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Space systems — Programme management — Requirements management

Systèmes spatiaux - Management de programme - Programme management - Management des Exigences

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

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Introduction

There is consensus that successful aerospace programmes/projects depend on meeting the needs and requirements of the stakeholders/customers. When the requirements are for a complex system or for a system that may take many years to be developed, a formal Requirements Management (RM) process is mandatory and justified.

Requirements Management concerns the collection, analysis, and validation of requirements with all the communications and negotiations inherent in working with people.

This International Standard will help to clarify and enhance current practices to improve Programme Management. It is intended to be used by space programmes when establishing, performing, or evaluating Requirements Management processes in the space sector.

This International Standard describes Requirements Management functions and principles and defines a common Requirements Management terminology for use with any product line.

Requirements Management is an integral element of any programme, but, in space, it is particularly important due to

— specific environmental conditions in space,

— a need for a high level of performance,

— a limited number of models,

— limited access to the product during operations,

— quasi-impossibility of repairing in the case of failure during flight,

— often high complexity of the organization, and

— associated high costs.

The deployment of this standardized common set of Requirements Management is intended to encourage and facilitate international space cooperation.

Annex A of this International Standard gives the general template for a Requirements Management plan.

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Space systems — Programme management — Requirements management

1 Scope

This International Standard presents the requirements for Requirements Management (RM) for space projects.

This International Standard addresses the space programme/project management requirements, applicable through a top-down approach in a contractual relationship between customers and suppliers.

The objective of this International Standard is to state and establish a common reference framework for all the customers and suppliers in the space sector to deploy Requirements Management for all space products and projects.

This International Standard on Requirements Management includes

— a definition of the Requirements Management scope for the space sector,

— the standard processes for Requirements Management within the product lifecycle management, and

— a set of rules for Requirements Management activities to be implemented by the actors (customers and suppliers), including rules derived from best practices.

The primary target audience for this International Standard includes

— the Requirements Management/Systems Engineering process owners of the customers and suppliers,

— the Programme/Project Managers managing the space programmes, and

— the Chief Engineers and the Quality Managers.

The term programme is understood as a group of several projects. Both "programme" and "project" may be used in the same context throughout this International Standard.

ISO 21351 defines the requirements for the format and the content of the functional and technical specifications.

In addition, it allows customer/supplier flexibility in its implementation and tailoring.

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2 Normative references

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

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

ISO 10795, *Space systems — Programme management and quality — Vocabulary*

ISO 14300-1, *Space systems — Programme management — Part 1: Structuring of a project*

ISO 21351, *Space systems — Functional and technical specification*

ISO/IEC/IEEE 29148 — *Systems and software engineering — Life cycle processes — Requirements engineering*

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3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 9000:2005 and ISO 10795 and the following apply.

3.1
design verification
evaluation of the implementation of the design (architecture, components) against the requirements to determine that they can be met

Note 1 to entry: This is compliant with ISO 9001 Verification.

3.2
product lifecycle
description of all stages of the product throughout its life starting from the expression of its need until the disposal, whatever the form is

3.3
product verification
evaluation of the implementation of the product against the requirements to determine that they have been met

Note 1 to entry: This is compliant with ISO 9001 Verification.

3.4
qualification
act or conduct of the **supplier** to provide evidences to prove that the design and manufacturing (including manufacturing process) of hardware/software is adequate to fulfil all **requirements** under required environment conditions

Note 1 to entry: This may be implemented by analysis, test, inspection, or demonstration of a set of tasks that provide proofs, while basing on theoretical and experimental justifications that the defined product satisfies the specified need and can be produced.

Note 2 to entry: The qualification decision is the act by which the customer, at the origin of the technical specification, attests on the basis of theoretical and experimental justifications that the defined product, identified by the design data file, meets all the requirements of the technical specification and can be produced.

3.5
requirement
formalized statement identifying a capability, a functionality, a physical characteristic, or a quality that must be met or possessed by a system or system component to satisfy a contract, a standard, a specification, or other formally imposed documents

Note 1 to entry: A requirement may be developed at any point in the product lifecycle by any number of stakeholders.

Note 2 to entry: A requirement is a need or expectation that is stated, generally implied, or obligatory.

[SOURCE: ISO 10795]

3.6
requirements baseline
set of requirements that has been formally reviewed and agreed upon, that thereafter serves as the basis for further development, and that can be changed only through formal change control procedures

3.7
Requirements Management
RM
discipline that covers all the tasks that shall be performed to manage requirements, such as gathering, developing, organizing, tracing, analysing, reviewing, allocating, changing, and validating requirement objects, as well as managing documents and databases that contain them with the purpose of defining and delivering the right product or service

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3.8
Requirements Management plan
RM plan
management plan which describes all the activities related to Requirements Management for a specific project or programme that includes the requirement cascading activity and the Requirements Management interaction with Configuration Management and Functional Analysis

Note 1 to entry: This plan describes the activities that need to be performed to support the verification and validation activities in order that the design and product can be verified against requirements.

3.9
requirement validation
set of activities to ensure that requirements are correct and complete so that the product meets upper-level requirements and user needs

3.10
stakeholders
customers and/or users

3.11
Systems Engineering
interdisciplinary approach and means to enable the realization of successful systems, starting with the definition of customer needs, the identification of product functionality, and the intended validation very early in the lifecycle

Note 1 to entry: Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user's needs.

3.12
traceability
ability to identify the relationship between various artefacts of the development process

EXAMPLE Artefacts of the development process include the lineage of requirements, the relationship between a design decision and the affected requirements and design features, the assignments of requirements to design features, and the relationship of test results to the original source of the requirement.

Note 1 to entry: Bidirectional traceability is required to permit top-down impact analysis and down-top traceability analysis.

Note 2 to entry: Traceability is the ability to trace the history, application, or location of that which is under consideration.

[SOURCE: ISO 10795]

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4 Abbreviated terms

The following abbreviated terms are used in this document.

CM	Configuration Management
KPI	Key Performance Indicators
PLM	Product Lifecycle Management
RM	Requirements Management
ROI	Return on Investment
SE	Systems Engineering
SMART	Specific, Measurable, Achievable, Relevant, and Traceable
TBC	to be confirmed
TBD	to be defined
V&V	Validation and Verification

5 Objective and scope of Requirements Management

5.1 Objective of Requirements Management

The objective of Requirements Management (RM) is to ensure that stakeholders' needs (customers, users, system's operating environment, trade and marketing, regulations, etc.) are understood, agreed upon, and realized (i.e. that the final design and the delivered products fulfil stakeholders' needs). The best opportunity for Requirements Management to influence a good outcome of the project is an early implementation. Greatest Return on Investment (ROI) of Requirements Management is if it is implemented early.

5.2 Scope and interfaces

5.2.1 Requirements Management scope

a) Requirements Management is a transversal activity that lasts for the whole product lifecycle. Requirements Management shall be started as early as possible and shall be sustained through all the phases of the project, including

   1) Concept and definition,

   2) Design and development,

   3) Production,

   4) Support, and

   5) Disposal.

b) Requirements Management is a discipline that shall be applied to all engineering domains. Requirements Management shall, as a minimum, apply to technical requirements, although non-technical requirements may also be managed.

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c) Requirements Management covers the following high-level functional processes described in Clause 6:

   1) capture the needs and develop the requirements;

   2) allocate and flow down the requirements;

   3) validate the requirements;

   4) verify the design against the requirements;

   5) verify the product against the requirements;

   6) manage the requirement changes.

d) Requirements Management is an essential part of Systems Engineering. Requirements Management does not cover the full Systems Engineering discipline, but it is strongly linked to all elements of Systems Engineering.

e) The major objects managed by Requirements Management are

   1) "Requirement" (object to be detailed with attributes such as stakeholder, source, rationale, identification, author, status, allocation to design, and statement of the verification method),

   2) "Links" (object to be detailed as the link between requirements, but also links from/to other objects enabling Requirements Management to reach its primary objective and ensuring that stakeholders' needs are understood and realized),

   3) "Input documents" (source documents or data that contain the requirements),

   4) "Output documents" (reports, compliance matrix, verification matrix, traceability matrix, impact analysis, design documentation, and specification), and

   5) "Requirements baseline".

f) Requirements Management needs to use other types of objects, but is usually not a master of the following objects in order to ensure efficiency:

   1) "Product Breakdown Structure", "Configured Items", and "Functions", used to organize requirements and allocate them;

   2) "Analysis and Trade Items", used to make decisions on the validation of requirements, for example objects "Risk", "Issue", "Decisions", and "Discussions", used to support Requirements Management processes;

   3) "Change Management Items", such as "Change Request" and "Change Order".

5.2.2 Interfaces and support for other disciplines

Requirements Management interface with the following disciplines is based on an iterative data exchange throughout the project lifecycle. As a transversal activity, Requirements Management supports these disciplines as described in the following sections.

5.2.2.1 Monitoring quality of requirements

Metrics or Key Performance Indicators (KPIs) shall be collected and analysed on a regular basis to measure quality of requirements and support the evaluation of the effectiveness of the Requirements Management process (see 8.3).

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5.2.2.2 Support to design

Requirements Management provides an input to the design team in terms of input requirements. Lower-level requirements will be derived as an output of the design effort. This is an iterative process where both sides shall be aware of the current development status.

5.2.2.3 Support to engineering

a) Requirements Management enables the Specification Authors/Engineers to create their documents with visibility of all the stakeholders' needs and design inputs and outputs. The Specification Authors/Engineers will know what impact any requirement changes may have on other requirements, design elements, and verification requirements which are linked to each of the requirements in their specification.

b) Requirements Management enables the product implementation to be traceable to customer needs.

5.2.2.4 Support to Configuration Management

a) Requirements Management enables the implementation of a change in the requirements database in line with the change process and generates changes for consideration within the formal Configuration Management process. Requirements Management may provide impact assessments of changes for input into the formal Configuration Management process.

b) Requirements Management enables the relationship between the requirements, design, and product baselines to be maintained.

5.2.2.5 Support to verification team

a) Requirements Management and verification have to be strongly integrated to enable close out and delivery of the product to the project.

b) Requirements Management provides an input to the verification team to be integrated into the verification activities. The verification activities include testing. Through the testing, it will be proved if the product complies with the customer requirements/user needs. Requirements Management ensures that the Requirements Management database is maintained with the latest verification input.

5.2.2.6 Support to specialist domains

Requirements Management provides the facilities to enable the specialists to identify, derive, and track their requirements. The main specialist domains are

— Customer Support,

— Environmental Engineering,

— Manufacturing,

— Marketing and Sales,

— Operations,

— Procurement,

— Qualification and Certification,

— Quality Assurance,

— Software Engineering,

— Reliability,

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— Safety,

— Supportability, and

— Through-Life Support.

6 Requirements Management overall process

The following describes the overall process of Requirements Management (RM).

a) The space systems to be developed include many levels of systems/subsystems/components which are described through the breakdown structure of the final product. Each system level is developed in accordance with its requirements which are defined by the upper level. The requirements are cascaded to the lowest level (part or module). These requirements have to be developed in order to address the needs of all identified customers (internal and external). The development of requirements is an iterative process that reproduces itself at each level of the product breakdown structure. As each customer need is developed into specific requirements, these are further developed by design activities into lower-level requirements.

b) 6.1 to 6.6 describe the individual activities of the overall Requirements Management (RM) process. A short description of the implementation of this process is given in Figure 1.

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RM Process Flow			RM Process Description
Iterative requirements engineering phases	Assess	1. Capture needs and develop requirements	Identify, agree, and capture stakeholder needs. Translate needs into agreed requirements. Prioritize requirements. Examine new and changed requirements to assess impact.
	Allocate and link	2. Allocate and flow down requirements	Assign functional breakdown to requirements. Allocate the applicable customer requirements to next requirements level and design elements. Flow down each level requirements to next lower-level requirements when applicable for traceability purposes.
	Validate	3. Validate requirements	Check that each requirement is validated to be correct, complete, and consistent with all the related upper-level requirement. Enter method of verification and raise Request for Deviation and Change Request for disputed requirements.
	Incorporate design	4. Verify design against requirements	Reference or link to the part of the design that is/will be related to the requirement. Check that the design element satisfies the requirement. **Design Verification Matrix (DVM)** Assign verification method, level, and milestones for each requirement.
	Verify product	5. Verify product against requirements	Reference or link to the product that is/will be related to the requirement. Check that the product element satisfies the requirement. **Product Verification Matrix (PVM)** Assign verification method, level, and milestones for each requirement.
Maintenance phase	Maintain quality	6. Manage requirements change	Assess the impact of changes and maintain current version of requirements and linkage. **Change Impact Assessment**

Figure 1 — Good practice example of "Single iteration of Requirements Management process"

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c) Figure 2 shows these activities within the context of the development hierarchy. The hierarchical level at which the manufacturing and development of products takes place is individual to each project and/or product. The Requirements Management process activities identified throughout Figure 1 can be conducted concurrently; this is only constrained, however, in the completion or 'closing out' of those activities. The completion of one activity shall not occur until the previous upper-level activity is completed. For example, at any development level, design verification should not be 'closed out' until the requirements that were used as input to design against them have been validated.

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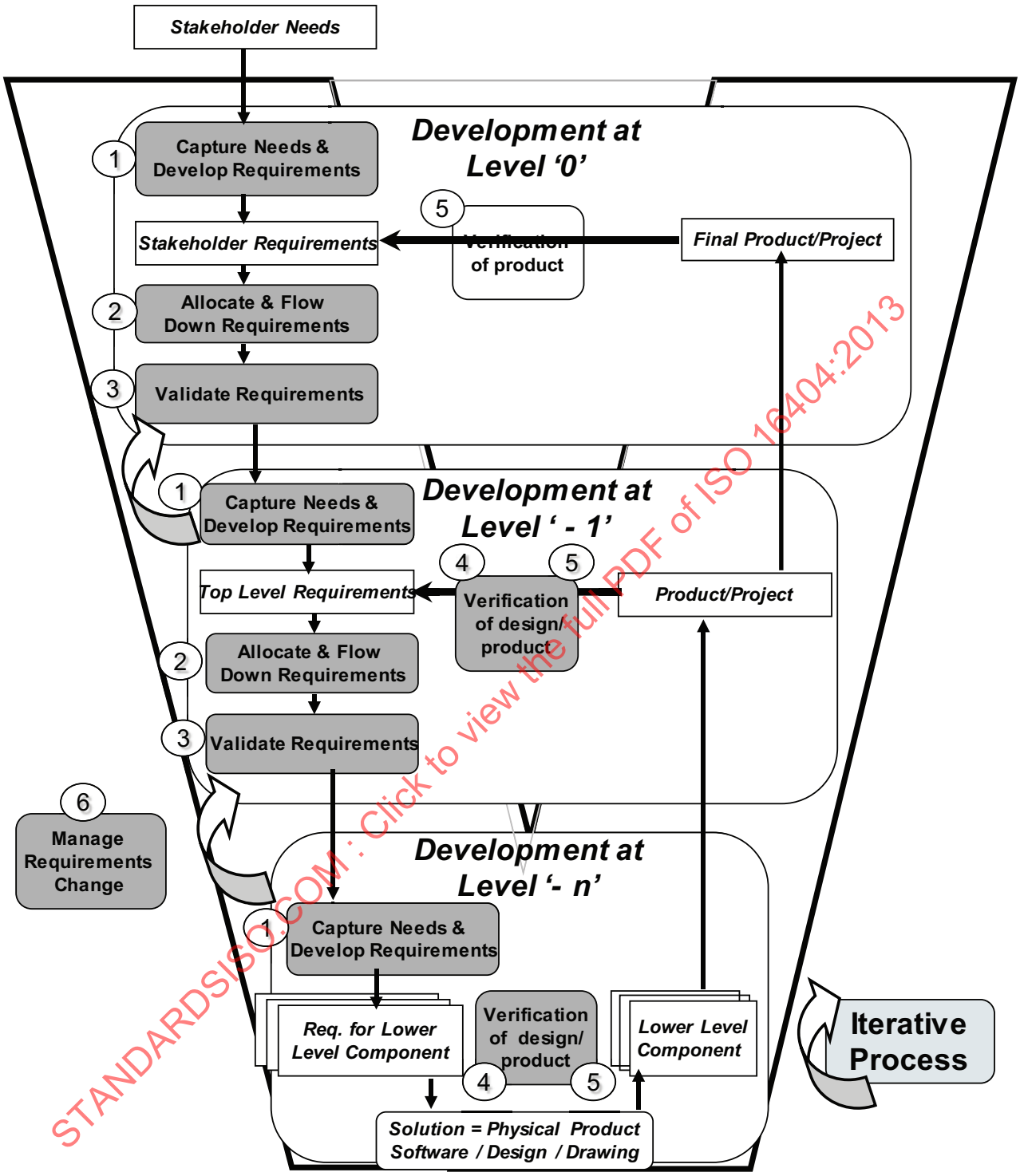

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Figure 2 — Requirements Management process activities in the "V-cycle" development model hierarchy

6.1 Capture needs and develop requirements

a) Stakeholders' needs (customers, users, system's operating environment, trade and marketing, regulations, etc.) shall be identified, captured, and analysed for their completeness, consistency, traceability, testability, and singularity. It shall be ensured that everyone understands the requirements and has access to them, and commits to perform the work. Stakeholders' needs (including customers), expectations, constraints, and interface shall be translated into documented

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requirements (missing information obtained, conflicts identified, analysed, and resolved) and prioritized (rejected, altered, etc.).

b) The ownership for each requirement shall be defined. Each requirement shall have a clear owner who defines the flow down and ensures that it satisfies the higher and lower levels. The owner must ensure that all mandatory attributes as defined in the Requirements Management plan shall be completed. This is an iterative process.

c) Requirements shall be consolidated. It shall be verified and ensured that the specified requirements are

1) unambiguous,

2) complete,

3) verifiable and concrete,

4) consistent with each other,

5) achievable,

6) expressing needs and not solutions,

7) appropriate for the level of requirement hierarchy, and

8) really needed.

6.2 Allocation and flow down requirements

Each requirement shall be allocated to at least one element of the product breakdown structure. A requirement may be allocated to one or many elements. Every lower-level requirement shall link or relate to the source of that requirement. This can be a higher-level requirement or a design element.

6.3 Validate requirements

Each requirement shall be validated to ensure that it is correct, complete, and consistent with all the upper-level requirements that it is related to.

6.4 Verify design against requirements

The design must be verified to ensure that it satisfies the requirements. The design verification shall ensure that all requirements have been taken into account by the design.

6.5 Verify product against requirements

Configuration items (physical products, software, designs, drawings, etc.) being passed 'up' from one level to another must be verified to ensure that they satisfy the respective requirements. There is a need to check that all requirements have been met and that the item satisfies the purpose it was designed for. This verification has to be performed at each level. At the highest level in the hierarchy, the final product must be validated against the highest level requirements/user needs. At any development level where multiple items are being integrated, there is a need for the verification activities to follow any integration sequence defined in the product/project integration plan.

6.6 Requirements change management

Any change in a requirement shall be documented and justified and an assessment shall be made of the impact of change and redesign utilizing requirements traceability throughout the lifecycle of the requirement. Requirements change management must be considered in the context of the Configuration Management of the product/project. Requirements change management is an embedded process within document change management.

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7 Requirements Management plan

7.1 General

Any company involved in a space project shall take into account the requirements stated in a quality management system standard, e.g. ISO 9001: 2008.

At a given level, the supplier shall adapt the management requirements contracted with his own customer to his own suppliers. The customer can consequently fulfil his own obligations towards the next higher level (see ISO 14300-1). Requirements Management (RM) is a subset of the quality management system of the stakeholder and the management requirements contracted between the customer and his own suppliers.

7.2 Functional and technical specifications

In ISO 21351, process guidelines for functional and technical specifications related to a product or a system are described. ISO 21351 defines the requirements for the format and the content of the functional and technical specifications.

7.2.1 Requirements Management plan

a) In response to the project management specification as defined in ISO 14300-1, each concerned supplier prepares a project Requirements Management plan which contains descriptions of main activities, implementation methods, and general related organization to set up these activities.

b) The Requirements Manager shall develop and maintain the project Requirements Management plan. It is the responsibility of the Project Manager to ensure that the plan is introduced to the project team and applied by the team.

c) The template to use to define the Requirements Management plan is in Annex A. In Annex A, each single section shall contain a description of the purpose of what should be included in the plan and an example of 'good practice' from the Divisions/Business Units.

d) The following are the rules to apply for programme/project RM plan implementation.

   1) Programme/project RM plan can be extended per project-specific needs.

   2) Programme/project RM plan can refer to other programme/project documentations, if the information already exists there.

   3) Sections of the RM plan may include all the details necessary for the implementation of the RM standard, but shall refer to other applicable documents, if they exist.

e) The Requirements Management plan defines the Requirements Management process, tool, and methods to be applied to the related programme/project. The roles and responsibilities of teams and individuals within the programme to support Requirements Management will also be defined.

f) The Requirements Management plan

   1) provides an overview of the structure and the content of the plan,

   2) addresses the main topics, such as adaptation of standard Requirements Management data, model, process, and interfaces to other processes (i.e. Configuration Management and Validation and Verification), and

   3) describes the project-specific environment, infrastructure, and tools supporting the process. The Requirements Management plan shall be applicable to all the requirements of the programme/project, including sub-contractors, etc.

g) The Requirements Management plan shall be developed at the earliest phase possible and shall be kept updated for the entire lifetime of the product defined by the project.

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8 Rules for Requirements Management

The objective of this International Standard is to deploy a high-value Requirements Management (RM) of all products based upon a common reference framework, enabling and facilitating collaboration between different stakeholders as well as cross programmes/projects.

Two categories of rules have been defined, the rules to be satisfied by each stakeholder for the implementation of Requirements Management activities and the rules for Requirements Management itself.

8.1 Rules for deployment of Requirements Management activities

Each stakeholder shall ensure that the deployment rules defined in Table 1 are implemented.

Table 1 — Mandatory rules for deployment of Requirements Management

Rules for deployment of Requirements Management activities	
Company/business level	
01	Each stakeholder shall ensure that requirements are managed for each programme/project in a correct and effective way.
02	A standard Requirements Management deployment method shall be defined and proposed for all new developments within each stakeholder.
03	A specific Requirements Management education and skill development plan shall be developed and applied at stakeholder level.
04	Each stakeholder shall establish and maintain a dedicated Requirements Management competence team to support all programmes/projects on all Requirements Management-related topics. In case no dedicated Requirements Management team is established, the Requirements Management function shall be assigned to a dedicated and competent member in every project.
05	Each stakeholder shall ensure that one RM toolset is available to all projects/products throughout the business.
06	Each stakeholder shall use the stakeholder recommended tool.
Programme/project level	
07	Each Programme Manager shall be informed of the benefits of Requirements Management and apply her/his stakeholder Requirements Management rules. Any intentional deviation from it shall be justified and documented within the Requirements Management plan.
08	Each programme shall identify a Requirements Management function and maintain it for the whole programme lifecycle.
09	A Requirements Management plan shall be documented and implemented for each programme/project.
10	Interfaces with other PLM tools and processes shall be defined for each programme/project.
11	Exchange of RM objects and related data between suppliers, industrial partners, and stakeholders shall be defined and implemented.

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8.2 Rules for Requirements Management

Each programme/project shall implement the rules and best practices defined in Table 2.

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Table 2 — Rules for Requirements Management

Rule	Rules for Requirements Management — best practices
01	Each requirement shall be uniquely identified.
02	Each requirement shall be Specific, Measurable, Achievable, Relevant, and Traceable ("SMART").
03	Each requirement shall be validated (correct, complete, and compatible with its source).
04	Each requirement shall be verifiable.
05	Each requirement shall have a statement of compliance to indicate that the requirement will be met by the delivered solution.
06	There shall be a link from each requirement to its destination to ensure that every higher-level requirement has been addressed and flowed down.
07	The reason for the existence of each requirement shall be defined by a rationale and/or by a trace to its source (e.g. higher-level requirement, customer requirement, and design element).
08	Requirements Management shall be implemented using a dedicated Requirements Management tool.
09	The version of each requirement shall be managed.
10	A requirement shall be expressed as text and may be supported by graphics, tables, etc. In an advanced modelling approach, models shall be the direct source of requirements.
11	Requirements Management at Business Unit and Division level shall facilitate reuse and product family management.

8.3 Key Performance Indicators

Table 3 lists metrics which could be implemented '**I**' (see 5.2.2.1) depending on the project management needs.

Table 3 — Requirements Management implemented metrics

ID	Description
KPI_I_01	Percentage of requirements which satisfy a higher-level requirement
KPI_I_02	Percentage of requirements which are flowed down to the lower level
KPI_I_03	Number of requirements with a verification method stated
KPI_I_04	Percentage of requirements that contain < TBD > / < TBC > in the requirement's statement
KPI_I_05	Number of requirements with a means of compliance/compliance method stated
KPI_I_06	Number of requirements by status, e.g. proposed, validated, change requested, deleted, and blank
KPI_I_07	Number of requirements allocated/non-allocated to lower-level teams
KPI_I_08	Number of requirements by verification status, e.g. passed, failed, and pending verification

Table 4 lists additional metrics which are suggested '**S**' depending on the programme or project (see 5.2.2.1).

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