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Space systems — Guidelines for the management of systems engineering

Systèmes spatiaux — Lignes directrices pour le management de l'ingénierie système

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

There is general consensus that to accomplish space programme/project requirements, it is mandatory to manage the systems engineering activities. The main role of systems engineering management is to ensure system performance conforms with expressed need, and to control the technical risks involved in development. Also, cost and schedule parameters are taken into account in space systems engineering in the search of optimal performance.

Thus, this document provides guidelines for managing the systems engineering activities related to planning, assessment and control of space programmes/projects.

These guidelines are intended to identify a set of recommendations to help customers and space system organizations to establish management requirements for systems engineering activities and help the organization to construct the elements of the systems engineering management plan (SEMP).

Given the need for systems engineering management, the overall systems engineering activities can be divided into two types:

— systems engineering management activities related to programme management which comprise planning, assessing, controlling, trade-off studies and decision making;

— the technical activities themselves, linked to the technical processes (stakeholder requirements analysis, system requirements analysis, system architectural design, system detailed design and assembly, integration, and verification and validation) applied to the system.

Therefore, systems engineering management reinforces the technical viewpoint within programme management.

In these guidelines, a set of leading indicators are suggested as measures for evaluating the effectiveness of each space systems engineering activity. Leading indicators are important tools for project management to make interventions and actions to avoid rework and wasted effort during the whole system engineering life cycle.

Space systems — Guidelines for the management of systems engineering

1 Scope

This document presents the guidelines for the management of systems engineering for space systems.

This document addresses the systems engineering activities and provides guidelines for interfacing with specific major management subjects (e.g. configuration management, data management, interface management, risk management, requirements management, and integrated logistics support), which are themselves the subject of this document.

This document establishes a common reference for all customers and suppliers in the space sector to work with management systems engineering for all space products and projects.

These guidelines emphasize the following aspects of managing space systems engineering:

— the positioning of space systems engineering activities related to the management of space activities;

— the framework for the management of systems engineering;

— the systems engineering management plan (SEMP);

— the system, product and work breakdown structures;

— the phasing, scheduling and recursivity of the systems engineering management;

— reviews, audits and control gates;

— the main activities of systems engineering and the respective management approach.

It is not the scope of this document to describe in detail the standard systems engineering process or project management process for all types of space systems.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
management
coordinated activities to direct and control an *organization* (3.2)

[SOURCE: ISO 9000:2015, 3.3.3]

3.2
organization
person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

[SOURCE: ISO 9000:2015, 3.2.1]

3.3
programme
group of *projects* (3.5) managed in a coordinated way to obtain benefits not available from managing them individually

[SOURCE: ISO 10795:2011, 1.166]

3.4
process
set of interrelated or interacting activities that use inputs to deliver an intended result

[SOURCE: ISO 9000:2015, 3.4.1]

3.5
project
unique *process* (3.4), consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constraints of time, cost and resources

[SOURCE: ISO 9000:2015, 3.4.2]

3.6
system
set of interrelated or interacting elements

3.7
systems engineering
interdisciplinary approach governing the total technical and managerial effort required to transform a set of stakeholder needs, expectations and constraints into a solution and to support that solution throughout its life

[SOURCE: ISO 24748-1:2016, 2.56]

3.8
systems engineering management
discipline to ensure that *system engineering* (3.7) is properly applied and can be divided in planning, control, assessment and decision analysis, including management tools like work breakdown structures, risk management, requirements traceability and reviews

3.9
stakeholder
customers and/or users or those who will receive the goods or services and are the direct beneficiaries of the *systems* (3.6) or other interested parties who affect or are affected by the *project* (3.5), providing overarching constraints within which the customers' needs should be achieved

4 Positioning of systems engineering management

4.1 General

This clause aims to justify the space systems engineering management activity in relation to the management of design and manufacturing engineering activities, in relation to project management and in relation to the mission/programme/project.

4.2 Need for systems engineering management

This subclause highlights what is special in systems engineering that requires management.

The main aspects to be approached are:

a) requirements not known beforehand but continuously engineered by the systems engineering process;

b) complexity of the elements in the environment, material, information and energy, that exchange with the system;

c) quantity and variety of stakeholders, requirements, concepts, functionalities, technologies, suppliers, contracts and life cycle process implementation organizations;

d) iterative nature of the systems engineering process from requirements until the convergence to a system solution;

e) recursive nature of the systems engineering process applicable to systems but also to subsystems in the various layers of the system breakdown structure;

f) risk management when verification activity cannot be exhaustive.

4.3 Systems engineering

Systems engineering provides the identification and understanding of a need and derives, develops and verifies a solution that will be balanced during the space system life cycle in order to meet that need. Systems engineering balances the satisfaction of all stakeholders involved in the solution life. Figure 1 presents the V-Model and its set of systems engineering processes in the classical life cycle stages.

The term systems engineering process describes the activities used to transform requirements in an effective product. These activities enable systems engineers to coordinate the interaction between engineers, other specialists, stakeholders, operators, and manufacturing.

The classical space systems life cycle is divided into stages, and each stage contains systems engineering processes. The concept stage includes the concept of the operations process; the development stage includes the requirements and architecture analysis processes, and detailed design process; the production stage includes the synthesis process, assembly, integration and verification process, and system validation process; and the utilization stage includes the operations and maintenance processes.

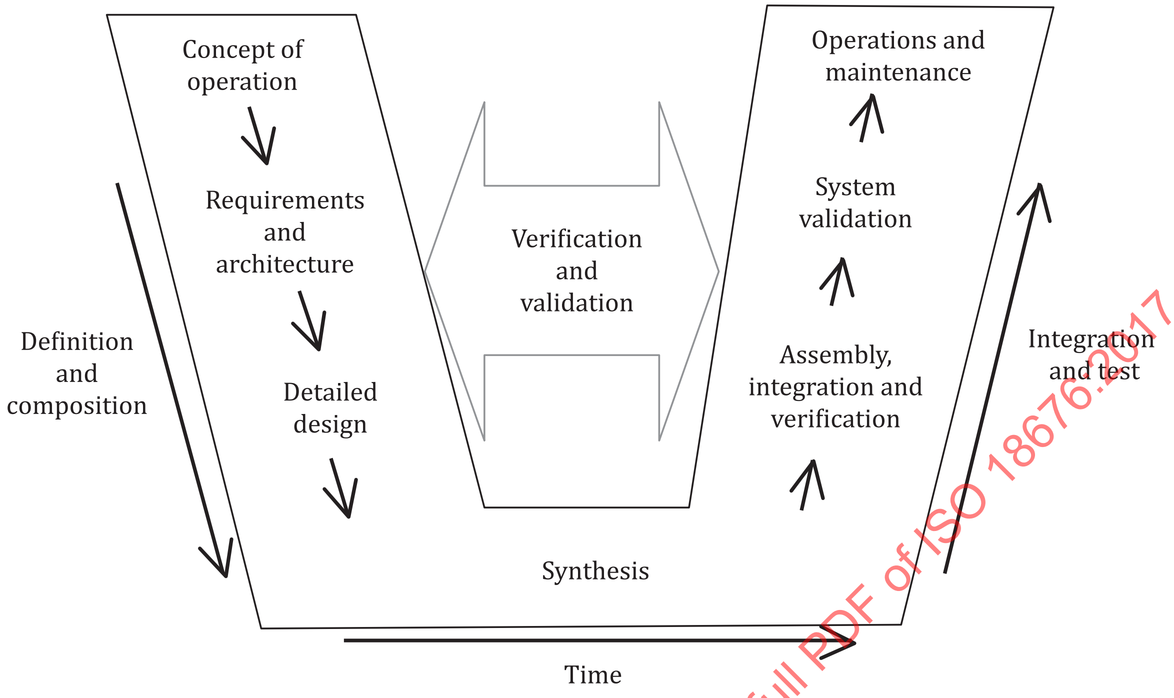

Figure 1 — Systems engineering V model

Systems engineering is concerned with the delivery of a technical solution that meets stakeholder needs and provides a set of baseline requirements to be used as a reference for project management.

Project management uses these references provided by systems engineering to compare what is being implemented to what has been planned.

Project management is responsible for the project organization, and other aspects of the project, such as, cost, schedules, human resources, communication, programmatic risk, acquisition strategy, sustainment and external interfaces.

4.4 Systems engineering management

The systems engineering process is managed from the time of need identification to a verified and validated solution. Also, systems engineering management includes configuration management, data management, technical risk management, and interface management.

4.5 Systems engineering management relative to the mission/programme/project

Systems engineering management is part of the mission/programme/project, and interacts with other management disciplines within the mission/programme/project activities.

Figure 2 presents the position of programme management related to systems engineering activities. The programme management circle consists of the management tasks including planning, assessment of progress, control actions and trade-offs and decision making to correct the course of the project. The systems engineering circle is related to the main activities of systems engineering process, such as stakeholder requirements analysis, system requirements analysis, system architectural design, system detailed design, assembly and integration, and verification and validation. The intersection circle corresponds to the interaction between management tasks and the systems engineering activities required to accomplish the mission/programme/project.

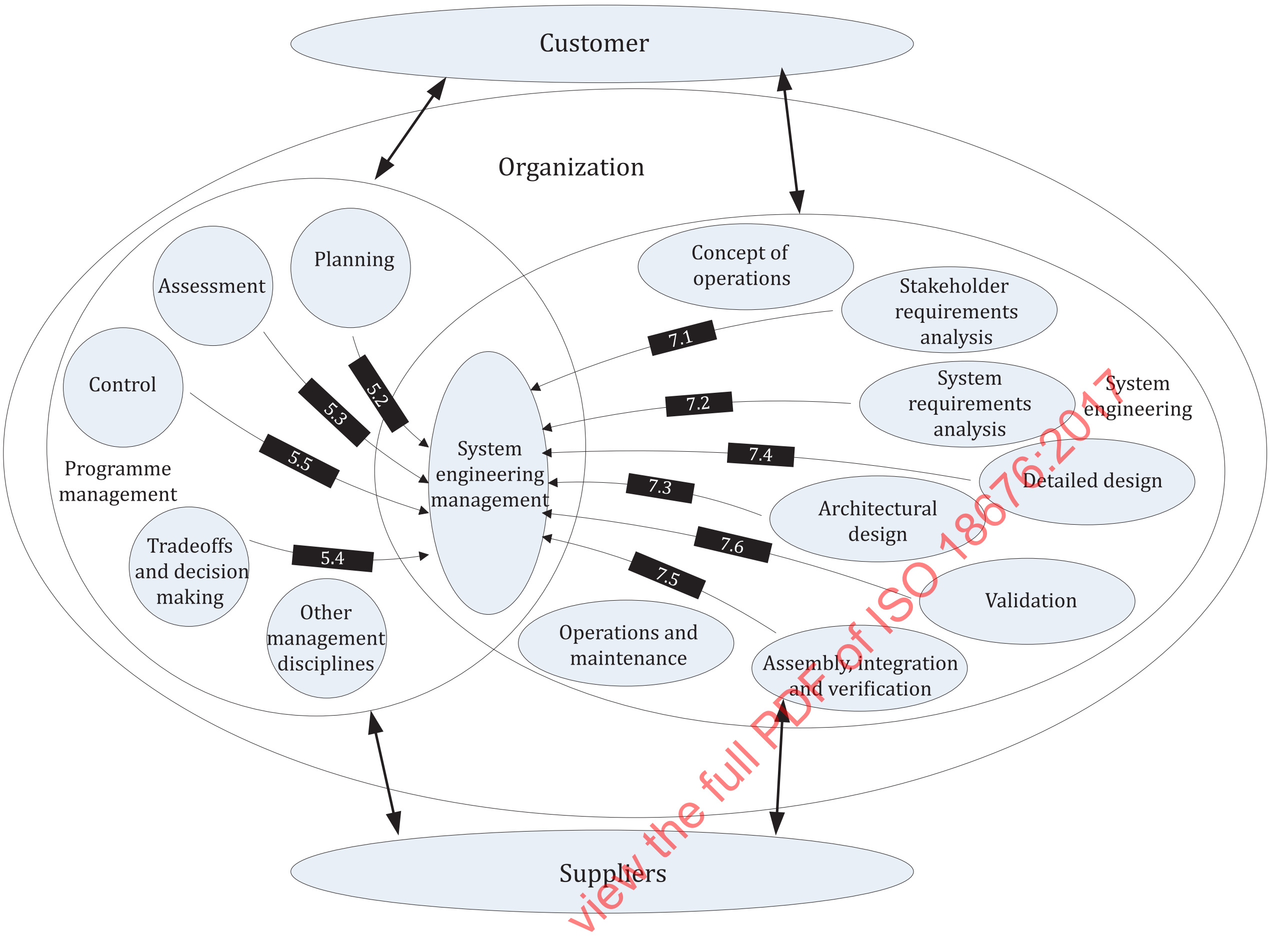

Figure 2 — Position of programme management related to system engineering activities

5 Management of the systems engineering activities

5.1 General

The objective of the management of systems engineering activities is to achieve the required outputs of the space system project. This management covers the task planning, assessment, control, trade-offs, and decision making applied to assure the correct management of the project in all phases of the systems engineering process.

5.2 Planning

Planning refers to the identification of the activities to be performed, their appropriate sequence and resources needed for their accomplishment. This task consists of preparing the necessary technical plans and complementary project planning information used to support the mission and the systems engineering activities, and should include the following.

a) Implementation strategy: Define a strategy for implementing the mission/programme/ project and the systems engineering activities as a basis for project technical planning;

b) Technical effort: Describe what will be accomplished, how systems engineering will be done, what resources are needed and how the systems engineering effort will be monitored and controlled in accordance with the implementation strategy;

c) Schedule and organization: Define how the technical effort will be scheduled and organized;

d) Work directives: Create work directives that implement the technical effort.

5.3 Assessment

Assessment refers to the evaluation of the project's progress along the planned activities of the systems engineering process. This task consists of determining progress of the technical effort against the mission/programme/project planning and the systems engineering activities. This assessment should be used to determine:

a) definition of the progress and outcome metrics to be used;

b) progress against plans and schedules: assess the progress of the technical effort against the accomplishments of the systems engineering activities;

c) progress against systems engineering activities: assess the progress of the system development by comparing mission/programme/project required results against the outcomes of the systems engineering activities;

d) technical reviews: use technical reviews to evaluate the progress and accomplishments in accordance with the appropriate technical plans.

Leading indicators (LIs) can be used to evaluate the effectiveness of specific space systems engineering activities to provide information about impacts that are likely to affect the space programme/project performance objectives. LIs can be associated with system attributes, such as, process milestone, phases, disposition actions (opened, started, approved, incorporated, rejected, stopped, closed, overdue), maturity states (planned, interim, actual), priority levels (critical, high, medium, low), causal states (error, customer request, external), impact levels (high, medium, low), classification type and dates/times.

5.4 Trade-offs and decision making

Trade-offs and decision making refers to recommendations and predictions of the results of the alternative decisions. This task consists of performing trade-off analyses to provide decision makers with recommendations, predictions of the results of alternative decisions and other appropriate information to allow selection of the best course of action. This task should include:

a) identifying the alternatives;

b) planning the trade-off analysis: plan the availability of required resources, execution and data collection requirements, expected outcomes, defined conditions (triggers and rigor), level of importance, objective, schedule of tasks, selection criteria that will determine desirability or undesirability of an alternative, weighting factors for each selection criterion, models (representative or simulation) to be used in the trade-off analysis, and options to be analysed;

c) performing the trade-off analysis: do appropriate effectiveness analysis activities to provide a quantitative basis for evaluating options, risk analysis activities to quantitatively or qualitatively assess the risk associated with each option; collect and analyse data to determine the cost, schedule, performance and risk effect of each option on the system; evaluate options against selection criteria and weighting factors and identify and define recommendations and communicate recommendations and impacts to appropriate decision makers;

d) recording outcomes: record the analysis in the information database, including assumptions, details of the analysis, lessons learned, models used, rationale for decisions made, recommendations and effects and other pertinent information affecting the interpretation of the decisions made.

5.5 Control

Control refers to the actions to be taken in order to keep the planned activities according to plan, to correct the course of activities needed to be brought back in line with the plan or to correct the plan. The control task is used to manage the conduct and the outcomes of the mission, to monitor variations from the plan, and to prevent anomalies relative to the systems engineering activities, and to ensure necessary communications are successful. This activity should support:

a) preventive actions: when assessments indicate a trend toward deviation of progress and outcomes;

b) problem resolution: when assessments indicate non-conformance with the outcome metrics, such as, the performance of systems engineering activities that lead to expected results outside the bounds of the success criteria;

c) information dissemination: ensure that required and requested information is disseminated in accordance with the project plans and organization policies.

6 Systems engineering management plan (SEMP)

The SEMP describes how the project will be technically managed. The SEMP is the document that defines to all project participants how the project will be technically.

The SEMP identifies what, when, where, by whom and how the activities are performed. It specifies the schedule for the development and the resources required. It is an implementation plan for the management of the performance of systems engineering activities and the development of systems engineering products. The SEMP should be aligned with the customer's Systems Engineering Plan (SEP).

Each project should prepare an SEMP that addresses the requirements of this document and describes the what, when, where, by whom, and how each is to be implemented.

The SEMP should include:

a) an organization structure along with responsibilities for the systems engineering team;

b) the major trades identified;

c) a schedule and list of resources required for the systems engineering effort.

7 Systems engineering management activities

7.1 Management of stakeholder requirements analysis

The purpose of this activity is to manage the mission and the stakeholder requirements analysis in order to achieve the expected outputs in the space system project. This management activity covers the identification of planning, assessment and control tasks to ensure the mission and stakeholder requirements analysis process.

It assesses whether the stakeholder requirements meet the expectations of the layout of the mission, the required capability or the market opportunity. It also identifies if the customer expectations, established by the mission need statement or capability definition, represent the problem space for systems engineering.

It creates leading indicators associated with the number of "requirements identified" and "requirements approved", and creates a measurement function to evaluate the performance of this activity, such as examples provided in reference [10] or equivalent. The results are used to evaluate the stability and adequacy of the stakeholder requirements analysis. Also, it can help to understand the level of stakeholder collaboration across the system life cycle.

7.2 Management of system requirements analysis

The purpose of this activity is to manage the system requirements analysis in order to achieve the expected outputs in the space system project. This management activity covers the identification of planning, assessment and control tasks to ensure the system requirements analysis process.

It assesses whether the system requirements were translated into technical system requirements, articulated from the perspective of the developers — hardware and software, the testers and integrators and so on.

It creates leading indicators associated with the number of requirements TBD (to be defined), number of requirements TBR (to be resolved), requirements defects, requirements changes and requirements change impact. It also creates a measurement function to evaluate the performance of this activity, such as examples provided by Reference [10] or equivalent. The results are used to evaluate the stability and adequacy of the system requirements analysis. These indicators can be associated with attributes like maturity, priority, impact level, stability, adequacy, risk/capability, time and budget.

7.3 Management of architectural design

The purpose of this activity is to manage the architectural design in order to achieve the expected outputs in the space system project. This management activity covers the identification of planning, assessment and control tasks to ensure the architectural design process.

It assesses if the architectural design of the system was established from its functional architecture, requirements allocation and technology selection.

It creates leading indicators associated with the interfaces and interoperability, data architecture, safety and security standards to evaluate the effectiveness of this specific system engineering activity related programme/project objectives. It evaluates the architectural design in terms of stability, adequacy, risks, capability, time and budget. It also evaluates the maturity of an organization with regard to implementation and deployment of an architecture process that is based on an accepted set of industry standards and guidelines. It defines score levels for each indicator, in order to provide an understanding of the level of organizational strategy and commitment to its architectural processes.

7.4 Management of detailed design

The purpose of this activity is to manage the system, subsystems and components detailed design in order to achieve the expected outputs in the space system project. This process covers the planning, assessment and control task to ensure the correct management of the architectural design.

It assesses whether the detailed design was decomposed from the architectural design, into smaller system level abstraction, providing a detailed specification for each component, thoroughly describing interfaces and functions provided by each component.

It creates leading indicators associated with organizational commitment, capability, plans and products, performance metrics and strategic direction to evaluate the effectiveness of this specific system engineering activity related programme/project objectives. It evaluates the detailed design in terms of stability, adequacy, risks, capability, time and budget. It evaluates the maturity of an organization with regards to implementation and deployment of a detailed design process that is based on an accepted set of industry standards and guidelines. It defines score levels for each indicator, in order to provide an understanding of the level of organizational strategy and commitment to its design processes.

7.5 Management of assembly, integration and verification

The purpose of this activity is to manage the assembly, integration and verification in order to achieve the outputs expected in the space system project. This management activity covers, the identification of planning, assessment and control tasks to ensure the assembly, integration and verification processes.

It assesses whether the assembly, integration and verification of the system were established from its requirements allocation, architecture, detailed design and technology selection.

It creates leading indicators associated with interface changes, interface defects and the number of requirements verified. It creates a measurement function to evaluate the performance of this activity, such as examples provided in Reference [10] or equivalent. It is necessary to define a leading indicator threshold for the analysis of the measurement function results, defining the acceptable value. The results are used to evaluate the stability and adequacy of the assembly, integration and verification process.

7.6 Management of validation

The purpose of this activity is to provide to the organizations in charge of the development of a space system a means to validate the system by examining their products and sub-products at every level of the structure. This management activity covers first, the identification of planning, assessment and control tasks to ensure the validation process

Validation is performed for the benefit of the customers and users to ensure that the system functions in the expected manner when placed in the intended environment. Validation confirms that realized end products at any position within the system structure conform to their set of stakeholder expectations captured in the concept of operations (ConOps), and ensures that any anomalies discovered during validation are appropriately resolved prior to product delivery.

Planning to conduct the product validation is a key first step. The type of validation to be used (e.g. analysis, demonstration, inspection, or test) should be established based on the form of the realized end product, the applicable life-cycle phase, cost, schedule, resources available and location of the system product within the system structure.

It is necessary to create leading indicators associated with the completeness of test execution, product and process validation in conformance with stakeholder expectations, number of pre-test and post-test corrective actions, validation environment (e.g. facilities, equipment, tools, simulations, measuring devices, personnel and operational conditions) and requirements validation to evaluate the effectiveness of this specific system engineering activity related programme/project objectives. It is also necessary to create a measurement function to evaluate the performance of this activity, such as examples provided by Reference [10] or equivalent. The results are used to evaluate the stability and adequacy of the validation process.

8 Work breakdown structures (WBS)

The WBS is part of the overall system structure and provides a framework to help manage the system engineering activities and products in terms of identifying products, processes and data, organize and manage risks, enable configuration control and organize work packages, technical reviews and audits.

The WBS is a means of organizing system development activities based on system and product decompositions. Because the WBS is a direct derivative of the physical and systems architectures, it could be considered an output of the systems engineering process. The WBS establishes the essential framework for the project: technical planning, scheduling, cost estimation and budgeting; defining the scope of statements of work and contracts; developing documentation products (including specifications and drawings); and program/project status reporting and assessment (including integrated cost/schedule performance measurement).

The WBS should:

1) define all the work necessary to complete the project;

2) be a product-oriented, hierarchical division (tree) of deliverable items (hardware, software and information) and associated services;

3) relate the elements of work to each other and to the end item (system or product).

The project WBS should contain the project's product breakdown structure (PBS), with the specified prime product(s) at the top and the systems, segments, subsystems, etc. at successive lower levels. At the lowest level are products such as hardware items, software items and information items (e.g. documents, databases, etc.) for which there are cognizant engineers or managers.

As part of the process of ensuring an adequate WBS has been created, the following activities are required:

— Create leading indicators associated with the number of work products to evaluate the effectiveness of this specific system engineering activity related programme/project objectives.

— Create a measurement function to evaluate the performance of this activity, such as examples provided by Reference [10] or equivalent to evaluate the effectiveness of the WBS related programme/project objectives. It is necessary to define a leading indicator threshold for the analysis of the measurement function results, defining the acceptable value. The results are used to evaluate the stability and adequacy of the WBS.

9 Phasing, scheduling and recursivity

One of the fundamental concepts used for the management of major systems is the program/project life cycle, which consists of a categorization of everything that should be done to accomplish a program or project into distinct phases, separated by key decision points (KDPs). Decomposing the program/project life cycle into phases organizes the entire process into more manageable pieces.

Scheduling is an essential component of planning and managing the activities of system engineering processes. The process of creating a schedule provides a standard method for defining and communicating what needs to be done, how long it will take and how each element of the project WBS might affect other elements. Scheduling starts with defining the technical content of project activities and establishing the project logic, i.e. the sequence in which activities are to be accomplished and the interfaces and interdependencies of the various activities. Once the project logic is established, time spans for activities and event dates can be applied to develop the project schedule. The preparation and monitoring of schedules at various levels is necessary in the evaluation of progress and problems and to help ensure efficient flow among interrelated activities. For any given project, there will be a hierarchy of interdependent schedules ranging in detail from the top-level program schedule to the individual cost account schedules.

There are three sets of common technical processes: system design, product realization and technical management. These processes are used both iteratively and recursively. Iterative is the application of a process to the same product or set of products to correct a discovered discrepancy or non-conformances. Recursive is defined as adding value to the system by the repeated application of processes to design next lower layer system products or to realize next upper layer end products within the system structure. The technical processes are then applied recursively and iteratively to break down the initializing concepts of the system to a level of detail concrete enough that the technical team can implement a product from the information. Then, the processes are applied recursively and iteratively to integrate the smallest product into greater and larger systems until the whole of the system has been assembled, verified, validated and transitioned. The system engineering management should be used to ensure that the repeating application of the processes meet its specification and satisfy phase success criteria.

10 Budgeting and resource planning

Budgeting and resource planning involve the establishment of a reasonable project baseline budget and the capability to analyse the impact of changes to that baseline resulting from technical and/or schedule modifications. The management of system engineering activities involves the corrective and preventive actions taken to ensure that the project is performing according to plans and schedules and within projected budget and resources.

The project's WBS, baseline schedule and budget should be viewed as mutually dependent, reflecting the technical content, time and cost of meeting the project's goals and objectives. The budgeting process needs to take into account whether a fixed cost cap or cost profile exists.

11 Status reporting and assessment

11.1 General

Work planning and accounting, performance measurement, cost reporting and scheduling at the various levels of system engineering activities should be assessed and reported by the management. Technical assessment is the crosscutting process used to help monitor technical progress of a program/project through technical reviews. It also provides status information to support assessing system design, product realization, and technical management decisions.

11.2 Cost assessments

Cost is of vital interest to all levels of management and is an integral part of financial management reports. Costs are defined by cost element (direct or indirect), function (engineering, manufacturing, etc.), and WBS element. It is imperative that the contractor's cost reports are compatible with the technical and schedule reports at the prescribed WBS level and with the contractor's disclosure statement. Direct costs are those costs that can be identified to a specific contract. These costs normally include direct labour, material, purchased equipment, travel, etc. Indirect costs are those costs that cannot be identified to a specific contract but are required for contract performance.

In order to conduct a cost assessment, the following should be considered:

— Create leading indicators associated with budget measures, costs and prices.

— Create measurement functions to evaluate the performance of this activity, such as examples provided by Reference [10] or equivalent to evaluate the cost performance of the system engineering activities. It is necessary to define a leading indicator threshold for the result of the measurement function, defining the acceptable value. The result is used to evaluate the stability and adequacy of the costs

11.3 Scheduling assessments

Project work should be planned, scheduled and authorized at the cost account level. For each cost account, resources are specified (material, manpower) and a firm schedule established. The interdependence of cost account schedules should be clear and be supportive of the overall project schedule. The critical path should be defined and monitored. The preparation and monitoring of schedules at various levels is necessary in the evaluation of progress and problems and to help ensure efficient flow among interrelated tasks. For any given project, there will be a hierarchy of interdependent schedules ranging in detail from the top-level programme schedule to the individual cost account schedules. Each is logically supported by sub-tier schedules and, in turn, compatible with the next higher level.

The WBS gives this hierarchy of schedules structure, which to a large extent is a hierarchy of products. For each WBS element from project level through system, subsystem, assembly, component, and cost account level, there should be a corresponding schedule, the total collection of which composes an integrated interdependent set.

In order to conduct a scheduling assessment, the following should be considered:

— Create leading indicators associated with plan schedule and actual schedule.

— Create a measurement function to evaluate the performance of this activity, such as in the example provided in Reference [10] or equivalent to evaluate the schedule performance of the system engineering activities. It is necessary to define a leading indicator threshold for the result of the measurement function, defining the acceptable value. The result is used to evaluate the stability and adequacy of the schedule.

11.4 Performance assessments

The technical plans (e.g. SEMP, review plans) provide the initial inputs into the technical assessment process. These documents will outline the technical reviews/assessment approach as well as identify the technical measures that will be tracked and assessed to determine technical progress.

In order to conduct a performance assessment, the following should be considered:

— Create leading indicators associated with progress towards meeting the measures of effectiveness (MOEs), performance (MOPs), key performance parameters (KPPs) and technical performance measures (TPMs).

— Create measurement functions to evaluate the performance of this activity. It is necessary to define a leading indicator threshold for the result of the measurement function, defining the acceptable value. The result is used to evaluate the overall performance or specific performance of a system engineering process.

11.5 Risk assessments

Project risks are inherent in space projects. An important function of project management is to manage those risks to minimize the impact upon the project implementation. Risk management includes the related activities of risk identification, risk assessment and risk mitigation. Risk identification begins and develops during the formulation process. As concepts are defined and technology assessed, certain project risks become apparent. Generally, items are identified as risks if events can prevent the project from meeting its performance, cost or schedule goals.

Project management should ensure that the team participates in the identification of project risks for their area of expertise and quantifies the impact upon the project. Risk assessments should be conducted continuously to identify the risks to a program due to technology considerations (i.e. new designs, materials, processes, operating environments), availability of vendors, potential system hazards, failure modes, schedule optimism, margin allocation and requirement stringency.

As part of the risk assessment, the following should be considered:

— Create leading indicators associated with risk such as probability of risk occurrence (quantitative or qualitative), impact of risk occurrence, criticality and risk treatment actions.

— Create a measurement function to evaluate the performance of this activity, such as in the example provided in Reference [10] or equivalent. It is necessary to define a leading indicator threshold for the result of the measurement function, defining the acceptable value. The result is used to evaluate the level and impact of the risk in the system.

12 Reviews, audits and control gates

12.1 General

The reviews inform the decision authority as to the readiness of a program/project to proceed into the next phase of the life cycle. This should be done for each milestone review and is tied to a KDP throughout the life cycle. For KDP/milestone reviews, external independent reviewers known as standing review board (SRB) members evaluate the program/project and, in the end, report their findings to the decision authority.

For a program or project to prepare for the SRB, the technical team should conduct their own internal peer review process. This process typically includes both informal and formal peer reviews at the subsystem and system level. The intent and policy for reviews, audits and KDPs should be defined during the feasibility phase or in the preliminary definition phase and described in the program/project plan.

12.2 Review

The purpose of a review is to furnish the forum and process to provide program management and their contractors assurance that the most satisfactory approach, plan or design has been selected; that a configuration item has been produced to meet the specified requirements; or that a configuration item is ready. Reviews help to develop a better understanding among tasks, project participants, open communication channels, alerts and management to fix problems and provide alternatives for solutions.

Reviews are intended to add value to the project and enhance project quality and the likelihood of success.

Typical activities performed for technical reviews include:

a) identifying, planning and conducting phase-to-phase technical reviews;

b) establishing each review's purpose, objective and entry and success criteria;

c) establishing the makeup of the review team;

d) identifying and resolving action items resulting from the review. Project reviews generally fall into three categories:

   1) those associated with discharging design, development, delivery and operational responsibilities;

   2) those associated with reviewing status, acquiring resources, reporting utilization and reporting program status;

   3) those associated with external evaluation of the program by a non-advocate team.

Each project should define the specific reviews in the project plan. The project reviews should be aligned with the associated program reviews.

12.3 Review list

The review list, as presented below, is for a typical project, although the review may be called by another name on any given project and other reviews, principally operational oriented, will be required depending on the specific project and the life cycle stages. These reviews inform if a program/project is ready to proceed into the next phase of the life cycle. This is done for each milestone review and is tied to a KDP throughout the life cycle. The main technical reviews that should be considered are as follows.

a) Project requirements review (PRR): the purpose of this review is to examine the functional and performance requirements defined for a specific space system and to ensure that the requirements and the selected concept will satisfy the programme and the higher level project requirements.

b) System requirements review (SRR): the purpose of this review is to examine the functional and performance requirements defined for the system and the project plan and to ensure that the requirements and selected concept will satisfy the programme.

c) Preliminary design review (PDR): the purpose of this review is to demonstrate that the design meets all system requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design.

d) Critical design review (CDR): the purpose of this review is to demonstrate that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration and test and that the technical effort is on track to complete the flight and ground system development and mission operations to meet mission performance requirements within the identified cost and schedule constraints.

e) Qualification review: the purpose of this review is to confirm that the verification process has demonstrated that the design, including margins, meets the applicable requirements and also to verify the acceptability of all waivers and deviations.