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Aerospace series — Programme Management — Guide for the management of Systems Engineering

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Série aérospatiale - Management de Programme - Guide pour le management de l'ingénierie Système

Luft- und Raumfahrt - Programm-Management - Leitfaden für das Management von Systemtechnik

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European foreword

This document (EN 9277:2015) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2016, and conflicting national standards shall be withdrawn at the latest by March 2016.

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Introduction

This document aims to address the current challenges of the programmes that are:

— the multi projects approach,

— the multi-disciplinary approach,

— new methods of acquisition,

— the increasing complexity of systems to be acquired,

— the evolving aspects of the system and its incremental development,

— the complexity of the management of projects in terms of organization,

— the evolution of the industrial sectors.

In this document the system considered comprises a target system and elements (products, processes, etc.) needed for developing, producing and using it, in other words a range of end products and products supporting the lifecycle of the target system.

The case where the system is only an element of the service provided (no system is acquired, service only) is not adressed in this document.

Systems Engineering (SE) cover a set of activities which, based on a perceived operational need and via an organized approach, aims to:

— describe this need in technical terms,

— gradually transform it into a system solution,

— at each stage, demonstrate that this system is compliant with the need.

Systems Engineering:

— considers the system as a whole and in all situations of its lifecycle,

— provides a framework for combining various technical disciplines (electronics, data processing, mechanics, ergonomics, etc.) and some enterprise functions (design, production, logistics, tests, etc.) without necessarily intervening in these disciplines and functions,

— aims for the overall optimization of the solution in a field of constraints (costs, schedule, performance, strategy, etc.) established by the Programme management,

— guarantees consistency between all components of the solution (functional and physical interfaces).

In this document, the organisational dimension is essential to reach the overall objectives. The complexity of the system and the complexity of the organisation are correlate (the more complex the system is, the more control of the organisation is necessary).

Its position with respect to other normative documents handling Systems Engineering (ISO/IEC 15288, EIA 632,IEEE 1220, EN 9200) is represented in Annex A. This document falls within the scope of EN 9200 and ISO/IEC 15288, focusing on aspects linked to the management of the technical activities of SE with a higher level of detail. It relies partly on the SE process described in ISO/IEC

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15288:2008 and if necessary with addition from EIA 632, adding the project phasing and scheduling aspect. It overlaps little with IEEE 1220 as such, which concentrates primarily on SE technical activities.

1 Scope

Based on the following considerations:

— reminder of Systems Engineering and its scope of application,

— positioning of SE management in Programme Management and in relation to Systems Engineering technical activities,

— identification of interfaces between SE management and the other disciplines linked to Programme Management,

the purpose of this standard is:

— to help the acquirer and the Organization to establish management requirements for SE activities,

— to help the supplier to construct the elements of the management plan (explain how to reply in particular to the management requirements).

This standard applies to the various levels of the product tree for the products that can be considered as systems:

— in the general case of an supplier which, with the help of one or more suppliers, develops a system on behalf of an acquirer,

— in the case of an integrated team (sharing of SE roles, responsibilities and risks).

NOTE ISO/IEC/IEEE 24765:2010 integrated team should include organisation discipline and functions which have a stake in the success of the work products.

This standard constitutes a guide illustrating the requirements and possible responses for SE management. It can be used as a check-list which should be adapted or completed according to the specific context of each project.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 9200, *General recommendation for the project management specification*

EN 12973, *Value management*

EN ISO 9000:2005, *Quality management systems — Fundamentals and vocabulary (ISO 9000)*

ISO 9220, *Metallic coatings — Measurement of coating thickness — Scanning electron microscope method*

EN ISO 9241-210:2011, *Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems (ISO 9241)*

ISO/IEC 15288:2008, *Systems and software engineering — Systems life cycle processes*

ISO/IEC/IEEE 24765:2010, *Systems and software engineering — Vocabulary*

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EIA 632:2003, *Processes for Engineering a System* 1)

IEEE 1220:2005, *Standard for Application and Management of the Systems Engineering Process* 2)

3 Terms and definitions

The following referenced documents are essential for the application of this document. For dated references, only the written issue applies.

For the purposes of this document, the following terms and definitions apply.

ISO/IEC/IEEE 24765:2010 Systems and software engineering vocabulary should be used for the definition. In addition, the following standards should be used for definition as ordered:

— ISO/IEC 15288:2008, *Systems and software engineering — Systems life cycle processes*

— EN ISO 9241-210:2011, *Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems*

— EIA 632:2003, *Processes for Engineering a System*

— IEEE 1220:2005, *Standard for Application and Management of the Systems Engineering Process*

— EN ISO 9000:2005, *Quality management systems — Fundamentals and vocabulary*

3.1
complexity
characteristic of a process linked to the number and diversity of participants, components and technologies, involved in the design and production of products and the supporting logistics

3.2
iterativity
characteristic of a process which is repeated several times in full or in part, with a search for convergence towards a product meeting the expressed need

3.3
recursivity
owing to the system breakdown into sub-systems, repetition of the SE process at various breakdown levels with strong interaction between the levels

3.4
system
set of complex hardware, software, personnel and operational processes, organized so as to satisfy the needs and fulfil the expected services, in a given environment

3.5
systems engineering
interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations, and constraints into a solution and to support that solution throughout its life

Note 1 to entry: Includes the definition of technical performance measures; the integration of engineering specialties toward the establishment of architecture; and the definition of supporting lifecycle processes that balance cost, performance, and schedule objectives.

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1) EIA National (US) Electronic Industries Association http://www.eia.org/

2) IEEE International Institute of Electrical and Electronical Engineers http://www.ieee.org/

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3.6
scalability
the ability to change the component configuration of a system to fit desired application context

Note 1 to entry: Component configuration changes may be obtained by deployment of items or by setting configuration parameters of each item.

3.7
upgradability
potential ability of a system, subsystem or component to respond to changes in operational requirements and anticipated or foreseeable technical changes without affecting the basis of its structure

Source: ISO 9220.

4 Symbols and abbreviations

For the purpose of this document, the abbreviations used are clarified below:

— CAD : Computer Assisted Design

— FS : Functional Specifications

— ILS : Integrated Logistics Support

— MP : Management Plan

— MS : Management Specification

— (N)TS : (Need) Technical Specification

— PDCA : Plan/Do/Check/Act

— PTS : Product Technical Specification

— SE : Systems Engineering

— TS : Technical Specification

5 Positioning of Systems Engineering and SE management within a project

5.1 The need for Systems Engineering Management

Within the business activities, two different and complementary visions co exist. SE vision highlights the following main objectives:

a) The management of SE activities giving assurance that all SE activities are identified, planed, monitored and controlled:

— before launch of the project through the identification of the technical activities to perform during the project to satisfy needs of the system development and project constraints (costs, schedule, performance),

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— during the project through the identification of the engineering tasks, the relevant resources including human resources, the appointment of the main responsibles, the reporting needed to monitor and control the progress of the engineering,

— along the project maintain the compliance of the system design and definition with the requirements.

b) Contribution of the Systems Engineering to the Programme:

— converting a set of needs into a system meeting the set of needs, through a systematic approach contributing towards an integrated design of the product and associated manufacturing, testing and support processes,

— from a technical point of view, managing and optimizing the system performance in accordance with the Programme objectives and constraints,

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— enable to deploy a gradual demonstration that this system meets the set of needs,

— identifying the system technical risks and conducting risk mitigation actions, and contributing to the overall risk management process.

A strong coordination and integration is essential, justifying the creation of formalized specific SE management, for example through an SE specification and MP.

Indeed, some main characteristics differentiate the SE with respect to conventional engineering activities and justify the need for specific SE management:

— imprecise requirements, which are refined during development, supplemented by assumptions;

— complexity of the environment, interacting closely with the system (Man Machine Interface, field of operation, etc.);

— complexity linked to the number and diversity of stakeholders, the number of different technologies, the products themselves and the supporting logistics (system dedicated to multi acquirers on multi markets);

— iterativity; recursivity of project processes;

— scalability of the system;

— upgradability of the systems, sub-systems and components.

Systems Engineering involves both the Acquirer and the Supplier(s) of the Organization and comprises the various technical processes which iteratively and exhaustively contribute to ensuring that the solution meets the need throughout the lifecycle of the system.

See Figure 1 — Systems Engineering positioning in relation to Programme Management.

SE management is therefore not restricted to management of the Organization's SE technical activities, but must also provide the link with the higher and lower level SE activities (Organization's acquirers and suppliers).

In this context, cooperative Acquirer/Organization/Supplier working methods will be encouraged in order to improve data exchanges, partner reactivity and convergence towards common requirements and solutions (for example: networking, shared data environment, etc.).

The large number of stakeholders (owing to the numerous disciplines involved and the Acquirer/Organization/Supplier tree) similarly requires specific SE management to ensure the consistency of the work done, the consistency of the data and of technical data flow.

Consequently, SE management requires the use of specific methods, tools and skills.

5.2 Relation between SE management and Programme Management

Given the need for Systems Engineering Management, the overall SE process can be split into 2 types of activities:

— SE management activities which are included in Programme Management and which comprise planning, management and control of SE technical activities,

— the technical activities themselves, linked to the technical processes (Acquirer needs analysis, design, verification, validation, etc.) applied to the system.

See Figure 1 — Systems Engineering positioning in relation to Programme Management.

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The main role of SE management within Programme Management is to ensure system performance in conformity with the expressed need and to control the technical risks involved in the development. Besides, SE management contribute to the Programme Management for all technical aspects of the system through the whole lifecycle. SE management therefore reinforces the technical viewpoint within the Programme Management.

The cost and schedule parameters, which are the responsibility of Programme Management are taken into account in SE management as input constraints in the search for optimum performance: SE management must measure all the resulting consequences in terms of technical choice and associated risks for the project and help Programme Management to define the performance/cost/schedule trade-off in cooperation with all the stakeholders.

5.3 Positioning of SE in relation to Programme Management

For a given Organization (level N), Figure 1 presents the positioning of Systems Engineering in relation to Programme Management within a generic Acquirer Supplier relationship, as well as the central positioning of SE management between Programme Management and technical activities.

This figure applies to any organization, from the end user up to the furthest downstream suppliers. In this figure, the notion of acquirer is to be taken in the broadest sense. It includes all the stakeholders outside the Organization expressing needs to it (contracting organizations, certification Authorities, end-user, etc.).

All the SE, technical and management activities together, are organized according to a reference process recalled in Clause 6 and described in Annex D. The relations between the SE technical and management activities are defined in Clause 7.

SE management uses the elements of the management plan related to SE in reply to all the management requirements specific to SE expressed on the one hand in the Acquirer's management specification and on the other hand internally by the Organization (Clause 8).

SE management also interfaces with all the other components of Programme Management such as Integrated Logistics Support, risks and RAMS management. These interfaces are explained in Clause 9.

In the Figure 1 — Systems Engineering positioning in relation to Programme Management, the solid line circles inside the Acquirer, Organization and Supplier entities represent the activities carried out by these entities (the what) without anticipating the organization put in place to carry them out (the who) which can fluctuate from one Organization to another and one project to another Figure 1 — Systems Engineering positioning in relation to Programme Management.

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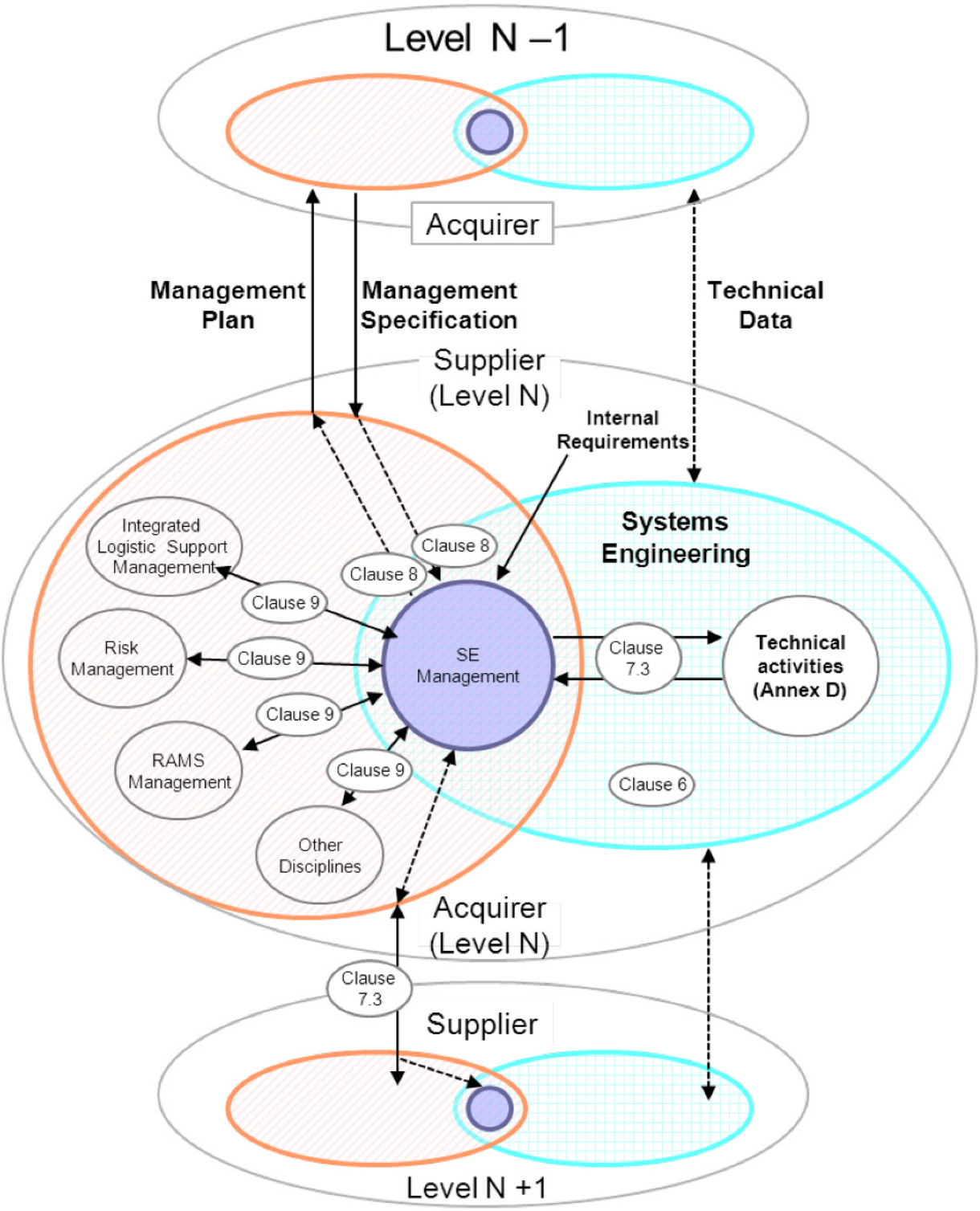

Figure 1 — Systems Engineering positioning in relation to Programme Management

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6 Systems Engineering process

6.1 Reference process

The basic SE process is described in EIA 632 through static relations (no phase sequencing) between activities, without specifying the Actors in this process. The approach of this standard is to supplement this view by handling the time aspects of the SE process within a project phasing and scheduling approach with responsibilities sharing in the Acquirer Supplier relationship, as envisioned by EN 9200.

Thus, it was proved necessary to combine these two visions in order to obtain a reference process for the rest of the document.

The description of the SE process activities is detailed in Annex D. Regular reference to this annex is strongly recommended for a clear understanding of the management requirements in Clause 8.

6.2 Technical activities

The SE process comprises the following technical activities:

- expression of the Acquirer's need;
- system design incorporating:
  - analysis by the Organization of this need and the system requirements definition,
  - definition of the system solution: structuring, requirements allocation and components specification.
- modelling/simulation (performance, etc.);
- technical assessment comprising:
  - requirements validation,
  - system analysis,
  - system verification,
  - system validation.

The content, players and inputs/outputs of these activities are described in Annex D.

NOTE Due to its growing role in the development of complex systems (for example mock-ups and virtual products), modelling/simulation is here considered to be an activity in its own right, going beyond the simple framework of systems analysis.

The SE process is also involved in the following technical activities:

- acquisition of components from the Suppliers of the Organization (or in-house),
- integration of these components into the system,
- development of the supporting logistics,
- transition to use placing of the final system at to the Acquirer's use (installation and commissioning in the Acquirer's environment).

The SE activities are carried out iteratively for each level of the product-tree which can be considered as a system, refining the requirements and the solutions at each iteration. Moreover, these activities are repeated recursively from level to level of the product-tree.

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These activities comprise the flow down of the needs, the search for and consolidation of solutions. The chosen solutions are gradually detailed and then implemented (the implementation activities are not part of SE).

All these activities contribute to controlling the performance of the system, in other words, obtaining, optimizing, checking and validating this performance.

6.3 Interactions between technical activities

Figure 2 represents the interactions, flows and looping (non-chronological) between the technical activities in the SE process. The activities are positioned in it according to the field of responsibility of each player (Acquirer, Organization, Supplier). The scale of shading differentiates the SE activities from those in which the SE process is simply involved. The "supporting logistics development" activity is not represented because showing its interactions with the other activities would degrade the overall legibility without really adding any significant value.

The direct process activities and flows, ranging from expression of need to transition to use, are represented differently (bold simple arrows) from the loop flows used to check that each step has been achieved correctly and iterate if necessary (simple arrows). The specific interactions between system analysis and the other activities are represented in a particular way (dotted two-way arrows).

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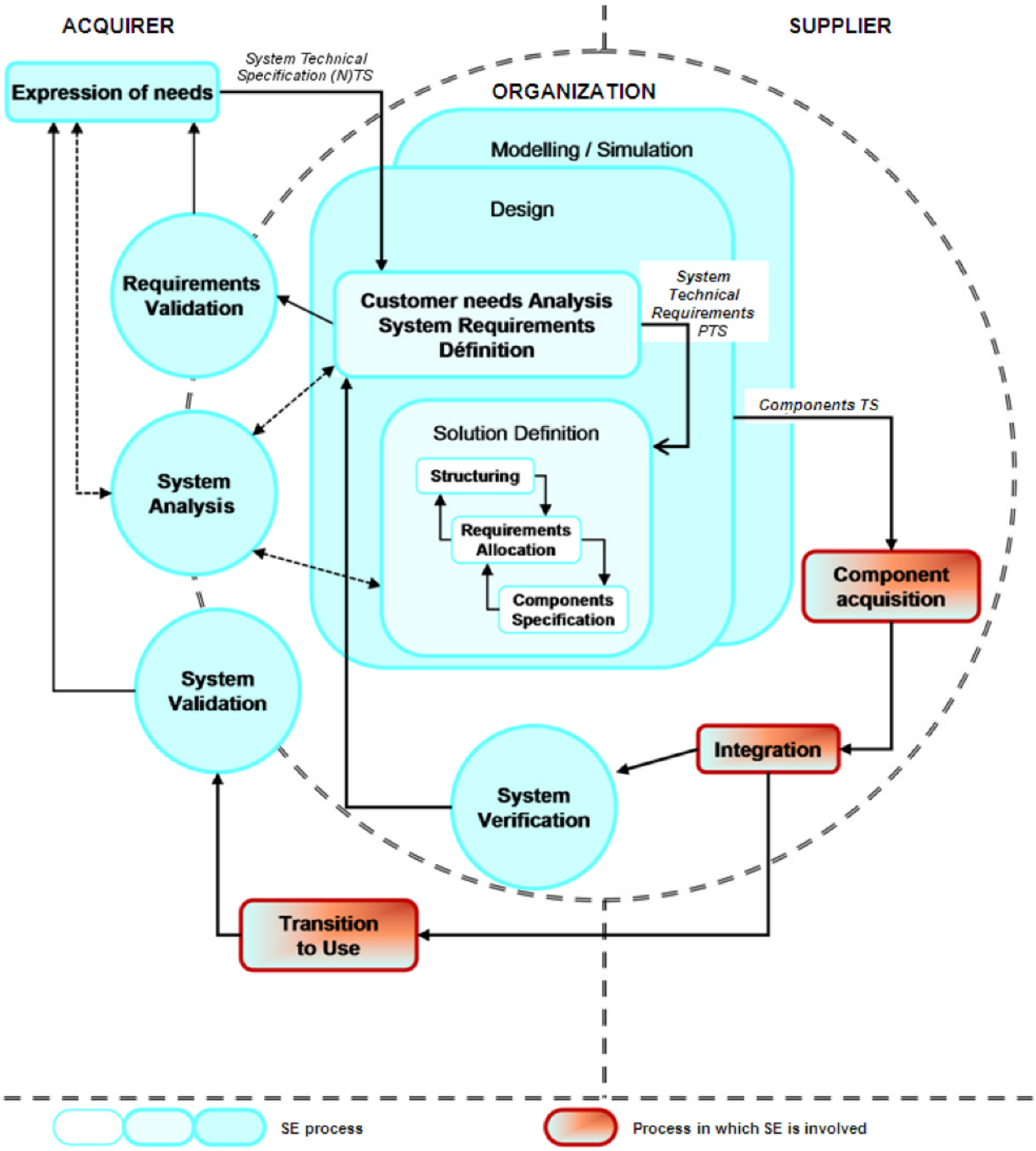

Figure 2 — Interactions between the SE process technical activities

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6.4 Activities specific to Systems Engineering management

This standard focuses on the management activities designed to control the specific aspects of SE described in 5.1, without dealing with the more conventional aspects linked to Programme Management (contract, breakdown of tasks, planning, etc.). See Table 1.

Table 1

Objective criteria	Activities
To guarantee the compliance of system design and definition with the requirements	Ensure the consistency and exhaustiveness of the requirement allocations during the breakdown into sub-systems. Ensure the consistency and exhaustiveness of the proposed sub-system solutions when reconstituting the system. Ensure the compatibility of the functional and physical interfaces both within the system and with the world outside the system. Specify and analyse the tests and provings concerning the system or its components.
To ensure system performance convergence	Iteratively seek consistency between the performance of the system and the performance of the sub-systems. Allocate or re-allocate performance values, taking account of the technical risks and design margins, by implementing the following techniques: — analysis of robustness, sensitiveness, reliability, limit tests; — use of models and simulation tools. Take advantage of the new properties of the system observed during development (notion of emerging properties). NOTE Given the characteristics of a system, the system optimum is rarely the sum of the optima of its sub-systems. Optimization is therefore carried out overall: — on the complete system rather than separately for each component of the system, — on a given component, between several performance parameters.
To ensure control of the SE process	Manage and coordinate the SE technical activities as defined in section 6.2. Manage the many independent technical data originating from all the technical disciplines involved in the project: — document, validate and regularly distribute technical data concerning the system (technical decisions, system design data, etc.); — implement processes and tools to ensure data traceability and consistency (in addition to traceability at document level); — organize data flows between the system components and ensure exchange compatibility (formats and synchronization); — manage changes and harmonize configuration management rules for the various areas of expertise (system and sub-systems configuration, models, CAD tools, etc.);
To reinforce the technical viewpoint of Programme Management	Ensure that the technical risks are identified and analysed and that risk mitigation actions are defined; Ensure that criteria have been established and indicators are in place to assess whether the engineering efforts and the system performed will be able to meet the requirements.

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