the functional specifications for next lower level constituents.

NOTE This FS, not agreed yet with the potential supplier, is sometimes called the preliminary technical specification.

b. Task a. above should include the following activities:

1. Confirm the partitioning of the system architecture.
2. Establish traceability with respect to higher level technical requirements.
3. Analyse all constraints e.g. operational, production, and cleanliness.
4. Establish the complete functional specification for the next lower level constituents.

EXPECTED OUTPUT:

a. *Functional specifications for next lower level elements, put under internal configuration control for the purpose of traceability of the configuration.*

b. *Consolidated requirement traceability matrix.*

c. *Preliminary interface requirements documents for next lower level elements.*

5.4.2.11 Consolidate SEP (design, development and verification approach)

a. The SE organization shall ensure that the design, development and verification plans are consolidated.

b. Task a. above should include the following activities:

1. Refine the model philosophy and define of the objective of each selected model (see ECSS-E-10 Part 2).
2. Detail the different appropriate verification, validation and control plans as described in the SEP, e.g.
   (a) verification plan (see ECSS-E-10 Part 2B Annex D),
   (b) AIT plan (see ECSS-E-10 Part 2B Annex E),
   (c) fracture control plan,
   (d) EMC plan,
   (e) safety plan.
3. Establish the preliminary verification matrix as part of the verification control document for the system level.

   NOTE See ECSS-E-10 Part 2B Annex C for internal configuration control.
4. Define input to management (ILS), and to the installation manual

   NOTE See ECSS-E-10 Part 16A Annex A.

5. Define input to management with respect to configuration aspects, as per the project management plan.
6. Define input to product assurance with respect to updates of the plans, as per the product assurance plan.

EXPECTED OUTPUT:
a. *Consolidated SEP including technology plan.*
b. *Preliminary VCD (verification matrix).*
c. *Technical notes input for installation manual.*
d. *Technical notes input to management (ILS).*
e. *Technical notes input to management.*
f. *Technical notes input to product assurance.*

5.4.2.12 Review status of system baseline and associated plans

a. The SE organization shall confirm the maturity, consistency, and completeness of the baseline design and of the various plans associated with its development.

b. Task a. above should include the following activities:
1. Confirm that the status of the system architecture is acceptable and that the requirements allocation is complete.
2. Determine that the system can fulfil the technical requirements of the system technical specification and can be build.
3. Ensure that adequate detailed information exists (e.g. technical specifications, and plans) to enable the involvement and acquisition of the next lower level.

NOTE The activity can be implemented as a formal or informal review (e.g. SDR).

EXPECTED OUTPUT: *Technical notes for lower level bid packages.*

5.4.2.13 Support to bid process and to the evaluation of the next lower level proposals

a. The SE organization shall support the bid process and contribute to the technical evaluation of the next lower level.

b. Task a. above should include the following activities:
1. Deliver technical input for the next lower level project requirement documents.
2. Analyze and evaluate the technical proposals, provide technical rating to management.

EXPECTED OUTPUT:
a. *Input to selection of lower level proposal and negotiation (technical proposals evaluations).*
b. *Proposals evaluation report.*

5.4.2.14 Selection of next lower level suppliers

a. The SE organization shall support management for the selection of the next lower level suppliers.

b. Task a. above should include the following activity:
deliver complementary technical input.

EXPECTED OUTPUT:
a. *Management decision.*
b. *Trade-off report.*

5.4.2.15 Establishment of the consolidated system baseline physical architecture

a. The SE organization shall consolidate the system baseline according to the selected suppliers.

b. Task a. above should include the following activities:

1. Evaluate the need to update lower level input with respect to compliance with system level assumptions and updates.
2. Identify and assess deviations.
3. Initiate system level mathematical models and system level analyses updates.
4. Provide input to analysis.
5. Evaluate analysis updates and assess consequences on design, interfaces and performances at all levels.
6. Update major changes to operational and physical architecture (including harmonization with other mission elements, e.g. ground segment).
7. Consolidate and optimize architectures, in view of above results.
8. Agree on the technical specification for the next lower level elements (where requested, conduct SRR at next lower level).
9. Consolidate the requirement traceability matrix.
10. Update of the preliminary verification matrix.

EXPECTED OUTPUT:

a. System technical specification.

b. Preliminary design definition file including:

1. technical specifications for the next lower level put under formal configuration control for the purpose of traceability of the configuration (formal configuration control change mechanisms such as engineering change request (ECR) do not apply with respect to customer, but can apply with respect to supplier if a Phase B contract is signed);

2. product tree;

3. preliminary interface control document.

c. Preliminary design justification file.

d. Requirement traceability matrix.

e. Preliminary verification matrix.

f. If specified at a highest system level (e.g. a spacecraft segment), preliminary system user manual.

g. Technical input to management (ILS) and installation manual.

5.4.2.16 Phase C-D technical implementation planning

a. The SE organization shall establish the technical planning for the agreed baseline for the Phase C-D.

b. Task a. above should include the following activities:

1. Confirm the design, development and verification approach.
2. Update the product tree, including characterization of each end product (e.g. COTS, reuse product, and develop common product).
3. Characterize the different planned models in terms of objectives (type and verification).
4. Characterize and evaluate the manufacturing and production processes.

5. Refine the SEP and all associated plans.
6. Provide input to project phasing and planning requirement document (PPPR) for the next phase.

NOTE For the PPPR, see ECSS-M-30.

EXPECTED OUTPUT: *Refined SEP plan for next phases and associated plans (see ECSS-E-10 Part 17A Annex E).*

5.4.2.17 System preliminary design review (PDR)

a. The SE organization shall support the system PDR process to ensure its successful completion.

NOTE For the PDR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities:
   1. Ensure availability of the following SE documentation according to the PDR review plan:
      (a) system technical specification;
      (b) requirement justification file;
      (c) system functional specification;
      (d) interface requirement document;
      (e) preliminary system design definition file;
      (f) product tree until two or more lower levels;
      (g) function tree until three or more lower levels;
      (h) technical budget;
      (i) preliminary interface control document;
      (j) technical specification of the elements of the next lower level;
      (k) requirement traceability matrix;
      (l) preliminary verification matrix;
      (m) preliminary system design justification file;
      (n) preliminary user manual;
      (o) mission description document;
      (p) preliminary verification control document;
      (q) SEP.
   2. Ensure execution of the SE activities for successful completion of the PDR (e.g. provision of clarifications, and reply to RIDs closure of actions).
   3. Update system design baseline, SEP plan and related documentation.

EXPECTED OUTPUT:
a. *Data package documents consolidated.*
b. *Approved system technical specification, including interface requirement document (see ECSS-M-30).*
c. *Approved technical specification for the lower level elements (see ECSS-M-30).*
d. *Agreed product tree (see ECSS-M-30).*

5.4.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.4.2 are summarized in Table 3, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 3: Phase B

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
1	Kick-off of Phase B			(C)	(C)	(Ag)					M	Agreed technical assumptions
2	Set up appropriate SE organization-plan for Phase B	Cus	Business agreement	IC(R)	(C)	(C)		(C)			SE M(Ag)	SEP
		Cus	Mission statement									
		SE	Phase A outputs									
		M	Project management plan and management instructions									
		STD	SEP (see ECSS-E-10 Part 17A Annex E)									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
3	Consolidation of preliminary system technical specification	SE	Preliminary system technical specification	An(R)	(C)		(C)	(C)		(C)	SE M(Ag) Cus(Ag)	Consolidated issue of preliminary system technical specification
		SE	Consolidated mission description document								SE M(Ag) Cus(Ag)	Requirement justification file
		Cus	Consolidated mission statement								SE, M(Ag), Cus(Ag)	Associated interface requirement document (see ECSS-E-10 Part 6)
		Cus	Consolidated business agreement									
		STD	Space environment (see ECSS-E-10-04)									
		STD	Human factors for space systems (see ECSS-E-10 Part 11)									
		STD	Communications (see ECSS-E-50)									
		STD	Ground systems and operations (see ECSS-E-70)									
		STD	Verification requirements (see ECSS-E-10 Part 2)									
4	Consolidation of programmatic aspects	SE	Consolidated synthesis of programmatic aspects	IC(R)	(C)	(C)		(C)		(C)		New issue of the consolidated synthesis programmatic aspects
		Cus	Consolidated mission statement									
		Cus	Consolidated business agreement									
		M	Project management plan and management instructions									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
5	Evaluation of system baseline	SE	Technology matrix	An(R)				(C)	(C)	(C)	SE	Requirement traceability matrix
		SE	Requirement traceability matrix								SE	Preliminary verification matrix (see ECSS-E-10 Part 2B Annex C)
		SE	Consolidated issue of preliminary technical specification									
		SE	Preliminary DDF									
		SE	Preliminary DJF									
6	System requirement review	M	SRR review plan	IC(C)	(C)	(C)	(C)	(C)	(C)	(C)	Cus (Ag) M SE	Agreed system technical specification
		M	SRR review data package									
7	Consolidation of the technological aspects	SE	Technology plan (part of SEP)	DC(R)		(C)	(C)	(C)	(C)	(C)	SE	Consolidated technology plan (part of SEP)
		SE	Technology matrix								SE	Consolidated technology matrix
		SE	Database								M	Technical input for risk assessment
		SE-M	COTS									
		Q	Risk assessment									
		M	"Make or buy" policy									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
8	Consolidation of the system operation concept and related functional architecture	SE	Functional architecture	IC(R)		(C)	(C)	(C)	(C)	(C)	SE	Consolidated functional architecture
		SE	Agreed system technical specification									
		SE	Consolidated mission description document									
		Q	System FMECA								SE	Preliminary FS of lower level element
		SE	Consolidated technology matrix								SE	Requirement traceability matrix
		SE	Function tree								Q	Technical input for risk assessment
		SE	Preliminary product tree									
		STD	Human factors for space systems (see Annex A)									
		STD	Communications (see ECSS-E-50)									
		Q	Risk assessment									
		Q	Safety analysis									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
9	Definition and justification of the system baseline physical architecture	SE	Agreed system technical specification	DC(R)		(C)	(C)	(C)	(C)	(C)	SE	Preliminary system definition baseline (DDF, DJF)
		SE	Consolidated functional architecture								SE, M	Product tree
		SE	Preliminary system definition base line (DDF, DJF)								SE	Preliminary interface control document (ECSS-E-10 Part 4 Annex A)
		SE	Technology matrix								SE	Technical budgets (DDF, DJF)
		SE	Function tree								SE, OPS	Technical input to system user manual (see Annex A)
		SE	Preliminary product tree								M	Technical input to cost assessment
		SE	Consolidated mission description document								M,Q	Technical input to schedule assessment
		Q	Risk assessment								M	Technical input to risk assessment
		STD	All DRDs to ECSS-E-10 concerning operational cleanliness, cost and schedule								M, ILS	Technical input to ILS assessment
		M	"Make or buy" policy									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
10	Establishment of lower level constituents specifications	SE	System definition baseline (DDF, DJF)	IC(R)		(C)	(C)	(C)	(C)	(C)	SE	Consolidated FS for lower level products
											SE	Consolidated requirement traceability matrix
		SE	Product tree								SE	Preliminary IRD for lower level products
		SE	Preliminary functional specifications for the lower level elements								SE	Function tree
		STD	All DRDs to ECSS-E-10 concerning operational, cleanness constraints									
		SE	Requirement traceability matrix									
		SE	Technical budgets									
11	Consolidate SEP (design development and verification approach)	M	Programmatic and industrial policy information	IC(R)	(C)	(C)	(C)	(C)	(C)	(C)	SE	Consolidated SEP including technology plan preliminary
		SE	System definition base line (DDF, DJF)								SE	Preliminary verification matrix (ECSS-E-10 Part 2B Annex C)
		SE	SEP								SE	System VP plan
											SE	System AIT plan
											OPS	Technical input for installation manual
											M	Technical input to ILS
											M	Technical input to schedule, cost assessment
											Q	Technical input to risk assessment

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
12	Review status of system baseline and associated plans	SE	Outputs of tasks 7 to 11	IC(R)	(C)	(C)	(C)	(C)	(C)	(C)	M	Technical input for lower level bid-packages
13	Support to bid process and to the evaluation of the next lower level proposals	M	Technical elements of lower level proposals	IC(R)	(C)	(C)	(C)	(C)	(C)	(C)	M	Input to selection of lower level proposal and negotiation (technical proposals evaluations)
14	Selection of next lower level suppliers	M	Technical proposals	IC(C)							M	Proposals evaluation report
											M	Trade-off reports

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
15	Establishment of the consolidated system base line physical architecture	M	Management decision	IC(R)		(C)	(C)	(C)	(C)	(C)	M, SE	System TS
		SE	System TS								SE	Consolidated TS for next lower level elements
		SE	N+1 element (end-product) TS								SE	Product tree
		SE	Preliminary system definition base line								M	Mission description document
		SE	Function tree								SE	Preliminary design definition file
		SE	Preliminary issue of ICD								Cus, M, SE	Preliminary system design justification file
		SE	Requirement traceability matrix								SE	Preliminary system ICD
		SE	Technology matrix								SE	Requirement traceability matrix
		SE	Mission description document								SE OPS	Preliminary system user manual
		SE	System operational handbook									
		SE	AIT plan									
		M,Q OPS	Input on cost, schedule, ILS, risk manufacturing, production and operation report									
		STD	Engineering DRDs relevant to the considered system									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 3: Phase B *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
16	Phase C/D technical implementation planning	SE	SEP for next phases, including technology plan, system VP plan and AIT plan	IC(R)		(C)	(C)	(C)	(C)	(C)	SE	SEP for next phases, including technology plan system VP plan and AIT plan (see ECSS-E-10 Part 2B Annex D and E)
		M	Input on project phasing and planning document (PPPR) for next phases								SE, M	Input to project phasing and planning document (PPPR) for next phases
		M	Management decision									
		SE	Input on the result of 13									
17	System preliminary review design	M	System PDR review plan	IC(C)	(A)	(C)	(C)	(C)	(C)	(C)	Cus(Ap) M, SE	Consolidated design and related document for approval
		M	System PDR review data package									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.5 Detailed definition: Phase C

5.5.1 Objective and process flow: Phase C

Phase C results in the establishment of the system detailed definition, which satisfy the technical requirements of the system technical specification.

The Phase C and D activities relating to the product can be overlapped for scheduling reasons. Inputs on re-use of GSE for operations are given. The SE organization has the responsibility to provide SE inputs to ground system and operations.

NOTE The flow of the generic SE tasks in Phase C is described in Figure 19.

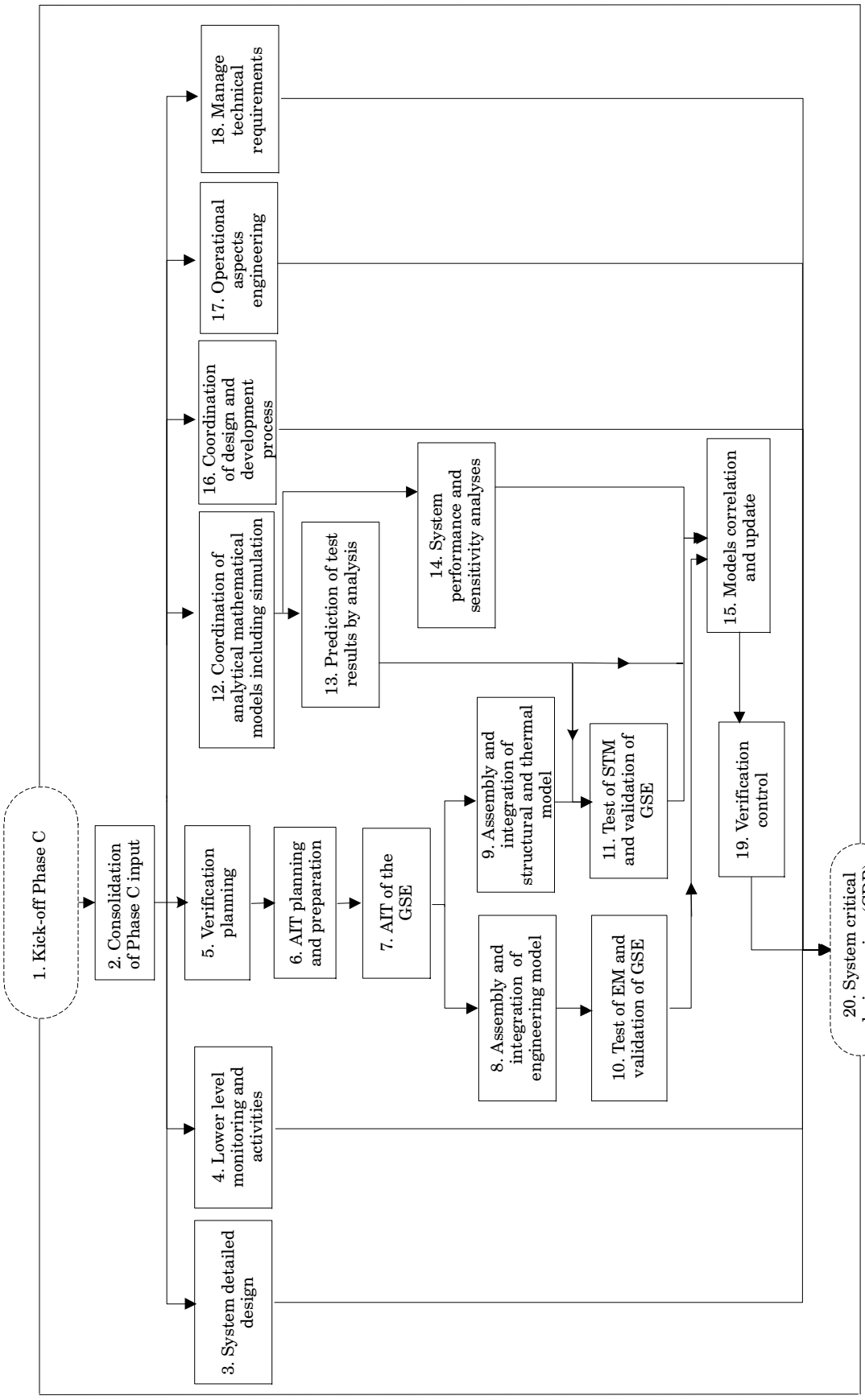

Figure 19: Phase C flow chart

5.5.2 Description of objectives, activities and clarifications on documents

5.5.2.1 Kick-off Phase C

a. The SE organization shall support the kick-off (KO) meeting of Phase C.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *Agreed technical assumptions.*

5.5.2.2 Consolidation of Phase C input

a. The SE organization shall consolidate the Phase C inputs and contribute to their implementation

b. Task a. above should include the following activities:

1. Review the synthesis of programmatic aspects (including new management input) in order to confirm, clarify or extend the programmatic aspects and constraints (e.g. strategy with respect to launcher-industrial policy-cooperation commitments, organizational, cost, risk, and schedule aspects).
2. Consolidate the system technical specifications (TSs) and the next lower level elements TSs on the basis of all updates and clarifications provided by the customer to the supplier during the kick-off meeting (mission statement analysis).
3. Prepare the SEP by tailoring.
4. Implement the SE organization, subject to management approval.

EXPECTED OUTPUT:
a. *SEP (and related plans), which covers the full scope of the project, detailing Phase C activities.*
b. *Consolidated system technical specification.*
c. *Consolidated issue of the lower level elements TSs.*
d. *Consolidated product tree.*
e. *System DDF.*
f. *System DJF.*

5.5.2.3 System detailed design

a. The SE organization shall consolidate the baseline physical architecture of the system into a system configuration and ensure the completion of its detailed design.

b. Task a. above should include the following activities:

1. Issue the consolidated next lower level elements TSs in order to confirm, clarify or extend the technical requirements (e.g. functional, configuration, interface, environmental, and operational requirements), and confirm the agreement of the management.

NOTE 1 For this activity, see ECSS-E-10 Part 6 and related DRDs.

NOTE 2 It is good practice to check the TS with suppliers to avoid any misunderstanding (in accordance with ISO 9000:2000 subclause 4.3).

2. Analyse the next lower level DDFs and DJFs.
3. Control the internal and external interfaces.
4. Consolidate and maintain the technical budget.
5. Maintain the specifications tree.
6. Design the physical and functional interfaces.

7. Implement in the design the technologies validated in Phase B.
8. Assess the coherency of the design with PPL, COTS, manufacturing capabilities and “make or buy” policy.
9. Perform detailed design and finalization of the system configuration.
10. Consolidate the SEP and related plans.
11. Analyse next lower level reviews and inspection reports.
12. Confirm the system baseline according to the system technical specification.

NOTE This task is performed in parallel and mutual relation with the tasks 4, 12, 13, 14 in Figure 19.

EXPECTED OUTPUT:
a. *System DDF (which contains e.g. product tree, specifications tree, drawings), system DJF.*
b. *Consolidated issue of the lower level elements TS.*
c. *Technical budget.*
d. *Consolidated technology matrix.*
e. *Consolidated technology plan.*
f. *Consolidated SEP and related plans.*

5.5.2.4 Lower level monitoring and activities

a. The SE organization shall monitor the SE activities of the subcontractors.
b. Task a. above should include the following activities:
   1. Control the subcontractor SE activities, e.g. monitor the implementation of
      (a) the subcontractor SEP,
      (b) the requirement traceability,
      (c) the verifications of all elements.
   2. Review at regular intervals the technical progress, e.g. monitor
      (a) the subcontractor development model activities,
      (b) the subcontractor detailed design activities.

NOTE It is good practice to take part in key meetings and CDRs of the lower levels critical elements

EXPECTED OUTPUT:
a. *Lower level SEP.*
b. *Lower level DDF and DJF.*
c. *Lower level EM and STM products with associated databases.*
d. *Lower level mathematical models.*

5.5.2.5 Verification planning

a. The SE organization shall refine the verification approach to an adequate level of detail for execution of Phase C and preparation of Phase D.
b. Task a. above should include the following activities:
   1. Confirm and refine the verification strategy (objectives, methods, models and their applicability to the lower levels).
   2. Issue the system test specifications and assess the adequacy of next lower level test specifications.
   3. Set up the system level verification database and the verification matrix.
   4. Establish the detailed planning of verification activities in terms of schedule, resources, cost, and provide input to management.

EXPECTED OUTPUT:
a. *Verification plan in SEP verification matrix.*
b. *Test specifications.*
c. *Technical inputs to schedule assessment.*
d. *Data for verification database.*

5.5.2.6 Assembly, integration and test (AIT) planning and preparation

a. The SE organization shall detail the system AIT Plan, and monitor the preparation of the related infrastructure and procedures.
b. Task a. above should include the following activities:
   1. Establish the system AIT plan (i.e. in the perspective of the project, Phase D).
   2. Establish the detailed AIT planning with respect to EM and STM.
   3. Control the AIT plans of the lower level elements (according to task 5.5.2.4).
   4. Analyse the test prediction reports.
   5. Analyse the lower level installation manuals.
   6. Define the tests specifications (in relationship with and for production).
   7. Comment and approve the test procedures established by production on the basis of the test specifications.
   8. Define input to production for the establishment of the integration procedures.
   9. Comment and approve the integration procedures established by production and their consistency with respect to the AIT plan.
   10. Establish the GSE specifications.
   11. Monitor the production of the models.

EXPECTED OUTPUT:
a. *Detailed AIT plan.*
b. *Input to management for establishment of the detailed AIT planning with respect to EM and STM.*
c. *Test specifications (see ECSS-E-10 Part 2B Annex G).*
d. *Approved integration procedures (see ECSS-E-10 Part 15A Annex A).*
e. *Approved test procedures (see ECSS-E-10 Part 2B Annex H).*
f. *GSE specifications.*
g. *AIT established specifications for test facilities.*

5.5.2.7 Assembly, integration and test (AIT) of the ground support equipment (GSE)

a. The SE organization shall ensure the availability of the GSE ready for use (with EM–STM).
b. Task a. above should include the following activities:
   1. Initiate and monitor design, assembly and integration the GSE from their elements.
   2. Validate the GSE ready for use (with EM-STM).

EXPECTED OUTPUT:
a. *GSE ready for use (with EM-STM).*
b. *GSE data package (including GSE user manual).*

5.5.2.8 Assembly and integration (AI) of engineering model

a. The SE organization shall ensure availability of the engineering models (EM) ready for use.

b. Task a. above should include the following activities:

1. Initiate and monitor (via the integration records) the AI of the EM.
2. Produce inputs relating to the configuration item data list (CIDL) defining the status of the EM.
3. Control the status of the lower level EM models.
4. Validate the AI of the EM.
5. Ensure availability of a validated EM installation manual.

EXPECTED OUTPUT:
a. *Inputs to CIDL of the EM ready for use.*
b. *Integration records (see ECSS-E-10 Part 15A Annex B).*
c. *EM installation manual.*

5.5.2.9 Assembly and integration of structural and thermal model (STM)

a. The SE organization shall ensure availability of the structural and thermal model for use.

b. Task a. above should include the following activities:

1. Initiate and monitor (via the integration records) the AI of the STM.
2. Produce the CIDL defining the status of the STM.
3. Control the status of the lower level STM models.
4. Validate the AI of the STM.
5. Ensure availability of a validated STM installation manual.

EXPECTED OUTPUT:
a. *Inputs to the CIDL of the STM ready for use.*
b. *Integration records.*
c. *STM installation manual.*

5.5.2.10 Test of EM and validation of GSE

a. The SE organization shall ensure performance of the tests of the EM according to the AIT plan.

b. Task a. above should include the following activities:

1. Validate the inputs (EM status, test procedures, GSE status).
2. Initiate and monitor execution of the EM tests.
3. Initiate and hold the test readiness reviews (TRRs) and the test review boards (TRBs).

   NOTE For the TRR and the TRB, see ECSS-E-10 Part 2.
4. Follow up the non-conformance review board (NRB) related activities, if any.

   NOTE For this activity, see ECSS-Q-20-09.
5. Ensure availability of the complete test reports, including the “as run” test procedures, the minutes of the TRRs and of the TRBs.
6. Validate the GSE for application to FM.

EXPECTED OUTPUT:
a. *Test reports (see ECSS-E-10 Part 2B Annex I).*
b. *Minutes of TRRs and TRBs.*
c. *Contribution to NRBs.*
d. *GSE consolidated data package (including GSE user manual).*

5.5.2.11 Test of STM and validation of GSE

a. The SE organization shall ensure performance of the tests of the STM according to AIT plan.

b. Task a.above should include the following activities:

1. Validate the inputs (e.g. STM status, test procedures, and GSE status).
2. Initiate and monitor performance of the STM tests.
3. Initiate and hold the TRRs and the TRBs.

   NOTE For the TRR and the TRB, see ECSS-E-10 Part 2.

4. Follow up the TRR and TRB related activities, if any.

   NOTE For these activities, see ECSS-Q-20-09.

5. Ensure availability of a complete test report, including the "as-run" test procedures, the minutes of the TRRs and of the TRBs.
6. Validate the GSE for application to FM.

EXPECTED OUTPUT:

a. Test reports.

b. Minutes of TRRs and TRBs.

c. NRBs.

d. GSE consolidated data package (including GSE user manual).

5.5.2.12 Coordination of analytical mathematical models including simulation

a. The SE organization shall coordinate the development and usage of the engineering analytical mathematical models and the simulation models to ensure adequate coverage of all system level life cycle activities.

NOTE 1 The analytical mathematical models cover the discipline aspects such as

- structural,
- thermal,
- RF,
- orbit dynamics,
- prediction of system performance.

NOTE 2 The simulation models are used, for example, for

- software verification,
- development of EGSE and test procedures; support of units and subsystem tests,
- prediction of system performance,
- control centre and crew operator training,
- operations procedure development and validation, and
- system troubleshooting.

b. The coordination specified in a. above shall ensure maximum re-use of the models specified therein and their related data in the various simulators used for system development and verification.

NOTE See ECSS-E-10 Part 7.

c. Tasks a. and b. should include the following activities:

1. Review system needs and coherence, model interface requirements (e.g. size, format), delivery requirements, and agree implementation with engineering disciplines.

2. Consolidate of the reference coordinate systems.

   NOTE See ECSS-E-10 Part 12.

3. Consolidate and implement the SEP analysis and simulation related aspects including planning aspects.

EXPECTED OUTPUT: *a. Consolidated SEP.*

b. Input to Project schedule.

5.5.2.13 Prediction of test results by analysis

a. The SE organization shall initiate and control, in accordance with the SEP, the activities of engineering disciplines to provide reference results for the planned tests.

b. Task a. should include the following activities:

1. Monitor the establishment of the engineering analytical mathematical models and the simulation models as defined in 5.5.2.12 for the purpose of the test predictions.
2. Monitor and control adequacy of the models (e.g. representativity, test set-up representation, capability of correlation with tests) and of the analysis.
3. Provide the models of the next lower levels.
4. Monitor the establishment and completeness of the test prediction analysis reports.

EXPECTED OUTPUT: *a. Models and related documentation.*

b. Analysis reports (DRD to ECSS-E-10 Part 2B Annex J) of the test predictions.

5.5.2.14 System performance and sensitivity analyses

a. The SE organization shall initiate and control, in accordance with the SEP, the functional performance prediction and sensitivity analyses activities performed by engineering disciplines.

b. Task a. above should include the following activities:

1. Monitor and control the establishment of the engineering analytical mathematical models and the simulation models as defined in 5.5.2.12. for the purpose of performance analysis.
2. Monitor and control adequacy of the models (e.g. representativity) and of the analysis. In particular, ensure that, once available, properly correlated models (see task 5.5.2.15) are used.
3. Provide the models of the next lower levels.
4. Follow up the establishment and completeness of the performance prediction and sensitivity analysis reports.

EXPECTED OUTPUT: *a. Models and related documentation.*

b. Analysis reports of the performance predictions.

5.5.2.15 Models correlation and update

a. The SE organization shall initiate and control the models correlation and models update activities to be performed by the engineering disciplines.

b. Task a. above should include the following activities:

1. Monitor the correlation and update activities of the engineering analytical mathematical models and of the simulation models (as defined in 5.5.2.12).
2. Ensure that the activities use the results of task 5.5.2.13 and the results of the tests performed at the current and next lower level.

EXPECTED OUTPUT: *a. Consolidated models and related documentation.*

b. Analysis reports.

5.5.2.16 Coordination of design and development process

a. The SE organization shall ensure adequacy of the design and development process in agreement with technical and management requirements.

b. Task a. above should include the following activities:

1. Control the SE process, including the consolidation of the system baseline physical architecture and plans.
2. Coordinate the engineering disciplines.
3. Coordinate with management (management issues and key engineering problem), product assurance, production and operations.
4. Maintenance of engineering database.
5. Contribute to system reviews, issue recommendations for the next lower level reviews, manage the system test related reviews (e.g. TRR, and TRB) and follow-up the NRBs.
6. Prepare input for the preliminary flight model (FM) installation manual.
7. Manage the internal-external interfaces.
8. Manage the technical aspects of the change requests.

EXPECTED OUTPUT: *a. Preliminary FM input for installation manual.*

b. System ICD.

c. Test plan.

d. Technical inputs to engineering database.

5.5.2.17 Operational aspects engineering

a. The SE organization shall ensure that the system design conforms to the operational requirements, and provide technical input and constraints to operations.

b. Task a. above should include the following activities:

1. Consolidate the operations scenario including installation, launch, flight operations, and related timeline.
2. Establish the preliminary detailed timeline.
3. Confirm the compatibility between the operational technical requirements of the TS and the operations scenario.
4. Establish the preliminary pre-launch, launch and flight operations procedures.
5. Contribute to the definition of the functional tests.
6. Contribution to the spacecraft database (TM-TC) and to the flight dynamics database.
7. Contribution to integrated logistics support (ILS) analysis.
8. Contribution to safety data package, considering input from product assurance with respect to safety aspects.

EXPECTED OUTPUT: *a. Consolidated system preliminary user manual.*

b. Preliminary issues of the installation plan (see ECSS-E-70B).

c. Installation manual and accommodation handbook (see ECSS-E-70B).

d. Preliminary launch campaign, pre-launch, launch and flight operations procedures.

e. *Technical Input to management (ILS).*

f. *Technical Input to product assurance for safety data package (see ECSS-Q-40B Part 2 Annex D).*

g. *Technical input to operations, e.g. for the operations plan, and for the telemetry and command list.*

h. *Technical input to AIT (functional test aspects).*

i. *Technical input to engineering database.*

5.5.2.18 Manage technical requirements

a. The SE organization shall manage the technical requirements for the duration of Phase C to ensure completeness and coherence of the requirements and their verification.

b. Task a. above should include the following activities:

1. Complete all requirement traceability analyses and ensure coherence and completeness at the next (or critical item) lower level technical specifications.
2. Ensure that all technical requirements have proper verification requirements.
3. Ensure that the technical requirements are expressed in a complete and coherent form.

   NOTE For the expression of technical requirements, see ECSS-E-10 Part 6.
4. Assess the impact of technical requirement changes.
5. Provide input to product assurance for dependability (reliability, availability and maintainability) and safety analyses.
6. Provide input to verification activities.

EXPECTED OUTPUT:

a. *Requirement traceability matrix.*

b. *Input to product assurance with respect to dependability and safety aspects.*

c. *Input for verification matrix support documents (e.g. traceability report).*

d. *Input to requirement database.*

5.5.2.19 Verification control

a. The SE organization shall compile evidence that all verification activities were properly performed.

b. Task a. above should include the following activities:

1. Ensure that the EM and STM test reports and inspection reports satisfy the related verification aspects according to the verification matrix.
2. Ensure that the predicted performances as obtained with the consolidated models (see task 5.5.2.14), satisfy the corresponding requirements identified in the verification matrix.
3. Ensure that the review of design reports satisfy the corresponding requirements identified in the verification matrix.
4. Perform a synthesis of all the verification aspects specified in 1. above, and check that all requirements identified in the verification matrix are properly covered.

EXPECTED OUTPUT:

a. *Verification report (see ECSS-E-10 Part 2B Annex M).*

b. *Verification control document.*

5.5.2.20 System critical design review (CDR)

a. The SE organization shall support the system CDR process to ensure its successful completion.

NOTE For the CDR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities:

1. Ensure availability of the following SE engineering documentation according to the CDR review plan:
   (a) system technical specification;
   (b) interface requirement document;
   (c) system design definition file (DDF) including the DDF of the lower level elements;
   (d) product tree;
   (e) technical budget;
   (f) specifications tree;
   (g) interface control document;
   (h) requirement traceability matrix;
   (i) next lower level elements technical specifications;
   (j) verification matrix;
   (k) technology matrix;
   (l) system design justification including the DJF of the lower level elements;
   (m) EM and STM data package;
   (n) test specifications;
   (o) verification specifications;
   (p) mathematical models;
   (q) analysis reports;
   (r) test reports;
   (s) verification reports;
   (t) GSE specifications;
   (u) GSE data packages;
   (v) verification control documents;
   (w) system qualification model AIT plan;
   (x) next lower level qualification model AIT plan;
   (y) mission description document;
   (z) system verification plan;
   (aa) preliminary launch campaign, pre-launch launch and flight operation procedures;
   (ab) preliminary issue of installation plan;
   (ac) installation plan;
   (ad) accommodation handbook;
   (ae) user manual.
2. Ensure execution of the SE activities for successful completion of the CDR, e.g. provision of clarifications, reply to review item discrepancies (RIDs), closure of actions.
3. Update system design baseline, SEP plan and related documentation.

EXPECTED OUTPUT:

a. *Data package documents consolidated.*

b. *DDF, DJF put under internal configuration control (see ECSS-M-30).*

c. *Interface control document under internal configuration control (see ECSS-M-30).*

5.5.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.5.2 are summarized in Table 4, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 4: Phase C

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
1	Kick-off of Phase C			(C)	(C)	(Ag)					M	Agreed technical assumptions
2	Consolidation of Phase C input	Cus	Business agreement	IC(R)	(C)	(C)	(C)	(C)		(C)	SE	Consolidated issues of system technical specification
		SE	Phase B outputs e.g. system technical specification								SE	System DDF
		SE	DDF (including next lower level TS)								SE	System DJF
		SE	DJF								SE M(Ag)	SEP and related plans
		SE,Q	Plans (including SEP)								SE, M(Ag)	Consolidated product tree
		M	Project management plan and management instructions								SE, M(Ag)	Consolidated issue of the next lower level TS

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
3	System detailed design	SE	System technical specification	IC(R)		(C)	(C)	(C)	(C)	(C)	SE,M	System DDF
		SE	DDFs (including next lower level TSs)								SE,M	System DJF
		SE	DJF								SE	SEP and related plans
		SE	Plans (including SEP), defined in the DRDs to ECSS-E-10 Part 1 (see ECSS-E-10 Part 17)								SE,M	Product tree, specifications tree
		SE	Technology matrix								SE,M	Technical budget
		SE	Analysis reports								SE	Consolidated technology matrix
		SE	DDFs and DJFs of lower levels								SE	Consolidated technology plan
		SE	Revue of design reports								SE,M	Consolidated lower level elements TSs
		SE	Inspection reports									
		SE	EM and STM test reports									
		SE	Verification reports									
		SE	Verification control document									
		SE	System ICD									
4	Lower level monitoring and activities	M	Lower level contracts	IC(R)		(C)	(C)	(C)	(C)		SE,M	DDFs, DJFs, SEPs of lower levels
		SE	Lower level TSs								SE,M	Lower level EM and STM products with associated data package
		M	Lower level data								SE,M	Lower level mathematical models
		M	Lower level VCDs									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
5	Verification planning	SE	SEP	IC(R)		(C)	(C)	(C)	(C)	(C)	SE	Verification planning in SEP
		SE	TS								SE	Verification matrix
		M	Project schedule input								SE	Test specification
											M	Technical input to schedule assessment
											SE	Data for verification database
6	AIT planning, preparation	SE	SEP	V(R)			(C)	(C)	(C-R)		SE,P,M	Detailed AIT plan
		M	Lower level installation manuals								SE,P	Test plan
		SE	Verification matrix								SE,P	Test specifications (see ECSS-E-10 Part 2B Annex F)
		M	Facility manuals								SE,M,P	GSE specifications
		M	Project schedule								SE,P	Test procedures (see ECSS-E-10 Part 2B Annex H)
		SE	Test prediction analysis reports								SE,P	Integration procedures (see ECSS-E-10 Part 15A Annex A)
											M	Input to project schedule
7	AIT of GSE	SE	GSE products and associated data package	IC(C)			(C)	(C)	(R)		SE,P	GSE ready for use
		SE	AI plan								SE,P	GSE data package

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
8	Assembly and integration of engineering models	SE	GSE ready for use	IC(C)			(C)	(C)	(R)		SE,P	CIDL for EM ready for test
		M	AI facility ready								SE,Q	Integration records (see ECSS-E-10 Part 15A Annex B)
		M	Lower level EM products including data packages								SE,P	EM installation manual
		SE	AI plan									
		SE	Integration procedure									
9	Assembly and integration of STM	SE	GSE ready for use	IC(C)			(C)	(C)	(R)		SE,P	Input for CIDL for STM ready for test
		M	AI facility ready								SE,Q	Integration record
		M	Lower level STM products including data packages								SE,P	STM installation manual
		SE	AI plan									
		SE	Integration procedure									
10	Tests of EM and validation of GSE	SE	EM ready for test	V(C)			(C)	(C)	(R)		SE	Test reports (see ECSS-E-10 Part 2B Annex I)
		SE	GSE ready for test								SE	Minutes of TRRs and TRBs
		M	Test facilities ready for use								SE	NRBs
		SE	Test procedures								SE	GSE data package ready for use
		SE	Test plan									
		M	EM installation manual									
		M	Configuration status report									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
11	Tests of STM and validation of GSE	SE	STM ready for test	V(C)			(C)	(C)	(R)		SE	Test reports
		SE	GSE ready for test								SE	Minutes of TRRs and TRBs
		M	Test facilities ready for use								SE	NRBs
		SE	Test procedures								SE	GSE data package ready for use
		SE	Test Plan									
		M	STM installation manual									
		M	Configuration status report									
12	Coordination of analytical mathematical models including simulation	SE	SEP	An(R)				(C)			SE, E	SEP (analysis planning, mathematical model requirements)
		SE	DDF, DJF								M	Input to project schedule
		M	Project schedule									
13	Prediction of test results by analyses	SE	SEP	An(R)					(C)		SE	Mathematical models and related documentation
		SE	DDF, DJF								SE, P	Test prediction analysis reports
		SE	Lower level DDFs, DJFs and mathematical models									
14	System performance and sensitivity analyses	SE	SEP	An(R)					(C)		SE	Mathematical models
		SE	DDF, DJF								SE	Analysis reports
		SE	Lower level DDFs, DJFs and mathematical models									
15	Model correlation and update	SE	Mathematical models	An(R)				(C)	(C)		SE	Consolidated mathematical models
		SE	Test prediction analysis reports								SE	Analysis report
		SE	EM and STM test reports									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
16	Coordination of design and development process	M	Lower level SEPs, AIs and Test plans	IC(R)		(C)	(C)	(C)	(C)		SE,P	AIT system plan
		SE	SEP								SE,P	Test plan
		SE-P	AI plan								SE,P	- Input to preliminary FM - Installation manual
		SE	EM and STN installation manuals								SE	System ICD
		SE	EM and STM integration records								SE	Technical input to engineering database
		SE	Preliminary system ICD									
17	Operational aspects engineering	SE	DDF	IC(R)		(C)		(C)		(C)	SE,OPS	- Consolidated system - Preliminary user manual
		SE	Preliminary user manual								M,OPS	Technical input to ILS
		SE-Q	Input from product assurance								M,OPS	Technical input to operations
											SE,P	Technical input to AIT
											SE,Q	Technical input to Q
											SE,OPS	Installation plan (see ECSS-E-10 Part 16A Annex B)
											SE,OPS	Consolidated operations scenario
											SE,OPS	Preliminary launch campaign, pre launch, launch operation procedures
											SE	Technical input to database
											SE,OPS	Accommodation handbook (see ECSS-E-10 Part 16A Annex C)

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 4: Phase C *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
18	Manage technical requirements	SE	Requirement traceability matrix	RE(R)		(C)	(C)	(C)			SE	Requirement traceability matrix
		SE	System TS								SE	Requirement Database
		SE	Lower levels TSs								M,Q	Input to product assurance (RAMS)
		SE	Specifications tree								SE	
		SE	Product tree									
19	Verification control	SE	SEP	V(R)							SE	Verification reports (see ECSS-E-10 Part 2B Annex M)
		SE	Verification matrix								SE	Verification control document
		SE	EM and STM test reports									
		SE	Analysis reports (from 8 and 9)									
		SE	Revue of design reports									
		SE	Inspection reports									
20	System CDR	SE	System CDR review plan	IC (R)							SE	Consolidated design and related document for approval
		SE	System CDR review data package									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.6 Production-ground qualification testing: Phase D

5.6.1 Objective and process flow: Phase D

This phase marks the end of the system development. The system is produced, and it is demonstrated that it is capable of fulfilling the specified requirements (i.e. qualified). This phase ends with the acceptance review by which the customer accepts the product PFM or FM1 and enables the start of the utilization and the series production (if any), Phase E.

NOTE The flow of the generic SE tasks in Phase D is described in Figure 20.

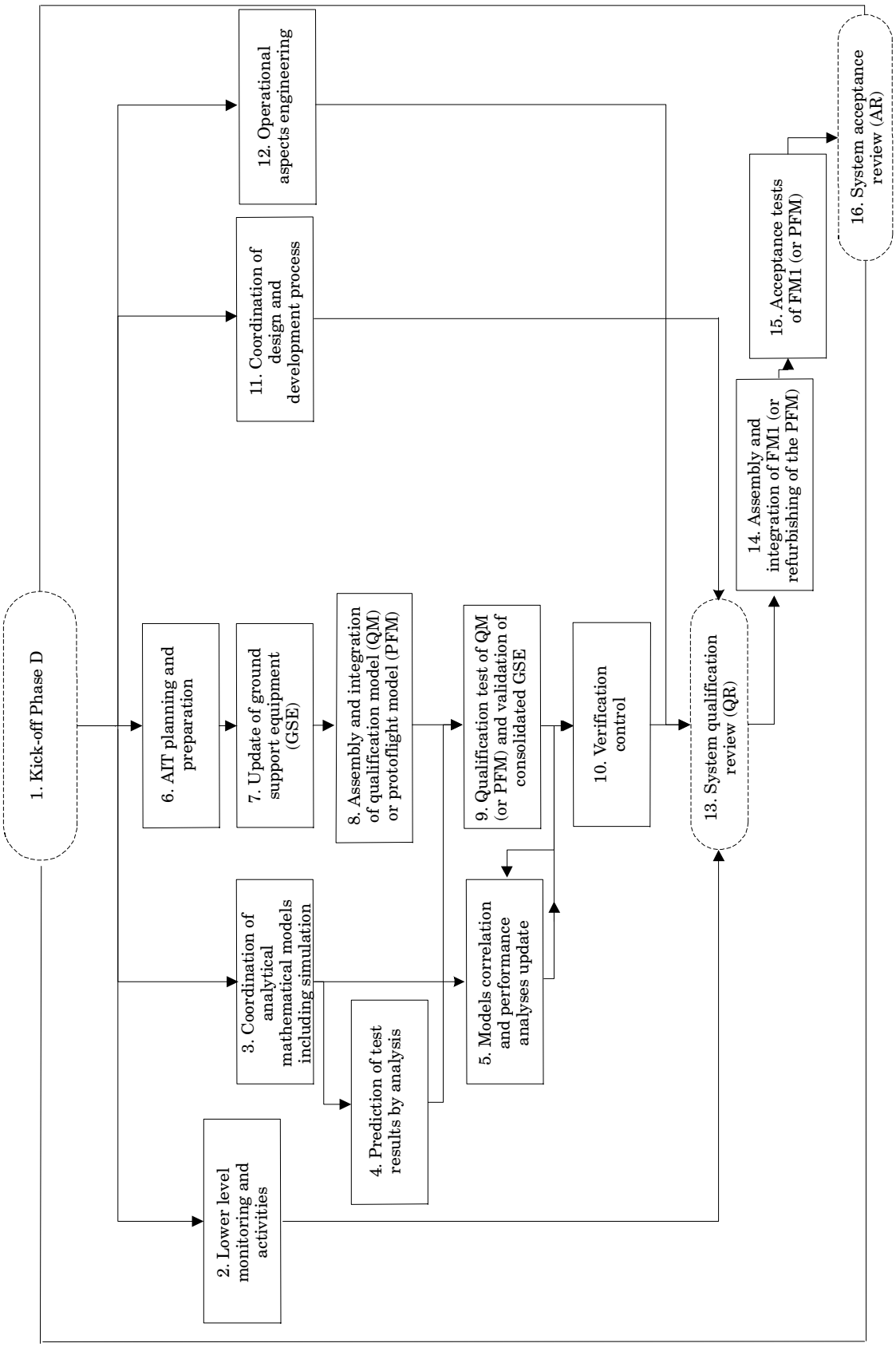

Figure 20: Phase D flow chart

5.6.2 Description of objectives, activities and clarifications on documents

5.6.2.1 Kick-off Phase D

a. The SE organization shall support the kick-off (KO) meeting of Phase D.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *Agreed technical assumptions.*

5.6.2.2 Lower level monitoring and activities

a. The SE organization shall monitor the SE activities of the suppliers.

b. Task a. above should include the following activities:

1. Control the subcontractor SE activities, e.g. monitor the implementation of
   (a) the requirements traceability,
   (b) the verifications of all elements,
   (c) production qualification activities (AIT).
2. Review at regular intervals the technical progress.

NOTE It is good practice to take part in key meetings and qualification reviews (QRs) and acceptance reviews (ARs) of lower levels critical elements.

EXPECTED OUTPUT:
a. Lower level SEP.
b. Lower level DDF and DJF.
c. Lower level qualification model (QM) or protoflight model (PFM) products with associated data packages.

5.6.2.3 Coordination of analytical mathematical models including simulation

a. The SE organization shall coordinate the maintenance and usage of the engineering analytical mathematical models and the simulation models to ensure adequate coverage of all system level life cycle activities.

NOTE The analytical mathematical models cover the discipline aspects such as per Phase C.

b. The coordination specified in a. above shall also ensure maximum re-use of the models there specified and their related data in the various simulators used for system development and verification.

NOTE See ECSS-E-10 Part 7.

c. Tasks a. and b. above should include the following activities:

1. Ensure consistent model maintenance and consolidation with respect to lower level inputs, interface requirements (e.g. size and format), delivery requirements, and agree implementation with engineering disciplines.
2. Implementation of the SEP analysis and simulation related aspects including planning aspects.

EXPECTED OUTPUT: *Mathematical models.*

5.6.2.4 Prediction of test results by analysis

a. The SE organization shall initiate and control in accordance with the SEP the test prediction analyses performed by engineering disciplines.

b. Task a. above should include the following activities:

1. Monitor the update of the engineering analytical mathematical models and the simulation models as defined in 5.6.2.3.
2. Monitor and control the adequacy of the models (e.g. representation facility, and capability to correlation with tests) and analysis.
3. Monitor and follow the establishment and completeness of the test prediction analysis reports.
4. Ensure that the results are used for:
   (a) setting the test conditions (e.g. notchings and limits),
   (b) interpretation of test results,
   (c) model correlation.

EXPECTED OUTPUT: *a. Consolidated test specifications.*
b. Analysis reports of the test predictions.

5.6.2.5 Models correlation and performance analyses update

a. The SE organization shall initiate the updates of the models correlation performance analysis to be performed by the engineering disciplines.

b. Task a. above should include the following activities:
   1. Follow up the correlation and update of the engineering analytical mathematical models and the simulation models (as defined in 5.5.2.12) resulting from task 5.5.2.14 on the basis of the results of the performed tests, including those from the next lower level.
   2. In case of changes in models used for performance analyses in Phase C, investigate impact and repeat the analyses.

EXPECTED OUTPUT: *a. Consolidated models and related documentation.*
b. Analysis reports.

5.6.2.6 AIT planning and preparation

a. The SE organization shall detail the system AIT planning for the QM (or PFM), and monitor the preparation of the related infrastructure and procedures.

b. Task a. above should include the following activities.
   1. SE activities:
      (a) comment and approve the test procedures established by production;
      (b) define input to production for the establishment of the integration procedures;
      (c) comment and agree the integration procedures established by production and their consistency with respect to the AIT plan.
   2. AIT activities
      (a) establish the detailed AIT operations planning for QM (or PFM);
      (b) analyse the test prediction reports in support to test facility selection;
      (c) analyse the lower level installation manuals;
      (d) establish the test procedures on the basis of the test specifications;
      (e) establish the integration procedures.

   NOTE Activities in b. above are a combination of system engineering and production (AIT) operations.

EXPECTED OUTPUT: *a. Test procedures.*
b. Integration procedures.
c. Inputs to project schedule (AI planning).

5.6.2.7 Update of ground support equipment (GSE)

a. The SE organization shall ensure the availability of the consolidated GSE ready for use (with QM or PFM).

b. Task a. should include the following activities:

1. Initiate and monitor update of the GSE.
2. Validate the GSE ready for use with QM or PFM.

EXPECTED OUTPUT: *a. GSE ready for use with QM or PFM.*

b. Consolidated GSE data package (including GSE user manual).

5.6.2.8 Assembly and integration of qualification model (QM) or protoflight model (PFM)

a. The SE organization shall ensure availability of the QM (or PFM) ready for use.

b. Task a. above should include the following activities:

1. Initiate and monitor (via the integration records) the AI of the QM or PFM.
2. Produce input to CIDL defining the status of the QM or PFM.
3. Control the status of the lower level QM or PFM Models.
4. Ensure availability of a validated AI of the QM or PFM, after its completion.
5. Ensure availability of a validated QM installation manual.

EXPECTED OUTPUT: *a. Input to CIDL of the QM or PFM ready for use.*

b. Integration records.

c. Validated QM or PFM installation manual.

5.6.2.9 Qualification test of QM (or PFM) and validation of consolidated GSE

a. The SE organization shall ensure that the QM or PFM tests are performed according to the AIT plan.

b. Task a. above should include the following activities:

1. SE activities:
   (a) validate the inputs (QM or PFM status, test procedures, ground support status);
   (b) initiate and monitor performance of the QM or PFM tests;
   (c) initiate and hold the test readiness reviews (TRRs) and the test review boards (TRBs);
   (d) hold NRBs and follow up related activities;
   (e) compile the complete test reports, including the “as-run” test procedures, the minutes of the TRRs and of the TRBs, and analyses;
   (f) validate the GSE for acceptance testing and Phase E.
2. AIT activities:
   (a) perform the tests;
   (b) establish test result reports.

NOTE Activities in b. above are a combination of system engineering and production (AIT) operations.

EXPECTED OUTPUT: *a. Test reports.*

b. Test result documents.

c. *Minutes of TRRs and TRBs.*

d. *NRBs.*

e. *GSE consolidated data package (including GSE user manual).*

5.6.2.10 Verification control

a. The SE organization shall control that all verification activities on QM or PFM are properly performed.

b. Task a. above should include the following activities:

1. Analyse QM or PFM test reports and inspection reports, and check the related verification aspects against the verification matrix.
2. Analyse the predicted performances as obtained with the consolidated models (see task 5.5.2.14), and check against the corresponding requirements identified in the verification matrix.
3. Analyse the review of design reports, and check against the corresponding identified in the verification matrix.
4. Perform a synthesis of all the verification aspects specified in 1. above, and check that all requirements identified in the verification matrix were properly covered.

EXPECTED OUTPUT: a. *Verification reports.*

b. *Verification control document.*

5.6.2.11 Coordination of design and development process

a. The SE organization shall:

1. Cover and manage all aspects of production, qualification and acceptance.
2. Cover small design consolidation and requirements management which can occur during Phase D.

b. Task a. above should include the following activities:

1. Control the SE process, including aspects related to the control of the "as built" configuration status.
2. Coordinate the engineering disciplines.
3. Coordinate with management (management issues, key engineering problem), product assurance, production and operations.
4. Maintain the engineering database.
5. Contribute to system reviews, issue recommendations for the next lower level reviews, manage the system test related reviews (TRRs and TRBs) and follow-up the NRBs.
6. Manage the internal-external interfaces.
7. Cover during Phase D all design consolidation aspects which can appear during this phase and manage the technical aspects of the change requests (e.g. NCRs, RFWs) up to the final "as built" configuration, and ensure proper documentation.

EXPECTED OUTPUT: a. *Engineering database.*

b. *DDF (including ICDs).*

c. *DJF.*

d. *Input for the final production master file (see ECSS-E-10 Part 15A Annex C).*

e. *Input to management for updates of configuration management.*

f. Input to databases.

5.6.2.12 Operational aspects engineering

a. The SE organization shall consolidate the engineering of the operation of the system on the basis of QM or PFM tests, whereby providing technical input to operations.

b. Task a. above should include the following activities:

1. Consolidate the operations scenario including installation, launch, flight operations, and related timeline.
2. Establish the preliminary detailed timeline.
3. Confirm the compatibility between the operational technical requirements of the TS and the operations scenario.
4. Contribute to the consolidation of the preliminary launch campaign, commissioning, and flight operations plans.
5. Consolidation of the spacecraft database (TM-TC) and flight dynamics database.
6. Contribution to integrated logistics support (ILS) analysis.
7. Contribution to safety data package, considering input from product assurance with respect to launch safety aspects.

EXPECTED OUTPUT:

a. Consolidated system user manual.

b. Installation plan, installation manual, and accommodation handbook.

c. Pre-launch, launch, and flight operations procedures.

d. Input to ILS.

e. Input to product assurance for safety data package (see ECSS-Q-40B Annex D).

f. Input to operations, e.g. for the flight operations plan, for the telemetry and command list, for the launch campaign plan, and the commissioning plan.

g. Input to production (to define to AIT the functional test aspects).

h. Spacecraft database.

i. Flight dynamics database.

5.6.2.13 System qualification review (QR)

a. The SE organization shall support the system QR process to ensure its successful completion.

NOTE For the QR, see ECSS-M-30 and related documents.

b. Task a. above should include the following activities:

1. Ensure availability of the following SE documentation according to the QR review plan:
   (a) system technical specification;
   (b) interface requirement documents;
   (c) system design definition file including DDFs of the lower level elements;
   (d) product tree;
   (e) technical budget;
   (f) specifications tree;
   (g) interface control document;

(h) requirement traceability matrix;
(i) next lower level elements technical specifications;
(j) verification matrix;
(k) technology matrix;
(l) system design justification including DJF of the lower level elements;
(m) QM data package;
(n) test specifications;
(o) verification specifications;
(p) mathematical models;
(q) analysis reports;
(r) test reports;
(s) verification reports;
(t) GSE specifications;
(u) GSE data packages;
(v) verification control documents;
(w) production master file for verification aspects;
(x) system flight model (FM) AIT;
(y) next lower level FM AIT;
(z) mission description document;
(aa) launch campaign, pre-launch launch and flight operation procedures;
(ab) preliminary issue of installation plan;
(ac) installation plan;
(ad) accommodation handbook;
(ae) user manual;

2. Ensure execution of the SE activities for successful completion of the QR (e.g. provision of clarifications, reply to RIDs, and closure of actions).
3. Update system design baseline, SEP plan and related documentation.
4. Support to management for the establishment of the qualification certificate for the qualified baseline and its DDF and DJF.

EXPECTED OUTPUT:
a. Data package documents consolidated.
b. Design definition file and design justification file under formal configuration control (see ECSS-M-30).
c. Production master file under internal configuration control.

5.6.2.14 AI of FM1 or refurbishing of the PFM

a. The SE organization shall ensure that the FM1 (FM or refurbished PFM) is available and ready for use.
b. Task a. above should include the following activities:
   1. Initiate and monitor (via the integration records) the AI of the FM1.
   2. Produce input to CIDL defining the status of the FM1.
   3. Control the status of the lower level FM1 models.
   4. Ensure availability of a validated AI of the FM1, after its completion.

5. Ensure availability of a validated FM1 installation manual and end item data package (EIDP).
6. In case of refurbishment of PFM:
   (a) analyse the status of the PFM;
   (b) identify the PFM refurbishment activities;
   (c) support production for the implementation of identified PFM and refurbishment activities;
   (d) monitor and control identified PFM refurbishment activities.

EXPECTED OUTPUT:
a. *Input to CIDL of the FM1 ready for use.*
b. *Integration records.*
c. *Validated FM1 installation manual.*
d. *Contribution to end item data package (EIDP).*

5.6.2.15 Acceptance tests of FM1 (or PFM)

a. The SE organization shall ensure performance of the acceptance tests of the FM1 (FM or refurbished PFM) according to the AIT plan.
b. Task a. above should include the following activities:
   1. SE activities:
      (a) validate the inputs FM1 status, test procedures, and GSE status;
      (b) initiate and monitor performance of the FM1 tests;
      (c) initiate and hold the test readiness review (TRR) and the test review board (TRB).

      NOTE For the TRR and the TRB, see ECSS-E-10 Part 2;
      (d) hold nonconformance review boards (NRBs) and follow up related activities.
      (e) Update VCD.
   2. AIT activities:
      (a) perform the tests;
      (b) establish test result reports.

      NOTE These are a combination of SE and AIT operations activities.

EXPECTED OUTPUT:
a. *Test reports.*
b. *Test result documents.*
c. *Minutes of TRRs and TRBs.*
d. *NRBs.*
e. *Updated VCD.*

5.6.2.16 System acceptance review

a. The SE organization shall support the system AR process to ensure its successful completion.

   NOTE For the AR, see ECSS-M-30 and related documents.
b. Task a. above should include the following activities:
   1. Ensure availability of the following SE engineering documentation according to the AR review plan:
      (a) system technical specification;
      (b) interface requirement documents;
      (c) system design definition file including DDF of the lower level elements;

(d) product tree;
(e) technical budget;
(f) specifications tree;
(g) interface control documents;
(h) requirement traceability matrix;
(i) next lower level elements technical specifications;
(j) verification matrix;
(k) technology matrix;
(l) FM data package;
(m) test specifications;
(n) verification specifications;
(o) analysis reports;
(p) test reports;
(q) verification reports;
(r) GSE specifications;
(s) GSE data packages;
(t) verification control documents;
(u) production master file for verification aspects;
(v) system FM AIT plan;
(w) next lower level FM AIT plan;
(x) mission description document;
(y) launch campaign, pre-launch launch and flight operation procedures;
(z) preliminary issue of installation plan;
(aa) installation plan;
(ab) accommodation handbook;
(ac) user manual.

2. Ensure execution of the SE activities for successful completion of the AR (e.g. provision of clarifications, reply to RIDs, and closure of actions).
3. Support to management for the establishment of the acceptance certificate.

EXPECTED OUTPUT: *a. Data package documents consolidated.*
b. FM end item data package.

5.6.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.6.2 are summarized in Table 5, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 5: Phase D

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
1	Kick-off of Phase D	Cus	Business agreement	(C)	(C)	(Ag)					M	Agreed technical assumptions
		M	Project management plan and management instructions									
2	Lower level monitoring and activities	M	Lower level contracts	IC(R)		(C)	(C)	(C)	(C)		SE,M	Lower level QM, PFM, FM1 products with associated data package
		M	Lower level TSs								SE	Lower level mathematical models
		M	Lower level DDFs, DJFs								SE,M	Lower lever DDFs and DJFs
		M	Lower level VCDs								SE	Lower level SEPs
		M	Lower level SEPs									
		M	Lower level AIT plans									
3	Coordination of analytical mathematical models including simulation	SE	SEPs	An(R)				(C)			SE, E	Mathematical models
		SE	DDFs, DJFs									
		M	Mathematical models project schedule									
4	Prediction of test results by analysis	SE	SEP	An(R)					(C)		SE	Test prediction analysis reports
		SE	DDF, DJF Lower level DDFs, DJFs Mathematical models								SE, P	Consolidated test specifications

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 5: Phase D *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
5	Model correlation analyses and performance analyses updates	SE	Mathematical models	An(R)					(C)		SE	Consolidated mathematical models
		SE	Test prediction analysis reports								SE	Analysis reports
		SE	QM (PFM) test reports									
		SE	SEP									
		SE	DDF, DJF									
		SE	Lower level DDFs, DJFs									
6	AIT planning, preparation	SE	SEP	V(R)			(C)	(C)	(C-R)		SE,P	Test procedures
		SE	Lower level installation manuals								SE,P	Integration procedures
		SE	Verification matrix								SE,M	Input to project schedule
		SE	Facility manuals								SE,P	AI planning
		M	Project schedule									
		SE	Test prediction analysis reports									
		SE	Test specifications									
7	Update of GSE	SE	GSE products and associated data package	IC(C)			(C)	(C)	(R)		SE,P	GSE ready for use including consolidated associated data package
		SE	AI Plan									
		SE	Mathematical models									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 5: Phase D *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
8	Assembly and integration of QM (or PFM)	SE	GSE ready for use	IC(C)			(C)	(C)	(R)		SE,P	QM ready for test
		M	AI facility ready								SE,Q	Integration records
		M	- Lower level QM products incl. data packages - AI Plan								SE,P	QM installation manual
		SE	Integration procedures								SE	Input to CIDL of the QM or PFM
		SE	Installation manual									
9	Qualification tests of QM (or PFM) and validation of consolidated GSE	SE	QM, PFM ready for test	V(C)			(C)	(C)	(R)		SE	Test result documents
		SE	GSE ready for test								SE	Test reports
		M	Test facilities ready for use								PA	Minutes of TRs and TRBs
		SE	Test procedures								SE	NRBs
		SE	- Test plan - QM, PFM installation manual								OPS	GSE consolidated data package (including GSE user manual)
		M	Configuration status report									
10	Verification control	SE	SEP	V			(C)	(C)			SE,M	Verification reports
		SE	Verification matrix and lower level VCDs								SE,M	Verification control document
		SE	QM test reports									
		SE	Analysis reports (from 9 and 19, as well as Phase C 8 and 9)									
		SE	Review of design reports									
		Q	Inspection reports									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 5: Phase D *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
11	Coordination of design and development process	M	Lower level SEPs, AI and test plans	IC(C)			(C)	(C)	(R)		SE	Engineering database
		SE	SEP								SE	DDF (including ICD)
		SE	AI plan								SE	DJF
		SE	QM integration records ICD								P	Input for the final production master file (see ECSS-E-10 Part 15A Annex C)
		SE	System technical specification								SE	Input to M for updates of configuration management
		SE	Consolidation of as built status of the physical baseline architecture								SE	Input to database
		SE	- DDF - DJF - System ICD									
		SE	Preliminary production master file									
		SE	Manage technical aspects of changes									
		SE	DJF, including requirement traceability									
		P	Matrix system TSs									
		SE	Lower levels TSs									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 5: Phase D *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
12	Operational aspects engineering	SE	DDF	V(C)			(C)	(C)	(R)		SE, OP	- Consolidated system user manual, including telemetry and command list - Input to ILS
		SE	Preliminary user manual								SE	Satellite database flight dynamics database input to flight operation plan
		OPS	"As run" QM, PFM test procedures									
13	System qualification review	SE	- System QR review plan - System QR review data package	IC(R)							SE	Consolidated DDF and DJF, and related documents
14	AI of FM1 (or refurbishment of PFM)	SE	- FM GSE ready for use - FM AI facility ready - Lower level FM products incl. end item data packages - AI Plan - Integration procedures - Installation manual	IC (R)							SE	FM ready for test
											SE	Integration records
											SE	FM installation manual

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 5: Phase D *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Documents		Cus	M	Q	E	P	Ops	To	Documents
15	Acceptance Test of FM1 (or PFM)	SE	FM ready for test	IC(R)							SE	Test result documents
		SE	FM GSE ready for test								SE	Test report
		SE	Test facilities ready for use								SE, M	Minutes of TRR and TRB
		SR	Test procedures test plan								SE	Updated VCD
		SE	- FM installation manual - Configuration status report								SE	NRBs
		SE	- SEP - VCD									
16	System acceptance review	SE	- System AR plan - System AR review data package	IC (R)							SE	End item data package

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.7 Utilization: Phase E

5.7.1 Objective and process flow: Phase E

Phase E results in the utilization of the system or in the production of recurring products.

NOTE In line with ECSS-M–30, this phase includes the launch campaign, launch and in-flight acceptance of the space element, as well as the production phase of recurrent systems.

Phase E is subdivided, according to ECSS-M-30, in:

- Phase E1: Commissioning phase, ending up with the flight qualification review.
- Phase E2: Exploitation phase, ending with the end of flight review.

As specified in ECSS-M-30-01, the following reviews are considered regarding progressive readiness and utilization:

a. Operational readiness review (ORR)
b. Flight readiness review (FRR)
c. Launch readiness review (LRR)
d. Flight qualification review (FQR)
e. End-of-life review (ELR)

The transition from Phase E1 to Phase E2 implies a change of emphasis for the SE function up to end of Phase E1 the SE function is mainly attached to the organizational entity responsible for the system development, while during Phase E2 the SE function is mainly attached to the organization responsible for the system utilization (operations, production of recurrent items, production of mission end products) which plays then the leading role.

NOTE The flow of the generic SE tasks in Phase E is described in Figure 21.

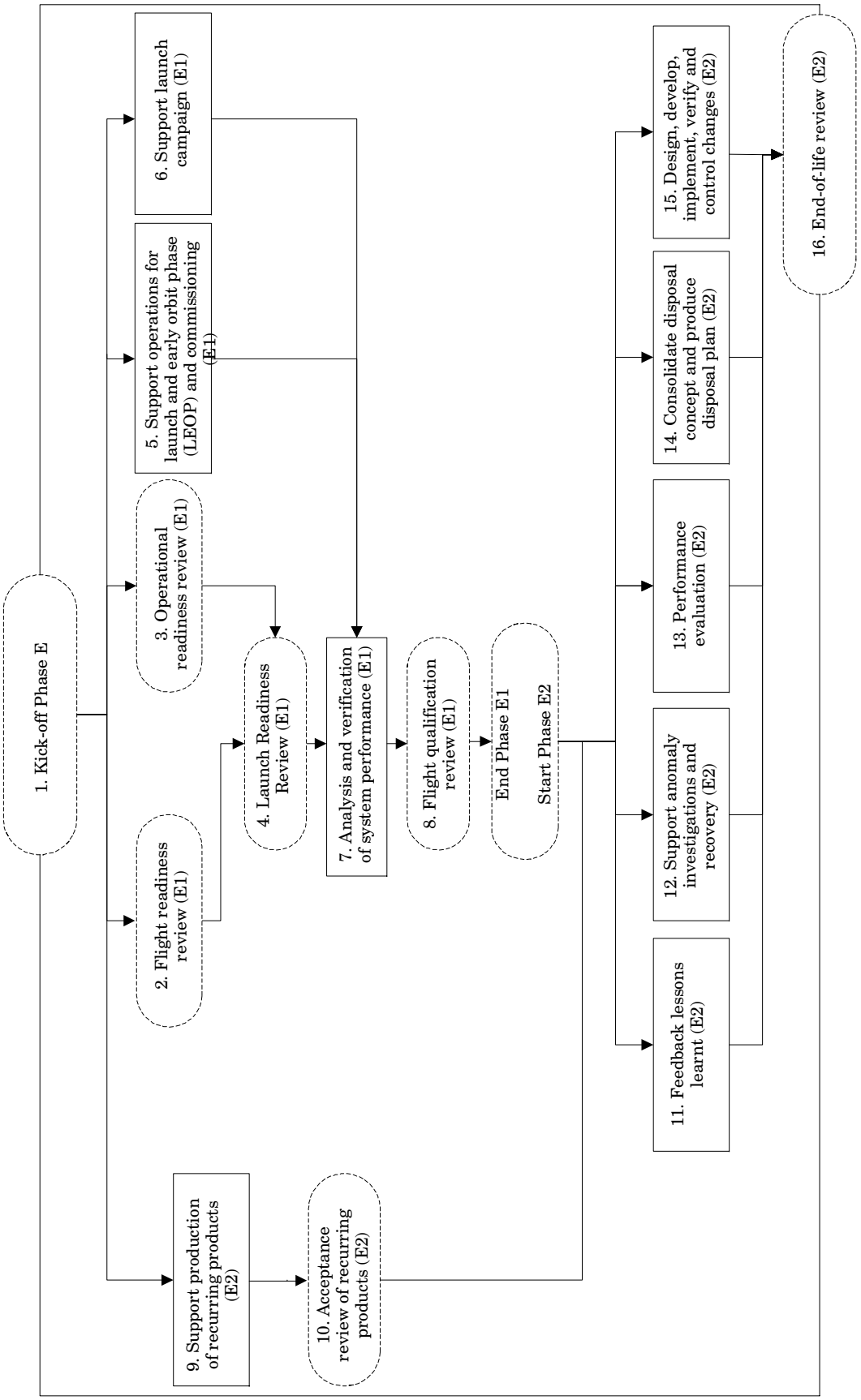

Figure 21: Phase E flow chart

5.7.2 Description of objectives, activities and clarifications on documents

5.7.2.1 Kick-off (KO) Phase E (E1)

Although the term KO is used here to be consistent with the other phases, the start of Phase E does not normally take place in the form of a contractual KO meeting, but follows on naturally from the successful completion of Phase D.

5.7.2.2 Flight readiness review (E1)

a. The flight readiness review (FRR) includes activities common to the AR, which shall be repeated if there is a significant gap in time between AR and shipment.

NOTE This is why in some projects both AR and FRR reviews are concatenated.

b. The SE organization shall support the flight readiness review to ensure its successful completion.

NOTE For the flight readiness review, see ECSS-M-30.

c. As a minimum, the flight readiness review shall address following specific issues.

1. Check the conformity of the FM in relation to the mission goals.
2. Check the as built configuration of the FM in relation to the current configuration baseline.
3. Check the state of the critical elements of the system, including limited life and sensitive items.
4. Verify the launch campaign plan.
5. Check the state of completion of the safety related issues.
6. Confirm that plans for ground segment readiness are consistent.

d. Tasks a., b. and c. above should include the following activities:

1. Ensure availability of the following SE documentation according to the FRR review plan:
   (a) system technical specification;
   (b) interface requirement documents;
   (c) interface control documents;
   (d) requirement traceability matrix;
   (e) next lower level elements technical specifications;
   (f) verification matrix;
   (g) FM data package;
   (h) test specifications;
   (i) verification specifications;
   (j) analysis reports;
   (k) test reports;
   (l) verification reports;
   (m) verification control documents;
   (n) mission description document;
   (o) launch campaign, pre-launch, launch and flight operation procedures;
   (p) preliminary issue of installation plan;
   (q) installation plan;

(r) accommodation handbook;

(s) user manual.

2. Ensure execution of the SE activities for successful completion of the FRR (e.g. provision of clarifications, reply to RIDs, and closure of actions).

EXPECTED OUTPUT: *Consolidated data package documents, e.g.:*

a. launch campaign plan;

b. Space segment documentation.

5.7.2.3 Operational readiness review (E1)

a. The SE organization shall support the operational readiness review (ORR), to ensure its successful completion.

NOTE For the ORR, see ECSS-M-30 and ECSS-E-70.

b. As a minimum, the review shall address following specific issues:

1. Review the results of the operational validation

NOTE 1 This refers to operational validation readiness review (OVRR) as described in ECSS-E-70.

NOTE 2 In ECSS-E-70 the term "validation" is used, whereas the term "qualification" is used in ECSS-E-10 series and ECSS-M-30.

2. Confirm the operational compatibility of the space segment and the ground segment.

3. Establish the suitability of the system to be used in operational conditions.

4. Establish the readiness of operations (ground segment and flight operations teams) to support operations.

c. Tasks a. and b. above should include the following activities:

1. Ensure availability of the following SE documentation according to the ORR review plan:

(a) system technical specification;

(b) interface requirement documents;

(c) interface control documents;

(d) FM data package;

(e) test specifications;

(f) verification specifications;

(g) analysis reports;

(h) test reports;

(i) verification reports;

(j) verification control documents;

(k) mission description document;

(l) launch campaign, pre-launch, launch and flight operation procedures;

(m) preliminary issue of installation plan;

(n) installation plan;

(o) accommodation handbook;

(p) user manual;

(q) ground segment documentation of SE related documentation as identified in ORR review plan.

2. Ensure execution of the SE activities for successful completion of the ORR (e.g. provision of clarifications, reply to RIDs, and closure of actions).

EXPECTED OUTPUT: *Consolidated data package documents, e.g.:*

a. space segment documentation;

b. input to ground segment documentation.

5.7.2.4 Launch readiness review (E1)

a. The SE organization shall support the launch readiness review (LRR), to ensure its successful completion.

NOTE For the LRR, see ECSS-M-30 and related documents.

b. As a minimum the review shall address following specific issues:

1. Check that all actions from FRR and ORR are closed.
2. Confirm the availability and operation readiness of launcher, launch pad, stations, network, and other elements for the launch.
3. Confirm completion of launch campaign activities and close-out of all NCRs.
4. Support the launcher organization in giving the authorization for launch.

c. Tasks a. and b. above should include the following activities:

1. Ensure availability of the following SE documentation according to the LRR review plan:
   (a) system technical specification;
   (b) interface requirement documents;
   (c) interface control documents;
   (d) FM data package;
   (e) test specifications;
   (f) verification specifications;
   (g) analysis reports;
   (h) test reports;
   (i) verification reports;
   (j) verification control documents;
   (k) mission description document;
   (l) flight operation procedures;
   (m) user manual;
   (n) ground segment documentation.
2. Ensure execution of the SE activities for successful completion of the LRR (e.g. provision of clarifications, reply to RIDs, and closure of actions).

EXPECTED OUTPUT: *Consolidated data package documents, e.g.:*

a. consolidated space segment documentation;

b. input to ground segment documentation;

c. input to launch segment documentation;

d. input to PA for NCRs closure.

5.7.2.5 Support operations for launch and early orbit phase (LEOP) and commissioning (E1)

a. The SE organization shall support operations, during LEOP and commissioning.

b. Task a. above should include the following activities:

1. Support operations in acquiring flight measurements.
2. Support LEOP operations, e.g. performance optimization.
3. Support operations in carrying out in-flight acceptance commissioning tests.
4. Support contingencies workaround during LEOP and commissioning.

EXPECTED OUTPUT:
a. *Consolidated user manual.*
b. *Consolidated ILS plan.*
c. *Input for update of operations documentation (e.g. FOP, GOP).*

5.7.2.6 Support launch campaign (E1)

a. The SE organization shall support production and operations for the execution of the launch campaign plan.
b. Task a. above should include the following activities:
   1. Support payload-launcher integration (e.g. alignment, and loading).
   2. Support the system check-out activities (e.g. system functional test).
   3. Support to properties and characteristics measurement (e.g. loaded spacecraft mass and sensor calibration).
   4. Ensure proper system configuration for launch (e.g. load AOCS parameters related to launch time).
   5. Support preparation for launch campaign decisions (e.g. "on the pad") and contingency recovery decisions.

EXPECTED OUTPUT: *Last minute data.*

5.7.2.7 Analysis and verification of system performance (E1)

a. The SE organization shall establish and verify the performance of the system after the LEOP, in the frame of the commissioning activities in preparation of the flight qualification review (FQR).
b. Task a. above should include the following activities:
   1. Verify the system performance in line with the commissioning plan and the validation plan, against
      (a) system requirements, and
      (b) inputs from AIT activities (e.g. test and reference values from ground AIT tests).
   2. Support the operations function for analysis of the test and measurement results in view of assessing system performance.
   3. Review the results of the analysis and verification of system performance.
   4. Identify the preventive maintenance tasks.
   5. Analyse potential malfunctions and corrective measures.
   6. Support the decision for entry into service of the whole system, i.e. the beginning of the exploitation phase, after completion of commissioning operations.

EXPECTED OUTPUT:
a. *Performance analysis reports.*
b. *Verification reports.*
c. *Consolidated space segment documentation (e.g. user manual).*
d. *Input to ground segment documentation (e.g. FOP, and GOP).*
e. *Input to PA (e.g. NCRs).*

f. Consolidated ILS plan.

5.7.2.8 Flight qualification review (E1)

a. The SE organization shall support the flight qualification review (FQR), to ensure its successful completion and establish the suitability of the system for exploitation.

NOTE 1 For the FQR, see ECSS-M-30, ECSS-M-30-01 and ECSS-E-70. FQR is the name used in ECSS-M-30-01. It is also known as "in-orbit qualification review" (IOQR) in ECSS-E-70, and as "in-space test review" in ECSS-M-30.

NOTE 2 This review depends on the type of procurement:

- for commercial spacecraft this review has the formal character of an acceptance by the customer;
- for scientific missions for which payloads are typically developed by third parties, where no formal contractual acceptance has been agreed, this review marks the beginning of the exploitation phase,

b. Task a. above should include the following activities:

1. Ensure availability of the following SE documentation according to the FQR review plan:
   (a) system technical specification;
   (b) FM data package;
   (c) test specifications;
   (d) verification specifications;
   (e) analysis reports;
   (f) test reports;
   (g) verification reports;
   (h) verification control documents;
   (i) mission description document;
   (j) flight operation procedures;
   (k) user' manual;
   (l) ground segment documentation.
2. Ensure execution of the SE activities for successful completion of the FQR (e.g. provision of clarification, reply to RIDs, and closure actions).
3. Contribute to the updating of the related documentation (e.g. FOP maintenance plan).

EXPECTED OUTPUT:

a. Consolidated space segment documentation (e.g. user manual, flight segment end item data package).

b. Input to ground segment documentation (e.g. FOP, GOP, ground segment end item data package).

c. Input to management for delivery of the flight qualification statement.

d. Input to management for delivery of the acceptance certificate.

5.7.2.9 Support production of recurring products (E2)

a. The SE organization shall support the production of recurrent products, e.g. in a series of spacecraft all the flight models (FMs) after FM1.

b. Task a. above should include the following activities:

1. The activities in 5.6.2.8.b.

2. In case of changes to the requirements design, tailor the full cycle, as defined in previous phases, according to the magnitude of the modifications (e.g. delta qualification), as per task 5.6.2.10.

EXPECTED OUTPUT:
a. *Same as expected output for 5.6.2.8.*
b. *Consolidated space segment documentation (e.g. user manual).*
c. *Input to ground segment documentation (e.g. FOP, and GOP).*
d. *In case of changes, documentation as defined in previous phases tailored adequately according to the magnitude of the modifications, as per task 5.6.2.10.*

5.7.2.10 Acceptance review of recurring products (E2)

a. For acceptance review of recurring products, 5.6.2.16.a. shall apply (for recurrent products).

b. Task a. above should include the activities specified in 5.6.2.16.b.

EXPECTED OUTPUT: *EIDP.*

5.7.2.11 Feedback lessons learnt (E2)

a. The SE organization shall provide feedback to a lessons learnt system for recurrent design and other missions.

b. Task a. above should include the following activities:
1. Extract the lessons learnt from disposal analysis, disposal operations and anomaly reports.
2. Ensure the generation and documentation of lessons learnt.
3. Propose in-flight actions to be performed using residual resources, for the purpose of identifying the real margins of the system in view of future design improvements.

EXPECTED OUTPUT: *Contribution to lessons learnt report.*

5.7.2.12 Support anomaly investigations and recovery (E2)

a. The SE organization shall support the detection of and recovery from anomalies.

b. Task a. above should include the following activities:
1. Analysis of the anomaly on the basis of
   (a) operations status reports,
   (b) operations reviews reports,
   (c) flight data.
2. Identify the reason for the anomaly.
3. Evaluate the impact of the anomaly.
4. Propose solutions to overcome the anomaly (e.g. adapt the operational procedures, change on-board control laws, and flight software redesign).
5. Support implementation of the recovery solution.

EXPECTED OUTPUT:
a. *Input to operations anomaly report.*
b. *Contribute to or produce changes to impacted documents (e.g. user manual, FOP and GOP).*

5.7.2.13 Performance evaluation (E2)

a. The SE organization shall assess the evolution of the performance against the nominal prediction.

b. Task a. above should include the following activities:

1. Support the assessment of flight and ground data.
2. Verify sustained compliance with requirements.
3. Identify anomalies and contingency cases.

NOTE These tasks can be executed in support of the periodic in-orbit operations reviews (IOORs), which have as an objective the assessment of the performance of both space segment and ground segment.

EXPECTED OUTPUT: *In-orbit performance reports.*

5.7.2.14 Consolidate disposal concept and produce disposal plan (E2)

a. The SE organization shall assess the disposal concepts, and contribute to the establishment of the disposal plan and its preparation activities

b. Task a. above should include the following activities:

1. Review the disposal concepts and revisit them taking into account the current situation.
2. Provide input to management for the selection of a disposal concept.
3. Carry out the analyses.
4. Develop products and processes for disposal.
5. Validate process and products for disposal.
6. Support the generation of disposal plan.
7. Support production to ensure a graceful phasing down consistent with the system operational scenario.

EXPECTED OUTPUT:
a. *Consolidated disposal concept (part of DDF).*
b. *Update mission analysis report for disposal phase (part of DJF).*
c. *Input to disposal plan.*

5.7.2.15 Design, develop, implement, verify and control changes (E2)

a. The SE organization shall ensure the application of the SE process to changes to the system or its products.

b. Task a. above should include the following activities:

1. Changes to the mission products (improvements).
2. Development of new products.
3. Improve the process of producing data and delivering it to the end use.

NOTE This process includes requirements, design, implementation and verification.

4. Changes to the system (e.g. to compensate for anomalies).
5. Changes to the recurrent products (improvements, obsolescence).
6. Document the updates to the system.
7. Document the logistics support upgrades.
8. Document the states for all the recurring products.

EXPECTED OUTPUT:
a. *Consolidated flight segment documents (e.g. DDF, DJF, configuration status report and user manual).*
b. *Consolidated ground segment documents (e.g. FOP and GOP).*
c. *Consolidated ILS plan.*

5.7.2.16 End-of-life review (E2)

a. The SE organization shall support the end-of-life review (ELR) to ensure its successful completion.

b. The end-of-life review shall mark the end of the useful period of operations.

c. Tasks a. and b. above should include the following activities:

1. Ensure availability of the following SE documentation according to the ELR review plan:
   (a) system technical specification;
   (b) FM data package;
   (c) test specifications;
   (d) verification specifications;
   (e) analysis reports;
   (f) test reports;
   (g) verification reports;
   (h) verification control documents;
   (i) mission description document;
   (j) flight operation procedures;
   (k) user manual;
   (l) ground segment documentation;
   (m) disposal concept;
   (n) disposal plan.
2. Ensure execution of the SE activities for successful completion of the ELR (e.g. provision of clarification, reply to RIDs, and closure actions).
3. Contribute to the update of the related documentation (e.g. user manual, FOP, and maintenance plan).

EXPECTED OUTPUT:
a. *Consolidated disposal concept (part of DDF).*
b. *Consolidated mission analysis report for disposal phase (part of DJF).*
c. *Input to disposal plan update.*
d. *Update related documentation or contribution to it (e.g. users manual, FOP, and maintenance documentation).*

5.7.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.7.2 are summarized in Table 6, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 6: Phase E

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
1	Kick-off		None									None
2	Flight readiness review (E1)	Cus	Organization note	IC(R)	A	C	C	C	C	C	Cus (Ap), SE	Consolidated documents
		SE	Data package								M	Change requests
		Cus	Review report									waivers
3	Operational readiness review (E1)	Cus	Organization note	IC(R)	A	C	C	C	C	C	Cus (Ap)	Consolidated documents
		SE	Data package								M	Change requests,
		Cus	Review report									waivers
4	Launch readiness review (E1)	Cus	Organization note	IC(R)	C	C	C	C	C	C	M,OPS	Consolidated documents
		SE	Data package								Cus(Ap)	Change requests
		Cus	Review report								M	waivers
5	Support operations for LEO and commissioning (E1)	SE	Space segment user manual	IC(R)		C	C	C		R	Ops, SE	Consolidated users manual
		Ops	Flight operations plan								Ops, SE	Consolidated ILS
		Ops	Operation status report								Ops, SE	Input to operation documents (e.g. GOP, and FOP)
		Ops	Operations verification plan									
6	Support launch campaign (E1)	SE	Data package	IC(R)	A	C	C	C		C	SE	Consolidated data package
		SE, OPS	Operations plan								M	Input to operations plan
		SE	Space segment user manual									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 6: Phase E *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
7	Analysis and verification of system performance (E1)	SE	Mission requirements document	An(R)		C	C	C		C	SE	Performance analysis report
		SE	SRD								SE, Q	Verification report
		SE	System and subsystem specifications (including ground segment)								SE, OPS	Consolidated subsystem documents
		OPS	Operations report[a)]								SE, OPS	Input GS docs
		OPS	Logistic support analysis report[b)]								SE,M	Consolidated ILS plan
		OPS	Flight operations plan								SE,Q	Input to PA (e.g. NCR)
8	Flight Qualification Review (E1)	Cus	Organization note	IC(R)	A	C	C	C		C	Cus (Ap), SE, OPS	Consolidated subsystem documents
		SE	Data package								M	Input GS documents
		Cus	Review report								M	Input to flight qualification statement
											SE, M,(Ag), Cus(Ag)	Input to acceptance certificate
9	Support production of recurring products (E2)		Same as specified in row 8 of Table 5	IC(R)	C	C	C	C	A	C		Same as specified in row 8 of Table 5
10	Acceptance review of recurring products (E2)		Same as specified in row 15 of Table 5	IC(R)	A	C	C	C	C	C		Same as specified in row 15 of Table 5
11	Feedback lessons learnt (E2)	OPS	Operations anomaly report	IC(R)	C	C	C	C	C	C	M,SE	Lessons learnt report
		OPS	Failure reports									

a) In ECSS-E-70 only the operations anomaly report is mentioned.
b) In ECSS-E-70 only the logistic support plan is mentioned.

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

Table 6: Phase E *(continued)*

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
12	Support anomaly investigations recovery (E2)	OPS	FOP	An		C	R	C		R	SE, OPS, Q	Input to operations anomaly report
		OPS	Flight data								SE, OPS, Q	Changes to the documents
13	Performance evaluation (E2)	OPS	Flight data	Vf(R)		C	C	C		C	M, SE Q Cus	In-orbit performance report
14	Consolidate disposal concept and produce disposal Plan (E2)	SE	Disposal concept	Vf	C	C	C	C	C	C	SE	Consolidated disposal concept
		SE	DJF								SE	Consolidated mission analysis report (DJF)
											OPS	Input disposal plan
15	Design, develop, implement, verify and control changes (E2)	SE	Design definition file	IC(R)	C	C	C	C	C	C	SE	Consolidated DDF
		SE	ILS plan								SE, M	Consolidated ILS plan
		SE	CIDL								SE, Q	Configuration status report (for the changed items)
											OPS, SE	Consolidated user manual
											OPS, SE	Ground segment documents
16	End-of-life review (E2)	SE	Disposal concept	IC(R)	A	C	C	C		C	Cus(Ap)	Consolidated disposal concept
		OPS	Disposal plan								SE	Consolidated mission analysis report
											OPS	Input disposal plan update data package

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

5.8 Disposal: Phase F

5.8.1 Objective and process flow: Phase F

a. At the end of the disposal phase the system shall have no impact on the environment or on the operations of other space products.

b. Task a. above should include the following activities:

1. Manoeuvre into graveyard orbit or deep space (e.g. for geostationary or scientific missions).
2. Destructive re-entry (e.g. for LEO missions).
3. Ground disposal (e.g. for retrievable missions).

NOTE The flow of the generic SE tasks in Phase F is described in Figure 22.

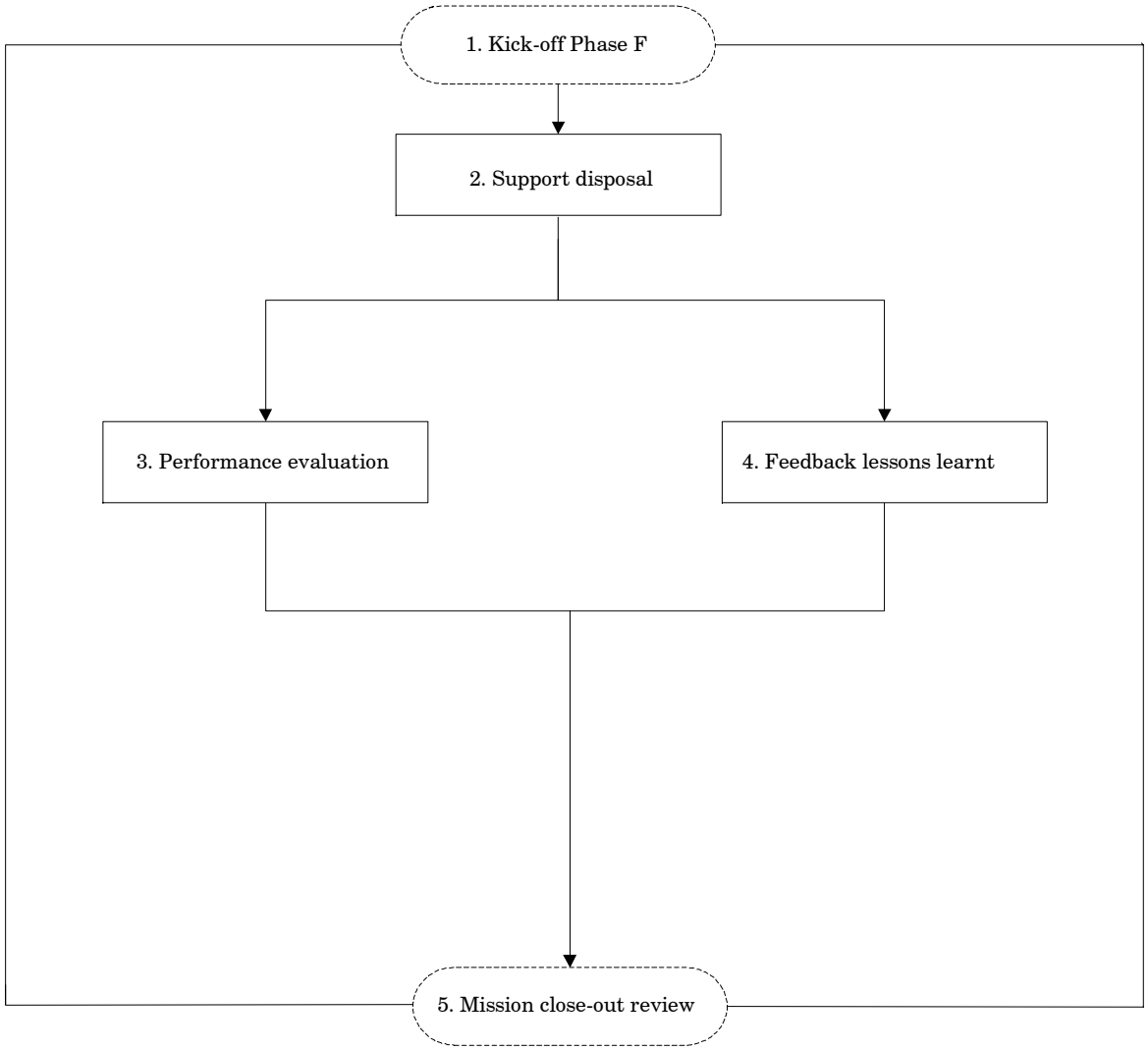

Figure 22: Phase F flow chart

5.8.2 Description of objectives, activities and clarifications on documents

5.8.2.1 Kick-off Phase F

a. The SE organization shall support the kick-off (KO) meeting of Phase F.

b. Task a. above should include the following activity:
highlight assumptions, critical issues and technical dependencies.

EXPECTED OUTPUT: *Agreed technical assumptions.*

5.8.2.2 Support disposal

a. The SE organization shall support the implementation of the disposal phase to ensure that it is feasible, safe, cost effective, and environmentally conscious.

b. Task a. above should include the following activities:

1. Monitor and validate the implementation of the disposal process and related analyses.
2. Support the processing of potential anomalies and workarounds in relation to disposal.
3. Support the processing of contingencies and workarounds in relation to disposal.
4. Support disposal or recycling of ground facilities or of retrieved space segment elements.

EXPECTED OUTPUT:
a. Disposal analysis and validation reports.
b. Consolidated users manual.
c. Consolidated ground segment documents (e.g. flight operations plan, Ground Operations Plan and related procedures).
d. Input to disposal plan (part of flight operation plan).
e. Input to operations anomaly reports.
f. Issue last in-orbit performance reports.

5.8.2.3 Performance evaluation

a. The SE organization shall assess the evolution of the performance against the nominal prediction.

b. Task a. above should include the following activities:

1. Support the assessment of flight and ground data.
2. Verify sustained compliance with requirements.
3. Identify anomalies and contingency cases.

NOTE These tasks can be executed in support of the periodic in-orbit operations reviews (IOORs), which have as an objective the assessment of the performance of both space segment and ground segment.

EXPECTED OUTPUT: *In-orbit performance reports.*

5.8.2.4 Feedback lessons learnt

a. The SE organization shall provide feedback to a lessons learnt system for recurrent design and other missions.

b. Task a. above should include the following activities:

1. Extract the lessons learnt from disposal analysis, disposal operations and anomaly reports.

2. Ensure the generation and documentation of lessons learnt.
3. Propose in-flight actions to be performed using residual resources, for the purpose of identifying the real margins of the system in view of future design improvements.

EXPECTED OUTPUT: *Contribution to lessons learnt reports.*

5.8.2.5 Mission close-out review

a. The SE organization shall provide technical assessment to support the mission close-out review.

NOTE This review is identified in ECSS-E-70 Part 1 to ensure that all mission disposal activities are adequately completed, but it is not mentioned in ECSS-M-30.

b. Task a. above should include the following activities:

1. Ensure availability of the following SE documentation according to the mission close-out review plan:
   (a) system technical specification;
   (b) FM data package;
   (c) test specifications;
   (d) verification specifications;
   (e) analysis reports;
   (f) test reports,
   (g) verification reports;
   (h) verification control documents;
   (i) mission description document;
   (j) flight operation procedures;
   (k) user' manual;
   (l) ground segment documentation;
   (m) disposal concept;
   (n) disposal plan.
2. Provide clarifications, reply to RIDs, closure of actions, and of the other SE tasks for the mission close-out review.

EXPECTED OUTPUT: *Data package documents consolidated, with emphasis on anomalies and lessons learnt aspects.*

5.8.3 Process summary

The SE tasks, the functions, the documentation, specified in 5.8.2 are summarized in Table 7, as well as the actors and their interfaces.

NOTE Conventions used in the table are described in 5.1.3.

Table 7: Phase F

ID	Task	Input		SE function	Other actors						Output	
		From	Document		Cus	M	Q	E	P	Ops	To	Document
1	Kick-off Phase F			(C)	(C)	(Ag)					M	Agreed technical assumptions
2	Support disposal	SE	Disposal plan	IC(R)	(C)		(Q)	(C)			SE	Disposal analysis
		Q	Anomalies reports								SE, OPS	User manual
											SE, OPS	Disposal plan
3	Performance evaluation	Ops	Flight dates	(C)	(C)	(C)	(C)	(C)		(C)		
4	Feedback lessons learnt	SE	Reports	IC (R)	(C)		(C)	(C)		(C)	M	Input to lessons learnt reports
5	Mission close-out review	M	MCR review plan	IC (R)	A	(C)	(C)	(C)	(C)	(C)	M	Consolidated documents
		M	MCR review data package									

(R)	Responsible for doing the activity	M	Management (company or project)	An	Analysis	DC	Design and configuration
(Ag)	Agreement	Q	Product assurance	E	Engineering	V	Verification
(Ap)	Approval	IC	Integrated control	Ops	Operations	Cus	Customer
(C)	Contributing	RE	Requirement engineering	P	Production	SE	System engineering

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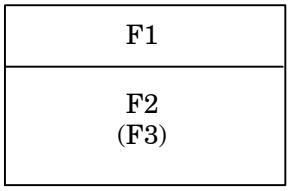
Annex A (informative)

Structure of the ECSS-E-10 discipline

A.1 Overview of ECSS-E-10 discipline

The system engineering branch and the related documents (standards and DRDs) are structured as shown in Figure A-1.

Some existing standards published prior to the definition of this branch structure presently bear an ECSS denomination different from the one defined in this new branch structure. The convention used for the documents presented in the Figure A-1 is as follows:



Where:

- F1 is the name of the ECSS document.

  EXAMPLE Verification.

- F2 is the denomination of the ECSS document adopted by the current structure.

  EXAMPLE ECSS-E-10 Part 2.

- (F3) is the denomination of the ECSS document superseded by the current structure.

  EXAMPLE (ECSS-E-10-02).

  NOTE The list of documents shown in Figure A-1 are those quoted in the text and can differ from the list of the published standards at the time of writing this Standard.

Dashed boxes represent documents that logically belong to the system engineering discipline but actually are attached to documents located to another branch within or outside system engineering.

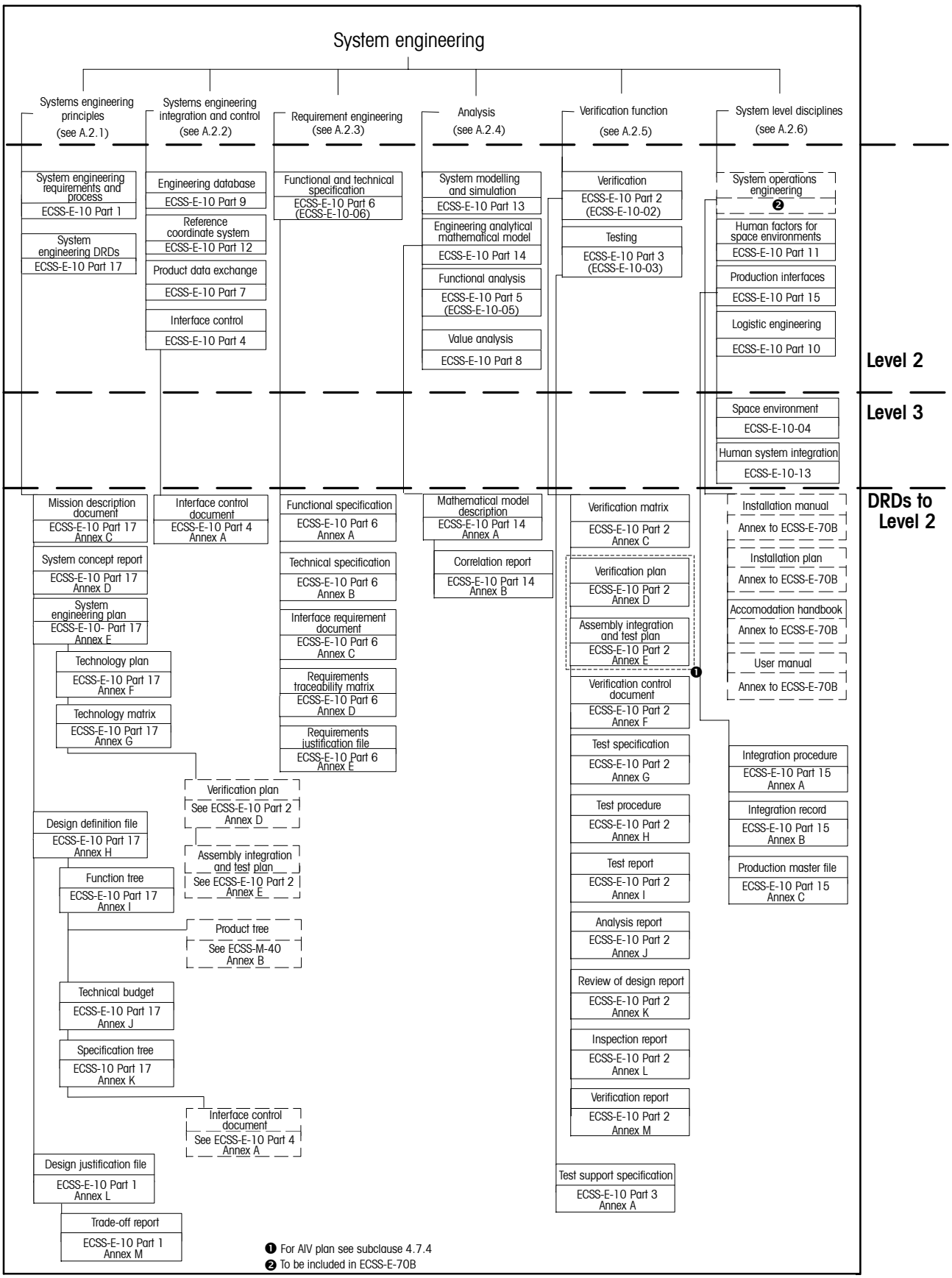


Figure A-1: Structure of the system engineering discipline

A.2 ECSS-E-10 Standards and document requirements definitions

A.2.1 System engineering principles

A.2.1.1 ECSS-E-10 Part 1: Requirements and process (Level 2 standard)

ECSS-E-10 Part 1 is the present standard, and defines the general SE requirements and the SE process.

A.2.1.2 ECSS-E-10 Part 17: System engineering DRDs (Level 2 standard)

ECSS-E-10 Part 17 includes the DRDs to ECSS-E-10 Part 1.

a. **Annex C: Mission description document (DRD)**

The mission description document defines the objectives, operation profile, major system events and capabilities, contingencies and performance standards to be met by one system concept that aims at satisfying a specified mission statement.

b. **Annex D: System concept report (DRD)**

The system concept report initially describes the principal technical characteristics of alternative concepts, relating to performance, interfaces and risks, and later addresses the selected concepts.

c. **Annex E: Systems engineering plan (DRD)**

The system engineering plan (SEP) defines the approach, methods, procedures, resources and organization to co-ordinate and manage all technical activities required to specify, analyse, design and verify a product in conformance with the user's requirements.

1. **Annex F: Technology plan (DRD)**

   The technology plan defines the approach, methods, procedures, verifications, resources and organization to evaluate the ability of a technology to meet the intended requirements.

2. **Annex G: Technology matrix (DRD)**

   The technology matrix presents, for each requirement, the list of technologies that have the potential to meet this requirement.

3. **Verification plan (DRD)**

   See ECSS-E-10 Part 2B Annex D.

4. **Assembly integration and test plan (DRD)**

   See ECSS-E-10 Part 2B Annex E.

d. **Annex H: Design definition file (DRD)**

The design definition file is a generic title referring to all of the documentation which establishes the product characteristics, including specifications, drawings, schematics and mandatory production and verification procedures.

1. **Annex I: Function tree (DRD)**

   The function tree describes the hierarchical decomposition of system capabilities into successive levels of functions and sub-functions.

2. **Product tree (DRD)**

   See ECSS-M-40B Annex B.

3. **Annex J: Technical budget (DRD)**

   The technical budget defines for each key engineering parameter of an item, the nature of the parameter, its measure, allocated value, metrics requirements and current actual or computed value.

4. **Annex K: Specification tree (DRD)**

   The specification tree defines the hierarchical relationship of all functional and technical specifications in a project.

5. **Interface control document (DRD)**

   See ECSS-E-10 Part 4A Annex A.

e. **Annex L: Design justification file (DRD)**

The design justification file is a generic title referring to all documentation, which justifies the evolution of the product from the requirements to the design and demonstrates that the design conforms to the requirements. This can include design notes, analyses, reports and other descriptive material.

1. **Annex M: Trade-off report (DRD)**

   The trade-off report describes the SE point of view on the evaluation of alternative design solutions and the justification of the choice.

A.2.2 SE integration and control

A.2.2.1 ECSS-E-10 Part 9: Engineering database (Level 2 standard)

ECSS-E-10 Part 9 specifies a database containing all the design information for a system and any of its elements.

A.2.2.2 ECSS-E-10 Part 12: Reference coordinate system (Level 2 standard)

ECSS-E-10 Part 12 specifies the standard coordinate systems and reference directions for spacecraft.

NOTE See also ISO 1151-1, ARINC 704 and ARINC 705-5.

A.2.2.3 ECSS-E-10 Part 7: Product data exchange (Level 2 standard)

ECSS-E-10 Part 7 applies to the space product engineering data exchanged between customers, suppliers and partners during the complete life-cycle. It specifies the protocols to be used to exchange the engineering data between heterogeneous PDM-CAD-CAE environment.

A.2.2.4 ECSS-E-10 Part 4: Interface control (Level 2 standard)

ECSS-E-10 Part 4 specifies the allocation of responsibility to document and manage interfaces between system elements controlled by different suppliers.

a. **Annex A: Interface control document (DRD)**

   The interface control document defines the implementation of the interfaces between two or more items.

A.2.3 Requirement engineering

A.2.3.1 ECSS-E-10 Part 6: Functional and technical specification (Level 2 standard)

ECSS-E-10 Part 6 specifies the relationships between the functional specification and the technical specification, and specifies requirements related to the technical requirements, the functional specification and the technical specification

NOTE ECSS-E-10 Part 6 is also published under ISO 21351.

a. **Annex A: Functional specification (DRD)**

   The functional specification is a document that establishes the intended purpose of a product, its associated constraints and the environment, the operational and performances features for each phase of life cycle, and the permissible flexibility.

b. **Annex B: Technical specification (DRD)**

The technical specification is a document that contains of a product, the specified technical requirements and the exact value for the performance. It defines all the necessary and sufficient attributes of a product, with the requirements for verification.

c. **Annex C: Interface requirement document (DRD)**

The interface requirement document defines the requirements for the interfaces between related items.

d. **Annex D: Requirement traceability matrix (DRD)**

The requirement traceability matrix defines the relationships between the requirements of a deliverable product defined in its technical specification and the apportioned requirements of its lower level elements.

e. **Annex E: Requirement justification file (DRD)**

The requirement justification file is a generic title referring to all documentation which records, describes the needs and the associated constrains resulting from the different trade-offs and relevant environment constrains and demonstrates how the requirements of the system technical specification can satisfy the need. This document is established at the upper level (customer, first level customer, see ECSS-M-00).

A.2.4 Analysis

A.2.4.1 ECSS-E-10 Part 13: System modelling and simulation (Level 2 standard)

ECSS-E-10 Part 13 specifies the requirements for specification, design, implementation, validation, documentation and deployment of simulation models and simulators used to support specification, design, verification and operations of space systems.

NOTE By simulation models it is meant here both data models, e.g. geometrical model of a system, and behavioural models, e.g. the algorithms representing the behaviour of a component or environment expressed in a high level programming language.

A.2.4.2 ECSS-E-10 Part 14: Engineering analytical mathematical models (Level 2 standard)

ECSS-E-10 Part 14 specifies the requirements for specification, design, implementation, validation, documentation and deployment of engineering analytical mathematical models used to support e.g. specification, design, verification of the space system regarding individual engineering disciplines (such as thermal, structures, and RF).

a. **Annex A: Mathematical model description (DRD)**

The mathematical model description lists requirements and recommendations for the definition, development, verification and application of mathematical models for one or more attributes of systems and equipment. Annexes define requirements applicable to specific classes of models (e.g. thermal, structural, and finite elements). See also ESA PSS-03-209

b. **Annex B: Correlation report (DRD)**

The correlation report lists requirements and recommendations for the correlation between test results and predictions of the engineering analytical models of the space system regarding individual engineering disciplines (such as thermal, structures, and RF).

A.2.4.3 ECSS-E-10 Part 5: Functional analysis (Level 2 standard)

ECSS-E-10 Part 5 specifies the inputs, performance, interactions and outputs of system functions and elements, including a functional block diagram.

A.2.4.4 ECSS-E-10 Part 8: Value analysis 0 (Level 2 standard)

ECSS-E-10 Part 8 specifies an organized and creative approach using functional and economic design process which aims at increasing the value of a value analysis subject. When applied to a new product, the term value engineering can be used instead.

A.2.5 Verification function

A.2.5.1 ECSS-E-10 Part 2: Verification (Level 2 standard)

ECSS-E-10 Part 2 specifies the general requirements for verification and for the selection and application of different verification methods.

a. **Annex C: Verification matrix (DRD)**

   The verification matrix defines for each requirement the corresponding verification method at the applicable verification level in the relevant verification stage.

b. **Annex D: Verification plan (DRD)**

   The verification plan describes the approach, methods, procedures, organization and resources to verify that a product conforms to the intended objectives

c. **Annex E: Assembly integration and test plan (DRD)**

   The assembly, integration and test (AIT) plan describes the approach, methods, procedures, organization, resources and schedule to assemble, integrate and test a product in line with its verification plan. This can include the installation of the product. It is established under responsibility of production with input from and the agreement of system engineering.

d. **Annex F: Verification control document (DRD)**

   The verification control document is a summary list of the requirements and the corresponding verification documentation and status for each, including references to the documentation of the verification procedures and results.

e. **Annex G: Test specification (DRD)**

   The test specification details the test requirements for a specific test activity.

f. **Annex H: Test procedure (DRD)**

   The test procedure details the logic of the tasks to be followed to perform a test.

g. **Annex I: Test report (DRD)**

   The test report is a document which records the test data, an analysis of that data and the verification status resulting from verification activities performed on an item.

h. **Annex J: Analysis report (DRD)**

   The analysis report is a document which records the verification data, an analysis of that data and the verification status resulting from verification activities performed on an item.

i. **Annex K: Review of design report (DRD)**

   The review of design report is a document which records the review of design data, an analysis of that data and the verification status resulting from verification activities performed on an item.

j. **Annex L: Inspection report (DRD)**

The inspection report is a document which records inspection data, an analysis of that data and the verification status resulting from verification activities performed on an item.

k. **Annex M: Verification report (DRD)**

The verification report is a document which records verification data, an analysis of that data and the verification status resulting from verification activities performed on an item.

A.2.5.2 ECSS-E-10 Part 3: Testing (Level 2 standards)

ECSS-E-10 Part 3 specifies the general requirements for the application and conduct of testing of systems and equipments. Annexes define standard test requirements for particular products and applications, e.g. thermal-vacuum, environmental and lifetime.

NOTE See also MIL STD 1540.

Annex A: Test support specification

The test support specification describes the general methodological test requirements applicable to a specific project.

It defines for the different tests the general constraints, conditions and sequences.

A.2.6 System level disciplines

A.2.6.1 System operations engineering (Level 2 standard)

System operations engineering relates to operations of the space segment covering, amongst others, modes, autonomy, FDIR operability, and interfaces to mission operations. It takes into account the results of FMECA as a tool to help designing for operations. It does not address engineering of the ground system, nor execution of mission operations. Both, system operations engineering and engineering of the ground system and mission operations are included in ECSS-E-70B.

a. **Annex to ECSS-E-70B: Installation manual (DRD)**

The installation manual is a document containing all of the procedures and information to unpack, install, connect and check-out one or more pieces of equipment, see ECSS-E-70B.

b. **Annex to ECSS-E-70B: Installation plan (DRD)**

The installation plan describes the approach, methods, procedures, resources and organization to install, commission and check the operation of equipment in its fixed operational environment, see ECSS-E-70B.

c. **Annex to ECSS-E-70B: Accommodation handbook (DRD)**

The accommodation handbook describes the location, mounting, all interfaces and clearances of an item in a platform or vehicle, see ECSS-E-70B.

d. **Annex to ECSS-E-70B: User manual (DRD)**

The user manual defines how to operate a product or system, including system configuration, set-up, limitations and command and telemetry information, see ECSS-E-70B.

A.2.6.2 ECSS-E-10 Part 11: Human factors for space environment (Level 2 standard)

ECSS-E-10 Part 11 specifies requirements regarding human measures and performance for human activities and environments associated with space systems.

NOTE See also ESA PSS-03-70 and MIL-STD-1472D.

A.2.6.3 ECSS-E-10 Part 15: Production Interfaces (Level 2 standard)

ECSS-E-10 Part 15 specifies the approach, methods, procedures, organization and resources to be implemented to ensure proper technical interfaces between system engineering and production.

a. **Annex A: Integration procedure (DRD)**

   The integration procedure specifies the approach, methods, interacting activities, organization and resources to be implemented for the assembly and integration of equipment, subsystem and system elements. It is established under responsibility of production with the input of system engineering.

b. **Annex B: Integration record (DRD)**

   The integration record describes the result of an integration activity, including product elements, tools, methods, facilities and personnel used, an analysis of results obtained, deviations from expected behaviour and externally controlled documents.

c. **Annex C: Production master file (DRD)**

   The production master file is a set of documents containing all data for manufacturing and verification purposes, including

   - part lists and process sheets,
   - specific and non-specific tool lists,
   - ordering documents,
   - verification procedures and records.

A.2.6.4 ECSS-E-10 Part 10: Logistics engineering (Level 2 standard)

ECSS-E-10 Part 10 specifies, for ground and in-orbit logistics and maintenance support aspects, the logistics engineering technical activities and the logistics engineering standards, in terms of approaches, methods and analyses to be performed for ensuring that development of space systems (manned and unmanned) properly takes into account and integrates the supportability and support aspects for the whole life cycle.

A.2.6.5 ECSS-E-10-04: Space environment (Level 3 standard)

ECSS-E-10-04 describes the natural environment for all space regimes and general models and rules for determining the local induced environment.

A.2.6.6 ECSS-E-10-13: Human system integration (Level 3 standard)

ECSS-E-10-13 defines provisions for implementation of design selections relating to humans for any item with associated human interface, including computer based system and equipment.

Annex B (informative)

Project reviews and system engineering documentation

Documentation relevant to the System Engineering responsibilities to be produced for the different Project Review, is specified in the text of the related phase, as in Table B-1.

Table B-1: Project reviews and system engineering documentation

For	Abbreviation	See
Mission definition review	MDR	Phase 0
Preliminary requirement review	PRR	Phase A
Preliminary design review	PDR	Phase B
System requirements review	SRR	Phase B
Critical design review	CDR	Phase C
System qualification review	SQR	Phase D
System acceptance review	SAR	Phase D
Flight readiness review	FRR	Phase E
Operational readiness review	ORR	Phase E
Launch readiness review	LRR	Phase E
Flight qualification review	FQR	Phase E
End-of-life review	EOLR	Phase E
Mission closed-out review	MCR	Phase F

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Annex C (informative)

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ECSS-M-10	Space project management – Project breakdown structures
ECSS-M-20	Space project management – Project organization
ECSS-M-30	Space project management — Project phasing and planning
ECSS-M-30-01	Space project management – Organization and conduct of reviews
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ECSS-M-50	Space project management – Information and documentation management
ECSS-M-60	Space project management – Cost and schedule management
ECSS-M-70	Space Project Management – Integrated logistic support
ECSS-E-00	Space engineering — Policy and principles
ECSS-E-10 Part 2B[1)]	Space engineering — Verification
ECSS-E-10 Part 4A[1)]	Space engineering – Interfaces control
ECSS-E-10 Part 5	Space engineering – Functional analysis
ECSS-E-10 Part 6A[1)]	Space engineering — Functional and technical specifications
ECSS-E-10 Part 7[1)]	Space engineering — Product data exchange
ECSS-E-10 Part 8[1)]	Space engineering – Value analysis
ECSS-E-10 Part 9[1)]	Space engineering – Engineering database
ECSS-E-10 Part 10[1)]	Space engineering – Logistics engineering

1) To be published.

ECSS-E-10 Part 11[1)]	Space engineering – Human factors for space environments
ECSS-E-10 Part 12[1)]	Space engineering — Reference coordinate systems
ECSS-E-10 Part 13[1)]	Space engineering – System modelling and simulation
ECSS-E-10 Part 14	Space engineering – Engineering analytical mathematical model
ECSS-E-10 Part 15A[1)]	Space engineering — Production interfaces
ECSS-E-10 Part 17A[1)]	Space engineering — System engineering DRDs
ECSS-E-10-03	Space engineering – Testing
ECSS-E-10-04	Space engineering – Space environment
ECSS-E-20	Space engineering – Electrics and electronics
ECSS-E-70B[1)]	Space engineering – Ground systems and operations
ECSS-Q-20	Space product assurance – Quality assurance
ECSS-Q-20-09	Space product assurance — Nonconformance control system
ECSS-Q-30	Space product assurance – Dependability
ECSS-Q-40B	Space product assurance – Safety
ECSS-Q-60	Space product assurance – EEE components
ECSS-Q-70	Space product assurance - Materials, mechanical parts and processes
ECSS-Q-80	Space product assurance – Software
EN 1325-1:1996	Value Management, Value Analysis, Functional Analysis vocabulary - Part 1: Value Analysis and Functional Analysis
ISO/DIS 21351:2002	Space systems – Functional and technical specifications
ISO 1151-1:1988	Flight dynamics – Concepts, quantities and symbols – Part 1: Aircraft motion relative to the air
ISO 9000:2000	Quality management systems - Fundamentals and vocabulary
ARINC 704A	Inertial reference system
ARINC 705-5	Attitude and heading reference system
MIL-STD-1472F	Human engineering design criteria
MIL-STD-1540E	Test requirement for launch, upper-stage, and Space vehicles
IEEE P1220-1994	Application and management of the system engineering process

ESA PSS-03-70: July 1994 Human factors

ESA PSS-03-209: January 1995 ESACRACK user's manual

ECSS Document Improvement Proposal

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ECSS-E-10 Part 1B	18 November 2004	System engineering — Part 1: Requirements and process

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

5. Reason for recommendation

6. Originator of recommendation

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Note: The originator of the submission should complete items 4, 5, 6 and 7.

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