



TECHNICAL REPORT	EIA-IS-731.1™	
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Systems Engineering Capability Model		

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EIA INTERIM STANDARD

Systems Engineering Capability Model

EIA/IS-731.1

DECEMBER 1998

ELECTRONIC INDUSTRIES ALLIANCE

**GOVERNMENT ELECTRONICS AND
INFORMATION TECHNOLOGY ASSOCIATION
ENGINEERING DEPARTMENT**



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SYSTEMS ENGINEERING CAPABILITY MODEL

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Foreword

This Interim Standard is intended to enable an organization to improve its capability to engineer and produce quality products, and deliver them on time at an affordable price or cost.

This Interim Standard, EIA 731, is intended to be the Standard for Systems Engineering Capability. As such, it complements the usage of the EIA 632, *Processes for Engineering a System*, and IEEE Standard 1220-1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process*. Those standards define the “what-to-do’s” of the processes for engineering systems, and this model provides a basis for determining “how well” those processes are defined and implemented. This Interim Standard is intended to provide complete coverage of the EIA 632 and be consistent with both it and IEEE 1220-1994.

Part 1 of this Interim Standard, EIA 731-1, is the Systems Engineering Capability Model (SECM). It is intended to be applied for measurement and improvement of systems engineering capability using Interim Standard, EIA 731-2, *SECM Appraisal Method*.

The application of this Interim Standard is independent of contractual arrangements.

This Interim Standard is consistent with ISO 9001: 1994. The practices and attributes of the model cover all 20 process elements.

Development of this Interim Standard was accomplished as a joint project of the Electronic Industries Alliance (EIA), International Council on Systems Engineering (INCOSSE), and Enterprise Process Improvement Collaboration (EPIC). This effort was chartered by the G-47 Systems Engineering Committee of EIA and has been identified as American National Standards Institute (ANSI) Project Number PN-3879. This Interim Standard has been approved by the EIA Engineering Department Executive Committee.

Intended users of this Interim Standard include: (a) developers of systems or portions thereof including: subsystems, equipment, assemblies, subassemblies, items, units, components, parts and materials; (b) acquirers of systems; (c) university professors, organizational trainers, and consultants; and (d) developers of other maturity or capability models. Use is not limited to specific disciplines, industry sectors, or technology domains.

This Interim Standard may be tailored for a specific domain, organization, or program.

This Interim Standard is intended to neither specify nor encourage the use of any particular implementation method or tool. The using organization is responsible for selecting those methods or tools necessary to support the objectives of the organization and program, and to define and implement engineering policies and procedures.

Annexes A and B are normative. Normative annexes are integral parts of the standard that, for reasons of convenience, are placed after all other normative elements. The fact that an annex is normative is made clear by the way in which it is referred to in the text, by a statement to the effect in the foreword, and by an indication at the head of the annex itself.

Annexes C, D, and E are informative. Informative annexes, formerly called appendices, give additional information and are placed after the normative elements of a standard. They do not contain requirements. The fact that an annex is informative is made clear by the way in which it is referred to in the text, by a statement in the foreword, and by an indication at the beginning of the annex itself.

Acknowledgments

This document was developed by a working group with representation from the following organizations:

Electronic Industries Alliance (EIA)
 International Council on Systems Engineering (INCOSE)
 Enterprise Process Improvement Collaboration (EPIC)

The Systems Engineering Capability Model (SECM) working group was formed by the G47 Systems Engineering Committee in accordance with EIA guidelines. The number of representatives from each organization was controlled by the working group charter.

Though all working group members, past and present, have contributed in some degree to this effort, Version 1.0 of this Interim Standard is primarily the result of the efforts of the following individuals:

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This document was generated primarily from information contained within the INCOSE Systems Engineering Capability Assessment Model (SECM), Version 1.50, and the EPIC Capability Maturity Model for Systems Engineering (SE-CMM), Version 1.1. These two source documents, in turn, were built upon previous version(s) of these documents. The contributors to those previous versions are listed in Annex E.

1 Introduction

1.1 Background

In October 1992, the INCOSE formed the Capability Assessment Working Group (CAWG). The CAWG charter included developing “a method for assessing and improving the efficiency and effectiveness of systems engineering” and one of its goals was to develop a Systems Engineering Capability Assessment Model (SECAM). Generation of the INCOSE SECAM was begun in November 1993 and completed as an initial release, Version 1.00, in February 1994. Version 1.00 of the SECAM Assessment Method (then called Supporting Documents) was released in March 1994. Following the initial release, five major updates and several minor updates were made to the INCOSE SECAM and several updates were made to the SECAM Assessment Method. The current release of the INCOSE SECAM is Version 1.50, dated June 1996; the current release of the SECAM Assessment Method is Version 1.50, dated July 1997.

In January 1994, the EPIC (then called Industrial Collaboration) began generating the Capability Maturity Model (CMM) for Systems Engineering (SE-CMM) and completed it as an initial release, Version 1.0, in December 1994. Version 1.0 of the SE-CMM Appraisal Method was released in June 1995. Following the initial release, one update was made to both the EPIC SE-CMM and the SE-CMM Appraisal Method. The current release of the EPIC SE-CMM is Version 1.1, dated November 1995; the current release of the SE-CMM Appraisal Method is Version 1.1, dated 1996.

In March 1996, an effort was initiated under the auspices of the EIA G-47 (Systems Engineering) Committee to merge the current versions of the INCOSE SECAM and its Assessment Method with the current versions of the EPIC SE-CMM and its Appraisal Method. The resulting EIA Systems Engineering Capability Model (SECM) and SECM Appraisal Method will be proposed as a US national standard for the measurement and improvement of systems engineering capability.

1.2 Benefits Associated with the Use of this Interim Standard

Proper implementation of this Interim Standard is intended to improve the capability to perform systems engineering. Improved capability enables an organization to:

- a) Reduce cycle time from concept to deployed system products;
- b) Improve the match of deployed system product capability with stakeholder requirements;
- c) Reduce total ownership cost of system products;
- d) Reduce the number of engineering changes;
- e) Improve system quality;
- f) Improve communications among personnel involved in the engineering of a system;
- g) Improve ability to sustain and upgrade system products after deployment; and
- h) Reduce development risks.

By proper implementation, it is meant that:

- a) Processes, activities, and tasks of this Interim Standard are appropriately tailored (see Annex A and EIA/IS 731-2, *EIA SECM Appraisal Method*);
- b) Skilled personnel are used to accomplish the purpose of this Interim Standard as tailored;
- c) Users of this Interim Standard have training and familiarity with the usage of this Interim Standard.

2 Scope

2.1 Purpose

The purpose of this Interim Standard is to support the development and improvement of systems engineering capability.

2.2 Coverage

The scope of this standard includes all activities that associate with or enable systems engineering. Systems engineering is an inter-disciplinary approach and means to enable the realization of successful systems. In this context, systems engineering is not limited to what either Systems Engineering organizations or Systems Engineers do. Rather it is the interaction of many people, processes, and organizations resulting in the accomplishment of the required activities.

This Interim Standard is intended to provide complete coverage of EIA 632, *Processes for Engineering a System*, and be consistent with both it and Institute of Electrical and Electronic Engineers (IEEE) 1220-1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process*.

2.3 Application

The EIA SECM, EIA 731-1, is to be used in conjunction with the SECM Appraisal Method, EIA 731-2, to develop, improve, and assess systems engineering capability.

This Interim Standard applies to programs and organizations doing systems engineering: small or large; simple or complex; software intensive or not; precedented or unprecedented. It applies to systems that may contain hardware, software, personnel, facilities, data, materials, services, or techniques. This Interim Standard is applicable to the engineering of a new system or the reengineering of a legacy system, or portions thereof.

This Interim Standard is intended solely to be used for self-development, self-improvement, and self-appraisal. Organizations should not apply this Interim Standard to suppliers as a means of source selection or as a means of qualification to be a supplier.

2.4 Limitations

This Interim Standard is not intended to specify the details of “how to” implement process activities. It does not specify the methods or tools a developer would use to accomplish required activities. The developer will select methods, techniques, and tools that are consistent with program or organization needs, directives, and procedures.

Adherence to this Standard **shall** be entirely voluntary and within the discretion of individual organizations.

This Interim Standard does not prescribe the name, format, content, or structure of documentation. Throughout this Interim Standard, the terms “document” or “documentation” are used to mean a collection of data regardless of its medium.

This Interim Standard is, to a large extent, a process-based systems engineering capability model. Process maturity indicators were developed first because they were deemed easiest to develop and had received the most attention in other efforts, e.g., ISO initiatives, and other disciplines, e.g., software. This Interim Standard also includes non-process indicators of systems engineering capability. These non-process indicators represent high leverage characteristics of systems engineering capability.

This Interim Standard has not been validated. An inherent, necessary component of validation would be to demonstrate quantitatively that improvement in systems engineering capability, as measured by appraisal results, can lead to a more effective organization. This will be reflected by systems engineering's impact on product development in terms of the "bottom line", such as quicker time to market, lower product cost, reduction in cycle time, etc. Many organizations have utilized the INCOSE or EPIC models and have performed assessments using the applicable methodologies. This standard builds on the experience gained from these models that were deemed to be of value to the organizations that have been assessed.

2.5 Tailoring

This Interim Standard contains a set of Focus Areas, Themes, Practices, and Attributes designed to be tailored. Tailoring (see Annex A and EIA 731-2 for guidance) is deletion of non-applicable Focus Areas, Themes, Practices, and Attributes, or addition of unique or special Focus Areas, Themes, Practices, and Attributes provided in organization policies and procedures, or in an acquirer-supplier agreement.

3 Normative References

EIA 632, *Processes for Engineering a System*

EIA STD 649, *National Consensus Standard for Configuration Management*

IEEE STD 1220 - 1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process*

4 Model Definition

4.1 Using the Model

The SECM is structured to support a wide variety of improvement activities including appraisals, process improvement, and process design. A short description of each is provided here.

Appraisal:

Appraisals may be either self-administered or augmented by expert “facilitators” from inside or outside the organization. This model is intended for internal process improvement. It has not been calibrated or qualified for evaluation of a potential vendor’s capability to perform its systems engineering process. The latter use, vendor selection, could lead to incorrect conclusions about a supplier’s ability to perform, and is not recommended.

Although it is not required that any particular appraisal method be used with the SECM, an appraisal method designed to maximize the utility of the model has been designed by the SECM Project. Part 2 of this Interim Standard, designated EIA 731-2 SECM Appraisal Method, fully describes the recommended method and includes support materials.

Process Improvement:

Either with or without an appraisal to benchmark an organization’s systems engineering practices, an organization may use the SECM for guidance to design an improvement program. There are many sources within industry for approaches to organizational improvement and most should be able to be used with the SECM or adapted for SECM use.

A capability level and improvement method should be developed for each Focus Area, independently of each other. Any process improvement effort, using any reference model, should be constructed to support the business goals of the organization. An organization using the SECM should prioritize the Focus Areas relative to their business goals and strive for improvement in the highest priority Focus Areas first.

Process Design:

The first step in designing processes that will meet the business needs of an enterprise is to understand the business, product, and organizational context that will be present when the process is being implemented. Some questions that need to be answered before the SECM can be used for process design include:

- What life cycle will be used as a framework for this process?
- How is the organization structured to support programs?
- How are support functions handled (e.g., by the program or the organization)?
- What are the management and practitioner roles used in this organization?
- How critical are these processes to organizational success?

An organization must have a stable baseline to determine whether future changes constitute improvements. Appraisals can help in the establishment of such a baseline.

Common sense dictates that there is no value in looking for improvements in a process that the organization does not perform. The model may be tailored to an enterprise’s or program’s needs by selecting appropriate Focus Areas for appraisal or process improvement.

Not all processes look alike or can be measured by the same standards or metrics. An organization may find it useful to include current “delays” and “queues” in the baseline process. During subsequent process improvement efforts, these allow a good starting point for cycle-time reduction.

If an organization defines its process from the point of view of the responsibilities of its systems engineers, it should also define interfaces with the implementing disciplines of software engineering, electrical engineering, mechanical engineering, and more.

The model definition and usage is applicable to both programs and projects. The term “program” is equivalent to “project”. “Program” refers to an inter-related set of activities to produce a product or highly related set of products. “Program” does not refer to an organizational infrastructure.

4.2 Model Architecture

The architecture of the SECM defines its structure and components. The architecture provides a context for understanding the details contained in the model, including the questions asked in the appraisal method, and the levels of capability defined in the model.

4.2.1 Model Structure and Components

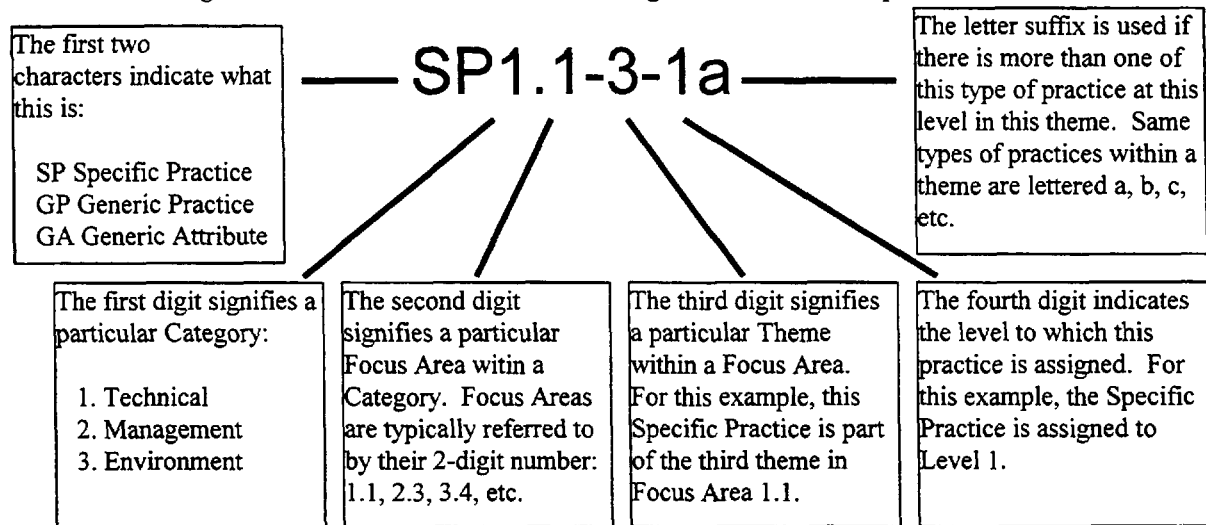
The SECM spans the breadth of Systems Engineering by defining Focus Areas (FA), each of which is defined by a set of unique Specific Practices (SP). Generic Characteristics (GC), which serve as differentiators of the maturity of an organization’s capability to perform Systems Engineering, provide depth to the architecture and are grouped into levels of maturity.

The components of the model are defined as follows:

Categories	A Category is a natural grouping of Focus Areas. The three categories are: Technical, Management, and Environment.
Focus Areas	A Focus Area is a set of related, unique practices that address some aspect of Systems Engineering. There are 19 Focus Areas assigned to 3 Categories.
Themes	A Theme is a subdivision of a Focus Area that defines a related set of Specific Practices. Themes put lists of practices in context.
Specific Practices	A Specific Practice is an activity that is essential to accomplishing the purpose of a Focus Area or that helps accomplish the purpose of the Focus Area more effectively or efficiently. A Specific Practice will not be generic to all Focus Areas. Specific Practices are associated with specific levels of capability within each Focus Area.
Generic Practices	A Generic Practice is an activity that, when applied to the Specific Practices of a Focus Area, enhances the capability to perform those practices. Generic Practices are applicable to any Focus Area.
Generic Attributes	A Generic Attribute is an assessment of the effectiveness of the applied process and of the value of the products of the process. Generic Attributes are applicable to any Focus Area.

The model architecture is depicted in Figures 1, 2 and 3. Figure 1 illustrates the numbering scheme for the elements of the model.

Figure 1. Model Architecture: Numbering Scheme and Description



4.2.1.1 Categories of Focus Areas

Focus Areas fall into three natural groupings, or categories: Technical, Management, and Environment.

Technical Focus Areas

These practices are indicative of the technical aspects of the field of Systems Engineering. They correspond strongly with the definitions and practices contained in two prominent standards for Systems Engineering, EIA 632, *Processes for Engineering a System*, and IEEE STD 1220-1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process*.

Management Focus Areas

These practices support the Technical Focus Areas through planning, control and information management. The practices of the Management Focus Areas couple corresponding practices from the standards for Systems Engineering with industry-wide best practices intended to promote efficiency, and hence cost-effectiveness, in the execution of the Systems Engineering process.

Environment Focus Areas

These practices enable sustained execution of the Systems Engineering process throughout an organization or enterprise and ensure the alignment of process and technology development with business objectives. These practices support the Technology and Management Focus Areas.

Figure 2. Model Architecture: Relationship of Categories, Focus Areas, Themes, Practices, and Attributes

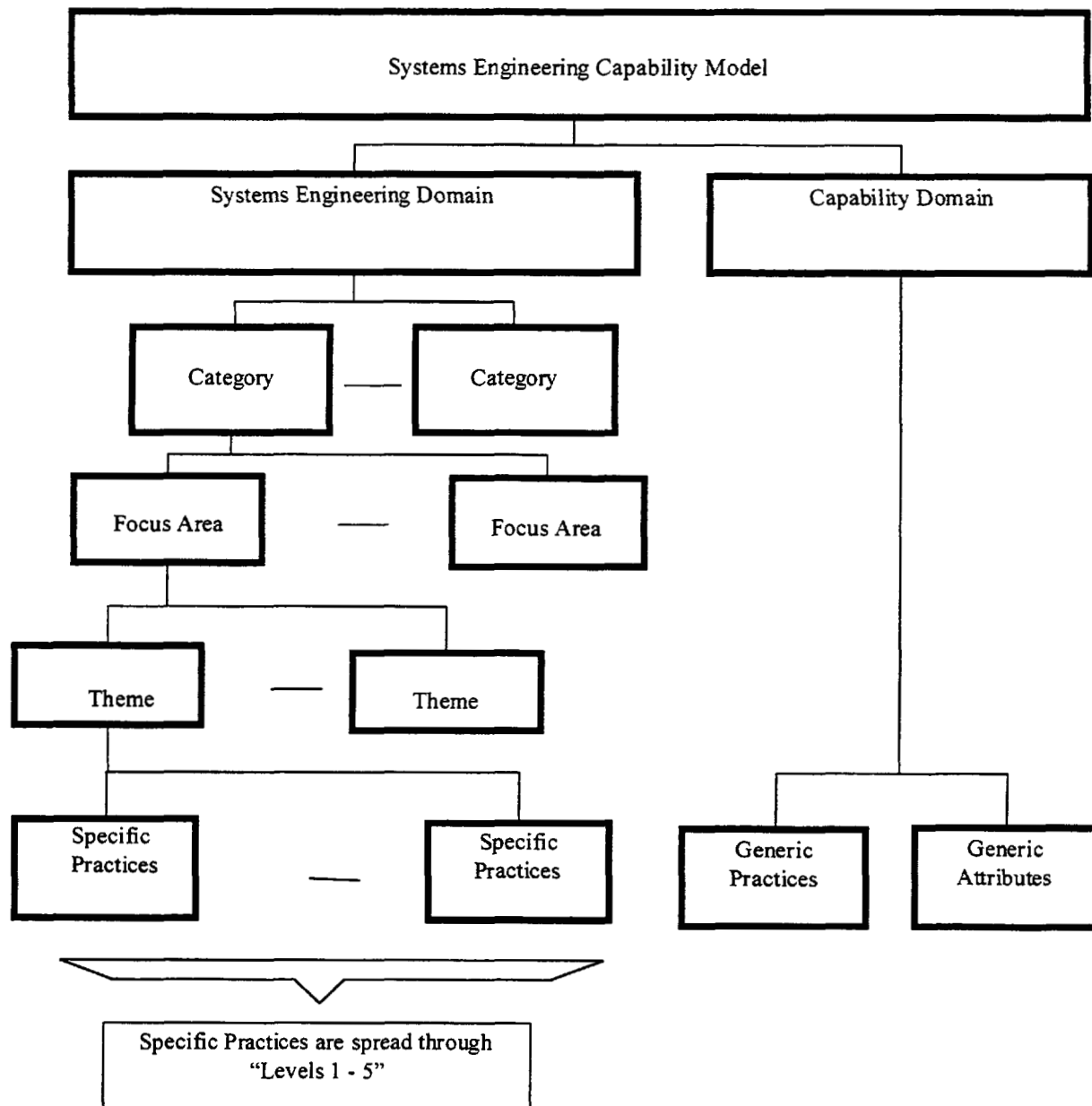
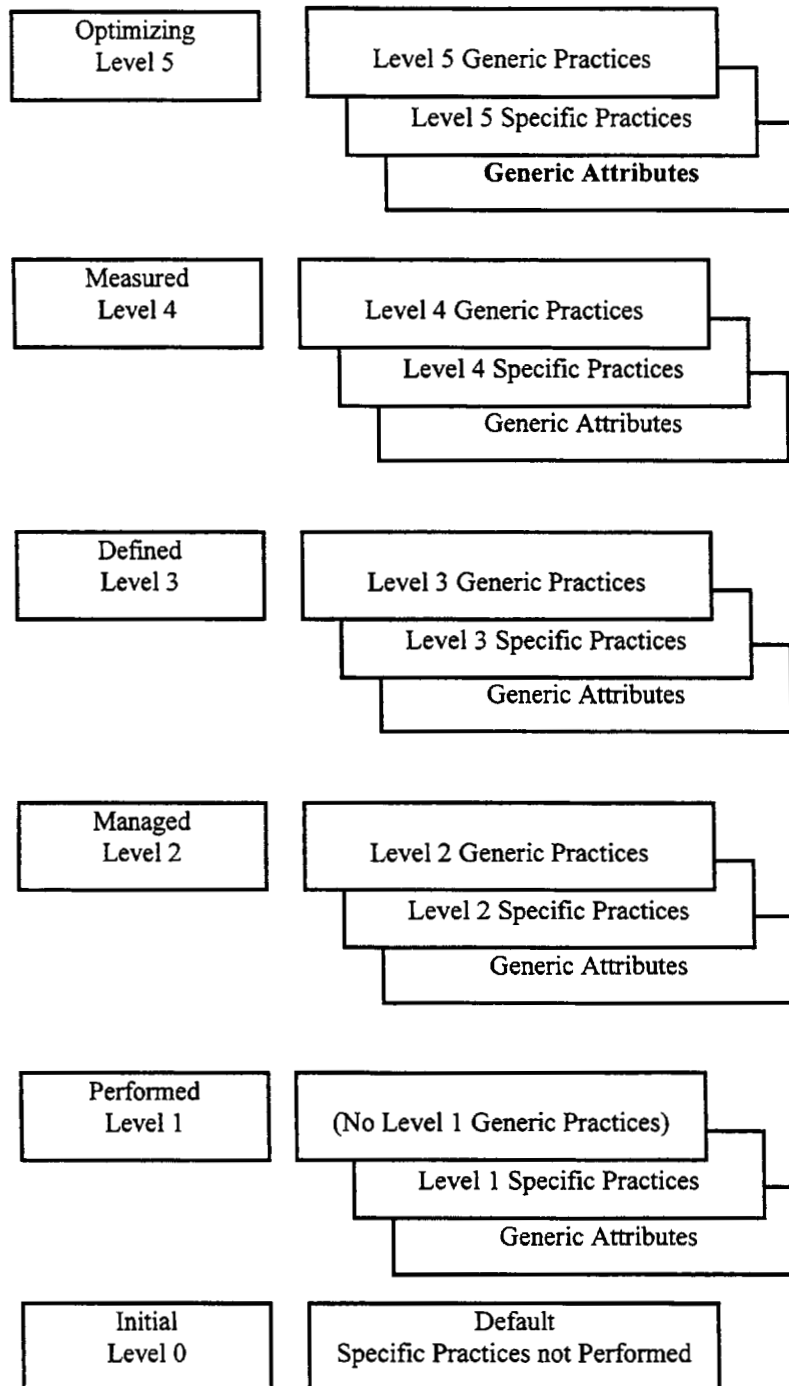


Figure 3. Relationship of Specific Practices and Generic Practices and Attributes to Levels of Capability



Note: Being "at a level" means doing all of the practices (Generic and Specific) at that level in a manner consistent with the descriptions of the Generic Attributes at that level.

4.2.2 Capability Levels and Their Basis

There are six levels of capability. As shown in Table 1, each level of capability has practices and attributes associated with process and non-process characteristics, respectively. The lowest level is "Level 0", and the highest is "Level 5". Characteristics of Level 5 represent the highest, or optimal, level of performance.

Process attributes address the manner in which the practices of each Focus Area are performed. Non-process attributes are indicative of the judgement used in executing the Focus Area practices, the effectiveness of the work, and the value of the work and work products.

Generic Practices are somewhat related to the Software Process Improvement Capability dEtermination (SPICE) Project. Generic Attributes are derived from SECAM.

Capability levels are defined based on widely observed plateaus of performance that organizations typically achieve as they strive to improve their business processes and systems engineering activities. They can be used as goals, guidance, benchmarks, or other means to assist an organization in structuring its improvement efforts.

The combination of performance in conducting the Specific Practices, Generic Practices, and Generic Attributes of the Focus Areas in a category indicates the capability level of an organization. Figure 4 shows an example appraisal chart for the Technical Category.

Figure 4. Example Appraisal Chart for the Technical Category

	Level 1 Specific Practices are performed Results are at least of marginal utility	Level 2 Specific Practices are performed Level 2 Generic Practices are performed Results are at least of adequate utility	Level 3 Specific Practices are performed Level 3 Generic Practices performed Results are of at least significant utility	Level 4 Specific Practices are performed Level 4 Generic Practices performed Results are at least of measurably significant utility	Level 5 Specific Practices are performed Level 5 Generic Practices performed Results are of optimum utility
	1.0	2.0	3.0	4.0	
1.1 Define Stakeholder & System Level Reqts	■				
1.2 Define Technical Problem	■	■			
1.3 Define Solution	■	■	■		
1.4 Assess and Select	■	■	■	■	
1.5 Integrate system	■	■	■	■	■
1.6 Verify System	■	■	■	■	■
1.7 Validate System	■	■	■	■	■
	Level 1	Level 2	Level 3	Level 4	Level 5

Table 1 - Capability Levels

Capability		Process	Non-Process
0	Initial	• Practices are not performed • general failure to perform activities • no easily identifiable work products • no proof tasks are accomplished	• activities and work products have little effectiveness or value • no assurance of success • information is difficult to identify • driving force for activities is indeterminate • no assurance of complexity management • no focus on the principles of systems engineering
1	Performed	• Specific Practices are performed • activities are done informally • non-rigorous plans and tracking • dependency on “heroes” • work products are in evidence • general recognition of need for activity	• activities are marginally effective and work products are of marginal utility • information is ad hoc • activities are driven only by immediate contractual or customer requirements • SE focus limited
2	Managed	• Specific Practices are performed, and performance is characterized by the Level 2 Generic Practices • policies define need for activities • processes are program specific • activities are planned, tracked, measured and verified • corrective actions are taken to assure the program specific process is followed • work products are reviewed for adequacy • defects are removed from work products • work products are controlled	• activities are adequately effective and work products are of adequate utility • key information managed • activities driven by customer and stakeholder needs in a suitable manner • SE focus is requirements through design
3	Defined	• Specific Practices are performed, and performance is characterized by the Level 3 Generic Practices • processes are well defined • the organization has a standard systems engineering process • tailoring guidelines exist for the standard systems engineering process • the standard systems engineering process is tailored and used by each program • tailoring is reviewed and approved • customer feedback is obtained	• activities are significantly effective and work products are of significant utility • consistent program success • information is managed and integrated • activities driven by benefit to program • SE focus is requirements through operation

Table 1 - Capability Levels (continued)

Capability	Process	Non-Process
3 Defined (continued)	• data are collected on the performance of the tailored process • qualitative process improvement is performed on both standard and tailored processes	
4 Measured	• Specific Practices are performed, and performance is characterized by the Level 4 Generic Practices • metrics are derived from data on the tailored process • the tailored process is quantitatively understood • performance of the tailored process can be predicted • tailored process induced defects are identified • measurable quality goals are established for systems engineering work products • causal analyses are performed for the tailored process • tailored processes are quantitatively improved • standard process continues to be qualitatively improved	• activities are measurably effective and work products are of measurably significant utility • all information fully integrated • activities driven by systems engineering benefit • SE focus on all phases of product life cycle
5 Optimizing	• Specific Practices are performed, and performance is characterized by the Level 5 Generic Practices • process effectiveness goals are established for the program based upon business objectives • causal analyses are performed for the standard process • standard processes are quantitatively improved • improvements to the standard process are flowed down into each tailored process	• activities are effectively balanced and work products effectively provide their intended utility • activities driven by systems engineering and organizational benefit • complexity management is fully scaleable • SE focus is product life cycle & strategic applications

4.3 Generic Characteristics

This section contains the Generic Characteristics (Generic Practices and Generic Attributes) that express the process and non-process capability aspects of the model. These Generic Characteristics are used to define the process capability levels as defined in the system architecture.

Process characteristics tend to describe, with increasing levels of capability, how well the process for a particular FA is defined, institutionalized, and followed. The process aspects of the capability levels of this model are derived from the International Standards Organization (ISO) Software Process Improvement Capability determination (SPICE) Basic Practices Guide (BPG). The generic process characteristics of the SECM are aligned with the ISO SPICE BPG generic practices.

The non-process attributes tend to describe, with increasing levels of capability, how effective a process is and how valuable are its products. Non-process attributes are intended to provide a “sanity check” on the level of capability indicated by the process attributes.

The SECM defines a level of capability for performing the practices of a Focus Area by combining Generic Characteristics with Specific Practices. Generic Characteristics are comprised of process-oriented Generic Practices (GP) and non-process-oriented Generic Attributes (GA). Generic Characteristics are so-called because each one applies equally well to the practices of every Focus Area. For example, a Generic Practice that requires tailoring of a standard process is used for assessing Define Solution, Ensure Quality, Manage Technology, and so on. Figure 3 shows how Generic Characteristics combine with Specific Practices to define a capability level.

4.3.1 Generic Practices

A Generic Practice is an activity that, when applied to the Specific Practices of a Focus Area, enhances the capability to perform those practices. Generic Practices are applicable to any Focus Area, and are grouped into levels.

Level I. Performed

Description:

There are no Generic Practices in Level 1.

Level II. Managed

Description:

Activities are planned and tracked. Performance according to specified procedures is verified. Work products conform to specified standards and requirements. The organization uses measurement to track Focus Area performance, thus enabling the organization to manage its activities based on actual performance. The primary distinction from the Performed Level is that the performance of the process is planned and tracked. There are 2 Generic Practices at Level II.

GP 2.1 Follow recorded and approved plans and processes, that were developed to meet program performance goals, in implementing the Focus Area.

Description:

The following activities are examples of evidence of this generic practice:

- Plan the performance of the process in accordance with the established program goals (such as profit, customer satisfaction, schedule delivery and quality goals).
- Document the approach to performing the activities of the Focus Area that meets the program performance goals (such as profit, customer satisfaction, schedule delivery & quality goals) in standards or procedures.
- Use the documented plans, standards, or procedures in implementing the process for the program.
- Assign responsibilities for developing the work products and providing the services of the Focus Area.
- Allocate adequate resources including people, training, tools, budget, and time for performing the Focus Area.

Notes:

1. At this level reasonable processes are documented at the program level. A reasonable process is practiced, documented, enforced, trained, and measured.
2. Plans for Focus Areas in the Systems Engineering Technical and Management Categories may be in the form of a program plan, whereas plans for the Systems Engineering Environment Category may be in the form of an organizational policy.
3. Processes in an organization or on a program need not correspond one-to-one with the Focus Areas in the SECM. Therefore, a program's process addressing a Focus Area may be described in more than one way (e.g., policies, standards, and procedures). Similarly, a program's process description may span more than one Focus Area. Process measures should be defined in the standards, procedures, and plans.

Relationship to other Generic Practices:

A vertical theme occurs where a practice at a lower level relates to one at a higher level. Vertical themes occur in Generic Practices as well as in the Focus Area. In this case, GP 2.1 evolves to GP 3.3.

GP 2.2 Verify compliance with approved plans and processes, and take appropriate action when performance deviates from plan or when processes are not followed.

Description:

The following activities are examples of evidence of this Generic Practices:

- Verify compliance of the process and work products with applicable standards and procedures.
- Track the status of the Focus Area against the plan using measurement.
- Take corrective action as appropriate when progress varies significantly from that planned.

Notes:

1. Building a history of measures, such as cost and schedule variances, is a foundation for managing by data quantitatively by fact, and is begun here.
2. Progress may vary because estimates were inaccurate, performance was affected by external factors, or the requirements, on which the plan was based, have changed. Corrective action may involve changing the process(es), changing the plan, or both.

Relationship to other Generic Practices:

The applicable standards and procedures were documented in GP 2.1.

This Generic Practice evolves to GP 3.4, GP 4.1, GP 4.2, GP 5.2, GP 5.3 and GP 5.4.

Level III. Defined

Description:

Activities are performed according to a well-defined process using approved, tailored versions of standard, documented processes. The primary distinction from the Managed Level is that the process is planned and managed using an organization-wide standard process. The organization's standard process is improved qualitatively. There are four Generic Practices at Level III.

GP 3.1 Standardize and record a well-defined FA process for the organization that is designed to meet specific business goals, and is based on experiences captured from previous programs.

Description:

Document a well-defined standard process or family of processes for the organization that describes how to implement the specific practices of the process. A well-defined process is characterized by:

- entrance criteria,
- inputs,
- standards and procedures,
- verification mechanisms (such as defect reviews),
- outputs,
- completion criteria, and
- metrics.

An organization's standard process (or processes) should be well defined. When the organization's standard process is well defined, a program may create a well-defined process for its use by tailoring the organization's well-defined process to meet program needs.

Notes:

1. The critical distinction between generic characteristics GP 2.1 and GP 3.1 in the Level 2 and Level 3 process descriptions is the scope of application of the policies, standards, and procedures. In GP 2.1, the standards and procedures may be in use in only a specific instance of the process, e.g., on a particular program. In GP 3.1, however, policies, standards, and procedures are being established at an organizational level for common use throughout the organization, and are termed the "standard process."
2. The organization may define more than one standard process to address differences among application domains, customer constraints, etc. These related standard processes are termed a "standard process."

family.” The members of a standard process family are typically similar in their descriptions of how and in what order tasks are done. They typically differ in customer constraints, application domain (technology), etc.

3. Processes in an organization or on a program need not correspond one-to-one with the Focus Areas in the SECM. Therefore, a program’s process addressing a Focus Area may be described in more than one way (e.g., policies, standards, and procedures). Similarly, a program’s process description may span more than one Focus Area. Process measures should be defined in the standards, procedures, and plans.

Relationship to other Generic Practices:

The Level 3 standard process description is tailored in GP 3.2.

GP 3.2 Tailor the organization’s standard process using standard guidelines to meet specific program or organizational needs.

Description:

Tailor the organization’s standard process family to create a well-defined process that addresses the particular needs of a specific use. Tailoring creates a program’s defined process.

Relationship to other Generic Practices:

The organization’s standard process (family) is documented in GP 3.1. The tailored process definition is used in GP 3.3.

GP 3.3 Implement and improve the FA activities (i.e., tailored process) per established and approved formal procedures.

Description:

Use the tailored, well-defined process in implementing the Focus Area.

Relationship to other Generic Practices:

This GP is related to GP 3.2.

GP 3.4 Improve the organization’s standard process using information from work product reviews and process compliance reviews.

Description:

Review the work products and the process implementation for compliance with requirements. Use data from reviews to improve the standard process.

Notes:

1. An example would be classification of defects by program phase (e.g., requirement, design) in which they were introduced, detected, and corrected.
2. Defect reviews are sometimes called peer reviews. The purpose of defect reviews is to identify sources of error in early or interim systems engineering work products.
3. Data collection, analysis, and reporting are planned, and benefit both control and improvement activities. Data are used, as in GP 2.2, to track and initiate corrective action when deviations from planned performance are significant. Data are also used as a basis for identifying and prioritizing improvement

opportunities. In addition, data should be collected on experiments or pilots of new or improved process elements, so as to understand their success or failure.

Relationship to other Generic Practices:

This practice is related to GP 2.2. GP 3.4 improves the standard process of GP 3.1. In addition, all of Level 4 Generic Practices builds on this Generic Practice.

Level IV. Measured**Description:**

Level IV activities apply measurements to the process. Metrics are defined for the organization and programs, and mechanisms are in place to track program and organizational performance quantitatively, and to take corrective actions on the basis of those measures. There are two Generic Practices at Level IV.

GP 4.1 Collect and analyze metrics to determine the performance of the tailored FA activities.**Description:**

Detailed measures of performance are collected and analyzed. This leads to a quantitative understanding of process capability and an improved ability to predict performance. Performance is objectively managed, and the quality of work products is quantitatively known. The primary distinction from the Defined Level is that the tailored process is quantitatively understood and controlled.

Process performance of the tailored FA activities can be quantitatively characterized by (1) the extent to which the process is followed and (2) the cost, schedule, and quality of the product resulting from performing the process. To accomplish these performance characterizations for those repeatable processes under similar conditions: (1) collect data for each execution of the FA process and (2) analyze the aggregate data obtained from repeated execution of the FA process over similar programs to determine the process performance.

Notes:

1. This is a quantitative process capability based on a well-defined GP 3.1 and measured process. Measurements are inherent in the process definition and are collected as the process is being performed.
2. Methods and techniques for analyzing data and determining performance quantitatively may include the use of histograms, cause and effect diagrams, check sheets, Pareto diagrams, graphs, control charts, scatter diagrams, trend charts, or other statistical process control (SPC) improvement techniques.

GP 4.2 Take appropriate action to align tailored FA performance and expectations.**Description:**

Take corrective action as appropriate when the process is not performing either as planned or as predicted.

Notes:

1. Actions may include cost analysis, specification changes, schedule or contract modifications, acceptance of risk, or implementation of process changes based on the analysis of the metrics.
2. For those processes that are repeatable, special causes of variation, identified based on an understanding of process capability, are used to understand when and what kind of corrective action is appropriate.

Level V. Optimizing

Description:

The organization establishes quantitative performance goals (targets) for process effectiveness and efficiency based on its business goals. The organization is able to continuously improve its process by gathering quantitative data from performing the processes and from piloting innovative ideas and technologies. The primary distinction from the Measured Level is that both the tailored process and the standard process undergo continuous refinement and improvement, based on a quantitative understanding of the impact of changes to these processes. There are four Generic Practices at Level V.

GP 5.1 Identify FA activities for which it is appropriate, and inappropriate, to quantify process repeatability.

Description:

A criteria for quantifying process repeatability is that a statistically significant number of cycles of the process can be performed under stable conditions. This generic practice requires that statistical or quantitative techniques be employed in a sound manner.

GP 5.2 Establish quantitative goals for improving the effectiveness of the standard process.

Description:

Establish quantitative goals for improving process effectiveness of the standard process family based on the business goals of the organization.

GP 5.3 Improve the organization's standard process based on data and metrics collected from a continuing program of process compliance reviews and work product reviews.

Description:

The goal of improving the standard process is to reduce common causes of variation. Continuously and quantitatively improve the process by changing the organization's standard process family to increase its effectiveness.

Notes:

The information learned from managing individual programs is communicated back to the organization for analysis. Changes to the organization's standard process family may come from innovations in technology or incremental improvements. Innovative improvements are often externally driven by new technologies. Incremental improvements will usually be internally driven and are often the results of tailoring the standard process by a program.

Relationship to other Generic Practices:

Improvements will typically be driven by the goals in GP 5.2

GP 5.4 Perform causal analysis of process and work product defects and eliminate causes of variation in quality, cost, and cycle time by changing the standard process.

Description:

Perform causal analysis of defects. Eliminate the causes of defects in the defined process selectively.

Notes:

1. Those who perform the process are typically participants in this analysis. This is a proactive causal analysis activity as opposed to reactive. Defects from prior programs of similar attributes can be used to target improvement areas for the new effort.
2. Defect causes are selectively eliminated because it may be impractical to perform causal analysis on all defects. In this case, some screening may be used.

Relationship to other Generic Practices:

GP 5.3 may be one source of improvements. Goals were established in GP 5.2.

4.3.2 Generic Attributes

Description:

The Generic Attributes address the effectiveness of the process and the value of the products of the process. Both of these are viewed over a range that is related to capability levels 1 - 5. With each increasing level, the worth of the product and process should increase. To be of maximum benefit, Focus Area (FA) activities must be performed in an effective manner, and the work products must be of value to the program. Good engineering judgment must be applied. The effectiveness of the activities and the value of the work products (marginal, adequate, significant, measurably significant, or optimal) are indicative of the level of performance.

GA-1*: Implement an effective set of FA activities (See Table 2).

GA-2*: Produce a valuable set of FA products (See Table 2).

*** The numbering of the Generic Attributes does not include a level. The levels are determined by the definitions in Table 2.**

Table 2 - Definition of Generic Attributes

Capability Level	Criteria	Generic Attribute 1: Effectiveness	Generic Attribute 2: Value
		<i>A measure of the performance of an activity. SECM characterizes effectiveness as marginal, adequate, significant, measurably significant, and optimal. These are defined as:</i>	<i>A measure of the desirability of the products of an activity. SECM characterizes value as marginal, adequate, significant, measurably significant, and optimal. These are defined as:</i>
1 Performed	Marginal	Effort is being expended but it is not clear that the benefits received for the effort invested are worth the cost of the effort. The effort could be removed without causing significant impact to the program or organization.	Products are generated by the activity, but it is not clear that the products are of use to those for whom they are intended. The products could be removed without causing significant impact to the program or organization.
2 Managed	Adequate	Effort is being expended and the activities provide reasonable benefit to the program or organization.	Products generated by the activity provide reasonable benefit to those that use them. Products providing adequate value are generally used by those for whom they are intended.
3 Defined	Significant	Effort being expended is obviously beneficial to the program or organization.	Products generated by the activity are obviously beneficial to those that use them. Products of significant value are avidly sought out and used by those for whom they are intended.
4 Measured	Measurably Significant	Effort being expended and the benefit are measured and found to be significant to the program or organization	The benefits of each product generated by the activity are measured and found to be of significant value to the program or organization.
5 Optimizing	Optimal	Effort expended is providing maximum benefit for the amount of effort, i.e., more effort results in a diminishing return to the program or organization.	Value of the products generated by the activity are of maximum utility to the program or organization.

5 Focus Areas

This section defines each of the nineteen Focus Areas, grouped into three categories, which comprise the EIA SECM. Each FA segment consists of a general description of the FA. The practices within each FA are organized into five levels of systems engineering capability; a sixth, and lowest, level of capability is a default level that contains no questions.

The numbering of each FA indicates the Category to which it belongs, as follows:

TC 1.0 Systems Engineering Technical Category

- FA 1.1 Define Stakeholder and System Level Requirements
- FA 1.2 Define Technical Problem
- FA 1.3 Define Solution
- FA 1.4 Assess and Select
- FA 1.5 Integrate System
- FA 1.6 Verify System
- FA 1.7 Validate System

TC 2.0 Systems Engineering Management Category

- FA 2.1 Plan and Organize
- FA 2.2 Monitor and Control
- FA 2.3 Integrate Disciplines
- FA 2.4 Coordinate with Suppliers
- FA 2.5 Manage Risk
- FA 2.6 Manage Data
- FA 2.7 Manage Configurations
- FA 2.8 Ensure Quality

TC 3.0 Systems Engineering Environment Category

- FA 3.1 Define and Improve the Systems Engineering Process
- FA 3.2 Manage Competency
- FA 3.3 Manage Technology
- FA 3.4 Manage Systems Engineering Support Environment

FA 1.1 Define Stakeholder and System Level Requirements

A Focus Area for the Systems Engineering Technical Category

Description:

Define Stakeholder and System Level Requirements produces a validated set of system-level requirements (technical, support, interface) which reflect stakeholder needs and expectations. To accomplish this purpose, the Focus Area includes collection and coordination of stakeholder needs, development of an operational concept, and analysis of needs and requirements. These practices are supported by definition of alternative and preferred system concepts developed in FA 1.3 - Define Solution.

Stakeholders include customer/users, developers, producers, testers, suppliers, marketers, maintainers, disposers and others who may be affected by, or may affect, the system or product. Needs and expectations are elicited, stimulated, analyzed, and communicated to obtain the system technical requirements which constitute a common, quantitative, understanding of what will satisfy all stakeholders. Define Stakeholder and System Level Requirements includes engaging all stakeholders in an ongoing dialogue to translate needs and expectations into a concept of operations, system concept and a verifiable set of requirements, technological limitations, cost drivers, time drivers and risks, which the stakeholders understand and which provide the basis for agreements between the acquirer/customer/user and the developer. Suppliers and developers engage in a continuing solicitation of feedback from customer/users to establish and maintain the validity of requirements. Stakeholder needs, objectives, and requirements are analyzed in relation to mission operations, operational environments and desired system characteristics to derive alternative system concepts which unify the system feature, function, performance, and costs. System concepts are used to define and communicate requirements with the customer. The evolution and impact of evolving stakeholder requirements and technological constraints and features on systems/products are planned and managed.

Notes:

Since this Focus Area supports the dialogue between those performing systems engineering and the customer/user, all other Focus Areas will use this Focus Area to keep stakeholders informed throughout the program life cycle. Customer, as used here, denotes either a directly contracted customer, an internal customer, or a customer surrogate who represents a particular market segment in a market-driven, multi-customer industry. In addition to being identified and collected, needs and expectations are elicited (stimulated) from stakeholders by such means as demonstrating new technology or improved methods for solving operational problems. This FA has strong interaction with development of system concepts in FA 1.3 and integrated with all technical category FA's to provide the customer interface. Outputs of this FA, such as system requirements, are baselined and controlled by the practices of FA 2.7 - Manage Configurations.

References:

Not Applicable.

Themes of Define Stakeholder and System Level Requirements:

- 1.1-1 Stakeholder Needs
- 1.1-2 System Level Requirements

Theme Descriptions, Typical Work Products, and Practices:

1.1-1 Stakeholder Needs

Description:

Frequently, stakeholder needs and expectations are poorly identified or conflicting. Stakeholder needs and expectations, as well as customer limitations, must be clearly identified and prioritized. An iterative process is used throughout the life of the program to accomplish this. In the case of non-negotiated situations, the surrogate for the user or customer stakeholder is frequently the customer relations or marketing part of the organization. Environmental, legal, and other constraints which may be external to the customer must also be applied when creating and resolving the set of system requirements.

Comments:

Examples of techniques to identify and elicit needs include:

- Technology demonstrations
- Interface control working groups
- Technical control working groups
- Interim program reviews
- Questionnaires, interviews, operational scenarios obtained from users
- Prototypes and models
- Brainstorming
- Quality Function Development (QFD)
- Market surveys
- Beta testing
- Extraction from documents, standards, specifications, etc.
- Observation of existing systems, environments, and workflow patterns

Typical Work Products:

- Technical performance measures
- Draft requirements
- Needs statement
- Operational concepts
- Operational requirements
- Results of requirement reviews
- Needs issues/conflicts
- Stakeholder baseline
- Quality Function Deployment Needs Matrix
- Quality Function Deployment Requirements Matrix

Specific Practices:

- | | |
|-------------|---|
| SP 1.1-1-1 | Identify, collect and baseline stakeholder needs, expectations and constraints. |
| SP 1.1-1-2a | Elicit or stimulate stakeholder needs. |
| SP 1.1-1-2b | Prioritize stakeholder needs, expectations and constraints. |
| SP 1.1-1-3a | Review, coordinate, and deconflict stakeholder needs and constraints. |
| SP 1.1-1-3b | Inform stakeholders on a regular basis about the status and disposition of needs, expectations, or measures of effectiveness. |

1.1-2 System Level Requirements

Description:

The needs of all stakeholders (customers, users, suppliers, builders, testers, etc.) are considered in determining a set of system or product requirements. Analyses are performed to determine what impact the intended operational environment will have on the ability to satisfy the customer's needs and expectations. Feasibility, mission needs, cost constraints, potential market size, etc., must all be taken into account, depending on the product context. The objectives of the analyses are to determine system concepts that will satisfy stakeholder needs and expectations, and then translate these concepts into system / product requirements. In parallel with this activity, the parameters that will be used to evaluate the effectiveness of the system or product are determined based on customer input and the preliminary system concept. Once a complete set of stakeholder needs and expectations and a preliminary operational and system concept are available, they are translated into system requirements.

Comments:

A role of systems engineering is often to help the customer formulate complete concepts. The customer's needs and expectations should be probed to ensure that the developer adequately understands them and has prioritized them correctly. Expression of logistics, support, maintenance, and training considerations are ways to capture system needs for feedback to the customer. Cost, feasibility, and risk should be considered in determining which requirements will be pursued. Examples of formal methods used to analyze needs include:

- Quality Function Deployment (QFD)
- Trade studies
- Mathematical techniques (design of experiments, sensitivity analysis, timing, sizing, simulation)
- Prototypes

System requirements may be initially provided by the customer. In this case, systems engineering performs a "validation" of these requirements by finding the inconsistencies or deficiencies, challenging infeasible or poor requirements, and negotiating changes as necessary. In other cases, the system engineering effort creates the entire set of system requirements. System requirements may be documented using a customer-specified format or development organization format.

Typical work products:

- System requirement documents or specifications
- Operational concept
- System cost objectives
- System installation, operational, maintenance and support concepts
- Disposal concepts
- Technical parameters
- Market-segment description
- System requirements baseline
- Requirement verification traceability matrix

Specific Practices:

- | | |
|-------------|---|
| SP 1.1-2-1a | Analyze and quantify functionality required by users. |
| SP 1.1-2-1b | Transform customer/user requirements into a set of system level requirements. |
| SP 1.1-2-1c | Define a system requirements baseline. |
| SP 1.1-2-1d | Obtain an agreement between acquirer and developer that system level requirements reflect their needs and expectations. |
| SP 1.1-2-2a | Develop operational concepts and scenarios, which include functionality, performance, maintenance, support and disposal as appropriate. |

SP 1.1-2-2b	Review adequacy of system requirements to meet stakeholder needs with key stakeholders.
SP 1.1-2-2c	Review operational concepts and scenarios to refine and discover requirements
SP 1.1-2-2d	Record system requirement decisions that have a significant effect on cost, technical or schedule performance, and the rationale for the decisions.
SP 1.1-2-2e	Define the environment the system will operate in, including boundaries and constraints.
SP 1.1-2-3a	Negotiate an agreement between stakeholders and developers that system level requirements represent an optimum balance of their needs and expectations.
SP 1.1-2-3b	Allow for expansion and growth in system requirements.
SP 1.1-2-3c	Analyze and quantify functionality indicated by stakeholder requirements.
SP 1.1-2-4	Perform analyses, simulations or prototypes to assure that system requirements will satisfy stakeholder needs and expectations.

FA 1.2 Define Technical Problem

*A Focus Area for the Systems Engineering **Technical** Category*

Description:

Define Technical Problem includes development and evolution of the functional architecture, requirements management, establishment of lower level requirement baselines and generation of requirement specifications. This includes the further refinement of system level requirements into a complete set of detailed technical requirements. Requirements are derived or decomposed and allocated to system functions, people, associated processes or services. A hierarchy of logical entities (functions and subfunctions or object classes and subclasses) is established through iteration with the evolving operational concept. Requirements are refined, derived and allocated to the logical entities. The derivation of system requirements includes identifying requirements that are necessary from the standpoint of practical, economical system design, manufacturing, and support, and consideration of existing systems from which the system might evolve. System design is based on this complete set of system requirements. These activities are conducted iteratively to ensure requirements are satisfied, and as feasible solution alternatives are defined and refined.

Define Technical Problem analyzes requirements in light of the concept of operations (including functionality, support, maintenance and disposal) and derives a more detailed and precise set of requirements. Derived requirements arise from constraints, consideration of issues implied but not explicitly stated by the customer or user, and factors introduced by the developer's unique business considerations, regulations and laws

The allocated requirements are the basis for the definition of the system solution. The traceability of requirements is captured and maintained throughout the allocation process. User requirements are re-examined with each successive, lower-level set of requirements and functional architecture refinement. Trade studies are used to select the preferred set of requirements and functional architecture from competing alternatives at each level of detail. This is an iterative process. It occurs recursively at successively lower (more detailed) layers of a system's architecture, until sufficient detail is available to enable detailed design, acquisition, and testing of the system to proceed.

Requirements evolve throughout the system life cycle. Design decisions, subsequent corrective actions, and feedback from system operations, support, and disposal are analyzed for their impact on derived and allocated requirements . The subsystem requirements baseline, sometimes referred to as an allocated baseline, is established and maintained as a result of these activities.

Communication and coordination with stakeholders gives them visibility into the evolution of requirements, the evolution of the system operational concept (including maintenance, support and disposal), and system, managing their expectations and assuring them that their requirements are being satisfied. Opportunities to trade off system features for reduced cost and development time are continually presented to the customer.

Notes:

The practices of this Focus Area are executed interactively and in coordination with the activities of FA 1.1 - Define Stakeholder and System Level Requirements and FA 1.3 - Define Solution. FA 1.1 generates a well-defined understanding of the needs of the user, customer, and others who hold a stake in the system design. In turn, the system design, i.e., the detailed description of the hardware, software, and processes that comprise the system, is driven by the system requirements. Outputs of this FA, such as system requirements, are baselined and controlled by the practices of FA 2.7 - Manage Configurations. Requirements are identified in FA 1.1, FA 1.2, and FA 1.3, baselined and documented in FA 1.2, and formally configuration managed in FA 2.7.

References:

Not Applicable.

Themes of Define Technical Problem:

- 1.2-1 Problem Refinement
- 1.2-2 Requirements Analysis
- 1.2-3 Requirements Quality
- 1.2-4 Requirements Evolution and Maintenance
- 1.2-5 Feedback and Verification

Theme Descriptions, Typical Work Products, and Practices:

1.2-1 Problem Refinement

Description:

Define Technical Problem analyzes user requirements in light of the concept of operations and derives a more detailed and precise set of requirements. Derived requirements arise from constraints, consideration of issues implied but not explicitly stated in the customer/user problem baseline, and factors introduced by the developer's unique business considerations. All specified usage modes for the system are considered, and a time line analysis is generated for time critical sequencing of functions.

Typical Work Products:

- Derived requirements
- Interface requirements
- Functional architecture
- Requirement status (e.g., traceability, acceptance, issues)
- Updated stakeholder requirements
- Updated concept of operations
- Updated maintenance concept
- Updated support concept
- Updated disposal concept

Specific Practices:

- SP 1.2-1-1a Develop a detailed operational concept of the interaction of the system, the user, and the environment, that satisfies the operational, support, maintenance, and disposal needs.
- SP 1.2-1-1b Derive, from the system and other (e.g., environmental) requirements, requirements that may be logically inferred and implied as essential to system effectiveness.
- SP 1.2-1-1c Identify key stakeholder requirements and constraints that have a strong influence on cost, schedule, functionality, risk, or performance.
- SP 1.2-1-2a Identify and manage non-technical requirements concurrently with operational, functional, support, maintenance and disposal requirements.
- SP 1.2-1-2b Balance system and development cost and complexity, schedule, performance, and capabilities of existing designs and products in all trade studies using established criteria.
- SP 1.2-1-2c Capture relationships between requirements for consideration during change management and requirements allocation.
- SP 1.2-1-2d Maintain this status of requirements.
- SP 1.2-1-3 Use validated models, simulations, and prototyping to reduce cost and risk of system development.

1.2-2 Requirements Analysis

Description:

A functional architecture is established, and the system requirements are allocated to system functions, objects, people, and processes. The allocated requirements are the basis for the synthesis of the system solution (the system design). The traceability of requirements to functions, objects, etc., is captured and maintained. The user requirements are re-examined with each successive, lower-level set of requirements and functional architecture, and the preferred system concept is refined. Trade studies are used to select the preferred set of requirements and functional architecture from competing alternatives at each level of detail. Prior requirements analyses are reviewed and updated. Inputs, outputs, and functional interfaces are also defined.

Typical Work Products:

- Derived and allocated baseline
- Functional architecture (functions or objects, behavior, data flow, allocated requirements)
- Interface specifications
- Trade studies
- Requirements traceability matrix

Specific Practices:

- | | |
|-------------|---|
| SP 1.2-2-1a | Partition requirements into groups, based on established criteria (such as similar functionality, performance, or coupling) to facilitate and focus the requirements analysis. |
| SP 1.2-2-1b | Consider the sequencing of time-critical functions both initially and subsequently during system component development. |
| SP 1.2-2-1c | Identify interface requirements associated with things external to the system and internally between functional partitions or objects. |
| SP 1.2-2-1d | Establish a derived requirements baseline, including the allocation of requirements to subsystems and system components. |
| SP 1.2-2-1e | Allocate requirements to functional partitions, objects, people, or support elements to support synthesis of solutions. |
| SP 1.2-2-2a | Maintain requirements traceability to ensure that lower level (derived) requirements are necessary and sufficient to meet the objectives of higher level requirements, and are consistent with the product's functional architecture. |
| SP 1.2-2-2b | Conduct trade studies or decision analyses to select between competing alternatives in all phases of the requirements process, including initial architecture development and subsequently in allocating requirements to lower levels of functional and physical architectures. |
| SP 1.2-2-3 | Capture rationale for system level requirements, derived requirements, allocations, and traceability. |

1.2-3 Requirements Quality**Description:**

Quality criteria for system requirements as well as the system itself should be determined. Requirements quality is measured in terms of attributes such as correctness, completeness, stability, lack of ambiguity, and verifiability. System or product quality is concerned with delivery of a system, free of defects, that fully satisfies the customer's needs, as stated in the requirements. Completeness of requirements requires description of multiple views of the system (physical, functional, interface, timing, etc.) and comprehension of practical design constraints.

Typical Work Products:

- Requirement quality criteria

- Requirements issues
- Records of reviews and corrective actions
- Documented verification criteria
- System quality criteria

Specific Practices:

- SP 1.2-3-1a Analyze requirements to ensure that they are complete, correct, realizable and verifiable.
- SP 1.2-3-1b Develop and document system and subsystem verification criteria concurrently with requirements development.
- SP 1.2-3-2 Formally review or inspect requirements for quality attributes including stability, lack of ambiguity, and traceability to the customer baseline.

1.2-4 Requirements Evolution and Maintenance

Description:

Requirements evolve throughout the system life cycle. Design decisions, subsequent corrective actions, and feedback from system operations are analyzed for their impact on derived and allocated requirements.

Typical Work Products:

- Requirements status
- Requirements decision database
- Trouble reporting system reports
- Change control process
- Requirements management plan
- Requirements traceability verification
- Requirements database

Specific Practices:

- SP 1.2-4-1 Document changes to requirements.
- SP 1.2-4-2a Establish a process for formally and proactively controlling and managing changes to requirements, considering impact prior to commitment to change, gaining stakeholder buy-in, and tracking and closing out the actions and results.
- SP 1.2-4-2b Evaluate the impact of requirement changes from the standpoint of all stakeholders.

1.2-5 Feedback and Verification

Description:

Communication and coordination with stakeholders gives them visibility into the evolution of requirements, the evolution of the system operational concept, and system design. This activity continually manages their expectations and assures them that their requirements are being satisfied.

Typical Work Products:

- Records of stakeholder interactions

Specific Practices:

- SP 1.2-5-1 Formally review requirements with stakeholders
- SP 1.2-5-2a Involve stakeholders in the process of requirements development.

- SP 1.2-5-2b Baseline (describe, capture, and control) and communicate requirements and functional architectures to all stakeholders.
- SP 1.2-5-2c Capture records of communications with stakeholders relative to requirements trade studies and allocations.
- SP 1.2-5-3 Periodically review requirements and their relationship with system functional and physical architectures.

FA 1.3 Define Solution

A Focus Area for the Systems Engineering Technical Category

Description:

Define Solution is the process of transforming system level and lower level technical requirements into documentation of components and interfaces, such that their implementation and integration would satisfy the requirements. It includes the identification of key design constraints and issues, determination of the physical components and interfaces, allocation of requirements to system components, and assuring that the specified system components would meet the requirements if built/purchased/reused and integrated. System requirements are augmented with design constraints imposed by the selected system components. A key concept of Define Solution is the identification of alternatives and selection of a balanced solution in terms of cost schedule and technical performance. The practices of Define Solution are repeated for successive levels of system decomposition to arrive at detailed specifications of design components for implementation by appropriate disciplines. They are first employed to develop a system concept in support of system level requirements. The practices Define Solution make extensive use of FA 1.4 - Assess and Select and are expected to be performed interactively with the practices of FA 1.1 - Define Stakeholder and System Level Requirements and FA 1.2 - Define Technical Requirements.

Notes:

Activities of FA 1.3 - Define Solution are based on the System Level Requirements Baseline, which results from the activities of the FA 1.1 - Define Stakeholder and System Level Requirements Focus Area. Practices for the selection of a preferred solution are addressed in the Assess and Select Focus Area. This Focus Area is concerned with the physical (as distinct from logical/functional) architecture and design.

References:

Not Applicable.

Themes of Define Solution:

- 1.3-1 Design Synthesis
- 1.3-2 Requirements Allocation
- 1.3-3 Design Assurance

Theme Descriptions, Typical Work Products, and Practices:

1.3-1 Design Synthesis

Description:

Alternatives and their relative merits are considered in advance of selecting a solution per the Assess and Select Focus Area. Key requirements, design issues and constraints are established for use in alternative solutions analysis. Architectural features are considered which provide a foundation for system/product improvement and evolution (e.g. the choice of a database with certain interface characteristics might be selected with the expectation that interfaces to the database would be stable over several generations of product evolution). Reuse of Commercial Off The Shelf (COTS) and Non-Developmental Item (NDI) components are considered relative to cost, performance and product maintenance. The rationale for the selected solution and its design features are captured. The rationale for solutions not accepted is also captured and maintained for future reference as the system evolves.

Components of solutions and their interfaces are identified, documented, communicated and maintained for each level of system physical decomposition. External and component interfaces are fully defined in terms of origination, destination, stimulus, data characteristics, and electrical and mechanical properties. The capability of the design solution to meet requirements (design verification) is established throughout design definition, in accordance with the Verify Solution Focus Area. This is done through reviews, analysis, simulation, modeling, prototyping, similarity with existing systems or combinations thereof. Solution risk areas are identified, assessed, and managed, including development items, commercial off-the-shelf (COTS) items, government off-the-shelf (GOTS) items, and non-developmental items (NDI).

Comments:

The terms solution and preferred solution refer to the identification of components and their interfaces at any level of design decomposition. A thorough, unbiased consideration of alternatives, as opposed to justification of a preconceived solution, should be emphasized.

Typical Work Products:

- System description (component identifications and specifications/schematics)
- System concept
- Trade studies
- Analysis reports (e.g., performance, cost)
- Decision trees
- Operational concepts (including maintenance, support and disposal) for alternatives
- Make/buy decisions
- System architecture/design documents
- Captured nomenclature and features of components
- Interface descriptions (specifications, schematics)
- Data dictionaries
- Captured rationale for selection of solution
- Design verification reports and analyses
- Design risk analyses, reports and plans
- Product baseline

Specific Practices:

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| SP 1.3-1-1a | Capture and maintain a description of solution component features and constraints. |
| SP 1.3-1-1b | Generate alternative system concepts physical architectures, and design solutions and select a solution in accordance with FA 1.4 - Assess and Select. |
| SP 1.3-1-1c | Identify interfaces between design components and their requirements for specification and management in accordance with the practices of FA 1.5 - Integrate System. |
| SP 1.3-1-2a | Identify architectural or design issues that must be resolved to support successful development of the system. |
| SP 1.3-1-2b | Evolve the operational concept to a level of detail appropriate to each level of physical decomposition and input to the practices of FA 1.2 - Define Technical Problem for maintenance. |
| SP 1.3-1-2c | Record and maintain the solution description and rationale in a way that is accessible to all stakeholders. |
| SP 1.3-1-2d | Assign responsibilities for establishing the system architecture and design, and for enforcing it during development. |
| SP 1.3-1-3a | Fully define interfaces in terms of origination, destination, stimulus and data characteristics for software, and electrical and mechanical characteristics for hardware. |
| SP 1.3-1-3b | Plan for evolutionary use of purchased or non-developmental (COTS, GOTS, and reuse) items. |

SP 1.3-1-3c	Develop system design alternatives which consider cost drivers, technology limitations and risk.
SP 1.3-1-3d	Develop timeline scenarios for system operation and user interaction for each alternative system design.
SP 1.3-1-3e	Establish a mechanism for determining if the prototyping of system functions is an appropriate part of the design process.
SP 1.3-1-3f	Establish a mechanism to identify design issues which should be subjected to decision analysis or trade studies throughout system development.
SP 1.3-1-3g	Capture the rationale for key (i.e., significant effect on cost, schedule or technical performance) decisions taken or defined.
SP 1.3-1-4a	Establish a mechanism to identify components which should be designed for reuse.
SP 1.3-1-4b	Develop system design alternatives which consider life cycle cost, complexity, system expansion, and growth.
SP 1.3-1-4c	Consider the evolution of requirement drivers and technology in selecting a preferred solution.
SP 1.3-1-5	Identify key architectural features which guide future system/product versions and upgrades.

1.3-2 Requirements Allocation:

Description:

Requirements are analyzed, assigned, or allocated to solution components. Initially requirements may be assigned to components without resolution of shared or redundant functionality or performance. When the performance or functionality of a requirement spans multiple components, analysis is performed to determine an allocation of the requirement's function or performance appropriate to each component. Derived requirements are formulated to specify the allocation appropriate to each component. As derived and allocated requirements are identified, they are updated and managed in accordance with FA 1.2 - Define Technical Problem. Requirements are verified for correctness and completeness against established criteria and in the context of operational concept threads, for both input requirements and requirements allocated to solution components. As requirements are analyzed and allocated, appropriate requirements are added to address all phases of the product's life cycle (e.g., production, support, and disposal) along with any design constraints associated with selected solution components. Cost, performance and time aspects of production and support requirements are communicated to stakeholders for consideration relative to business objectives. Requirements which have a significant impact on cost, schedule, or performance are designated "key requirements" for separate monitoring and input to risk analysis, as appropriate. Requirements are managed in terms of their status and volatility. The status of requirements, including issues, acceptance, and traceability to higher level requirements is maintained and communicated to stakeholders on a regular basis. The status of requirements is monitored and changes (or potential changes) are assessed for cost, schedule, and performance impacts.

Comments:

Operational concepts and scenarios for each level of system physical decomposition are used to achieve a common understanding of the design by reviewing requirement allocations in the context of operational concept thread reviews.

Typical Work Products:

- Subsystem specifications
- Thread analysis
- New/added requirements
- Requirement issues
- Allocation of key requirements to alternative solution components
- Requirement assignments
- Requirement allocations (including maintenance, support, and disposal)
- Allocation report
- Requirement change requests
- Requirement change impact assessments

Specific Practices:

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| SP 1.3-2-1a | Identify the assignment or allocation of requirements to design components and interfaces for recording and maintenance in accordance with requirement management practices of FA 1.2 - Define Technical Problem. |
| SP 1.3-2-1b | Identify traceability of derived requirements to parent requirements for recording and maintenance in accordance with requirement management practices of FA 1.2 - Define Technical Problem. |
| SP 1.3-2-2a | Identify requirement performance and functional allocations to design components and interfaces for recording and maintenance in accordance with the requirement management practices of FA 1.2 - Define Technical Problem. |
| SP 1.3-2-2b | Allocate key requirements to alternative solution components. |
| SP 1.3-2-3a | Identify and allocate appropriate derived requirements that address the effectiveness and cost of life-cycle phases following development, such as production and operation, to the extent they are compatible with business objectives. |
| SP 1.3-2-3b | Identify key requirements and design issues for separate tracking per the requirement management practices of FA 1.2 - Define Technical Problem, and for consideration by the practices of FA 2.5 - Manage Risk. |
| SP 1.3-2-3c | Review derived and allocated requirements for completeness and correctness against established criteria and in the context of operational concept threads or scenarios in accordance with the practices of FA 1.6 - Verify System. |
| SP 1.3-2-3d | Identify evolving requirement issues and their impacts to ongoing programs as inputs to the requirement management practices of FA 1.2 - Define Technical Problem. |
| SP 1.3-2-3e | Identify design constraints as requirements for each level of design. |
| SP 1.3-2-3f | Capture the rationale for requirement allocation decisions. |