CMMI – Use the Body of Knowledge to Create and Improve your System Integration Capability

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Abstract

*The Software Engineering Institute (SEI) Capability Maturity Model Integration (CMMI) is commonly used as an appraisal model to benchmark a Systems Engineering capability. In other words, a model against which an acquirer of complex systems can gauge the ability of the suppliers to successfully deliver, based on the process assets and effectiveness of the organization. However, in the introduction paragraph of "CMMI[SM] for Systems Engineering, Software Engineering, Integrated Product and Process Development, and Supplier Sourcing (CMMI-SE/SW/IPPD/SS, V1.1)" the SEI states: "The purpose of CMM Integration is to provide guidance for improving your organization's processes and your ability to manage the development, acquisition, and maintenance of products or services". This paper provides simple guidelines on how the CMMI Body of Knowledge can be used in developing organizations to create and/or improve their System Integration capability. This is **not** about appraisals, assessments or audits of organizations.*

Introduction

The Body of Knowledge that is captured in the CMMI [1] model and supporting documentation is based on over 25 years of research and development in the field of Systems and Software Engineering process improvement, and this is available for all practitioners to use at no cost. The information is in the public domain for System Integration organizations to use in order to approach World Best Practice in the delivery of their products and services. This paper provides an insight on how this can be achieved based on the author's own experience in assisting organizations improve their Systems Engineering process assets. The method suggested here is not unlike what is normally implemented to establish a Systems Engineering capability, but here the structure of the process assets is derived from the CMMI Body of Knowledge instead of using it to measure how good it is. This paper focuses on the Engineering areas of the capability.

Capability Architecture

The CMMI Model is effective in the definition of a set of 25 Process Areas (PA) grouped under 4 Process Groups, but since it is designed mainly as an appraisal model, the document [1] itself does not articulate how those processes fit together to form a capability. In the definition of a capability there is therefore a need to construct an architecture suitable for the business and technology areas that the organization needs to integrate systems for (i.e. Communications, IT, Intelligent Transport, Aerospace, etc). The System Integration capability itself is described in a set of manuals from which project related guidance documentation can be derived from, based on their size and complexity. To be able to integrate the Process Areas recommended by CMMI in this capability definition architecture, there is therefore a need to structure the architecture elements on the CMMI PA groups. Figure 1 below shows one of the possible options to achieve this goal. The result is a capability architecture defined in a set of 3 manuals, a Quality Manual, A Project Management Manual and a Systems Engineering Manual.

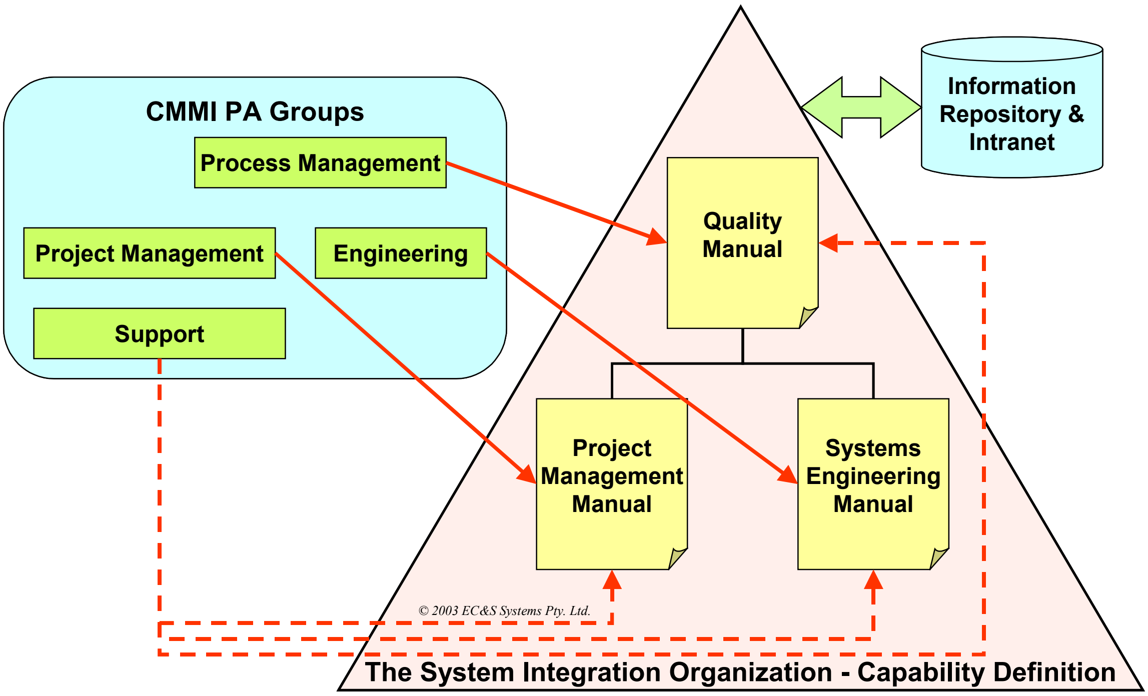

Figure 1: Development of Organizational Process Manuals

The construct of the 3 manuals starts by selecting the Process Areas that are appropriate to address the nature, size, complexity and risks of the business areas of the organization. Those 3 manuals will provide the direction necessary to implement the organization's System Integration projects based on the best practice recommendations of CMMI.

Quality and Project Management Manuals

This paper does not elaborate on the development of the Quality and Project Manuals, but the methodology suggested is similar to what is described below for the Systems Engineering Manual.

Systems Engineering Manual

Systems Engineering Process

As indicated in Figure 1 above, the process components that will make up the Systems Engineering Manual of the capability are derived from the CMMI Body of Knowledge, in particular from the Engineering and Support Process Groups. The starting position is to analyse the set of PAs listed in the CMMI model and, based on the nature of the business and project complexity, decide on the optimum set of PAs that is required to effective support the system development, integration and delivery activities. The Engineering Manual of the organization is the document that describes what and how the organization transforms the business needs of customers and stakeholders to a fully operational and deliverable system. The selected process areas, derived mostly from the Engineering PA Group of the CMMI model are then aggregated in a life cycle model that will define the end-to-end process, in other words the high-level technical transformation and control processes of the capability. Figure 2 below is an example of how the CMMI recommended Engineering PAs could be dovetailed together to construct the top-level architecture.

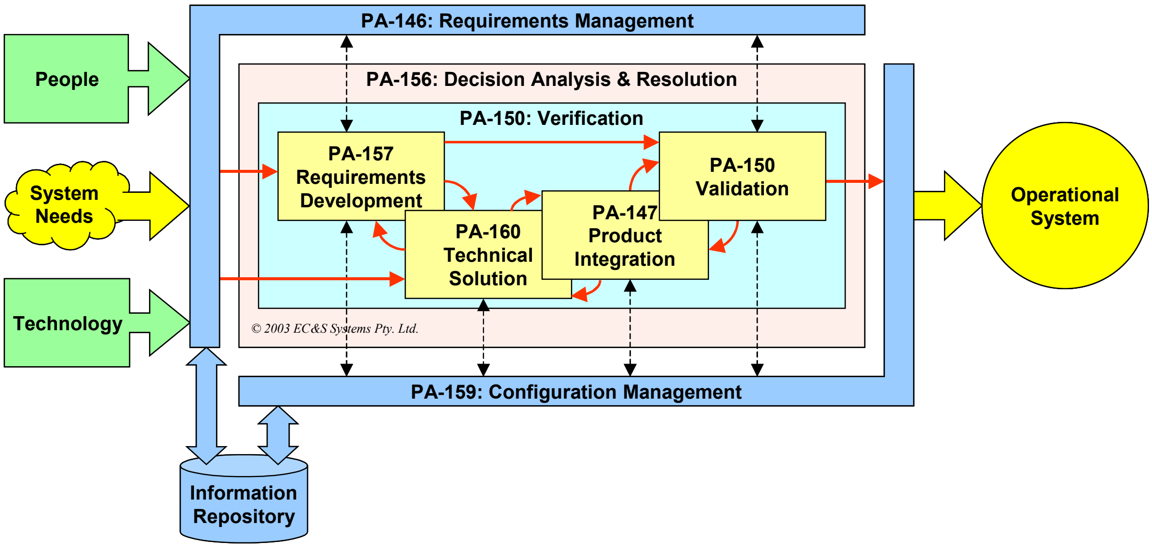

Figure 2: A Typical Systems Engineering Process using CMMI Process Areas

We are now in a position to develop Section 1 of the Systems Engineering Manual. This section will provide a good description of the Systems Engineering process, for example as defined above, and will use the CMMI Body of Knowledge when each of the contributing Process Area is described. There is a need to define the role of each process in the main transformation, and in particular relate those definitions to the industry and technology domain areas that the organization operates in. In the above example it is to be noted that CMMI groups the process areas of Configuration Management (CM) and Decision Analysis & Resolution (DAR) in the *Support* process group, but here they have been represented in relation to Engineering. Furthermore, both DAR and Verification are shown here to have a role in supporting the other four primary processes in the value chain of translating the system needs to the operational system. The comprehensiveness and complexity of the Systems Engineering Process that will be documented in the manual will vary greatly with industry domains and project complexity.

From Process Area to Specific Goals and Specific Practices

A four level hierarchical structure is used for the elaboration of each PA defined in the CMMI model. Note that in the description below the Generic Goals and Generic Practices have not been included as they are mostly used for appraisals. The Generic Goals provide the ability to assess the maturity of the process areas and can also be used in the design and documentation of the capability if the organization is planning to be externally appraised at a later stage, but this will not be addressed here.

Figure 3 below suggests how the hierarchical structure in the model can be used towards the development of the Systems Engineering Manual of the organization. In the CMMI document Level 1 is defined using descriptive language (nouns) and therefore appropriate for using in defining "What" needs to be done. Levels 2, 3 and 4 have more detail and use verbs as the first word and as such can be used to derive procedural information, or "how" to do it.

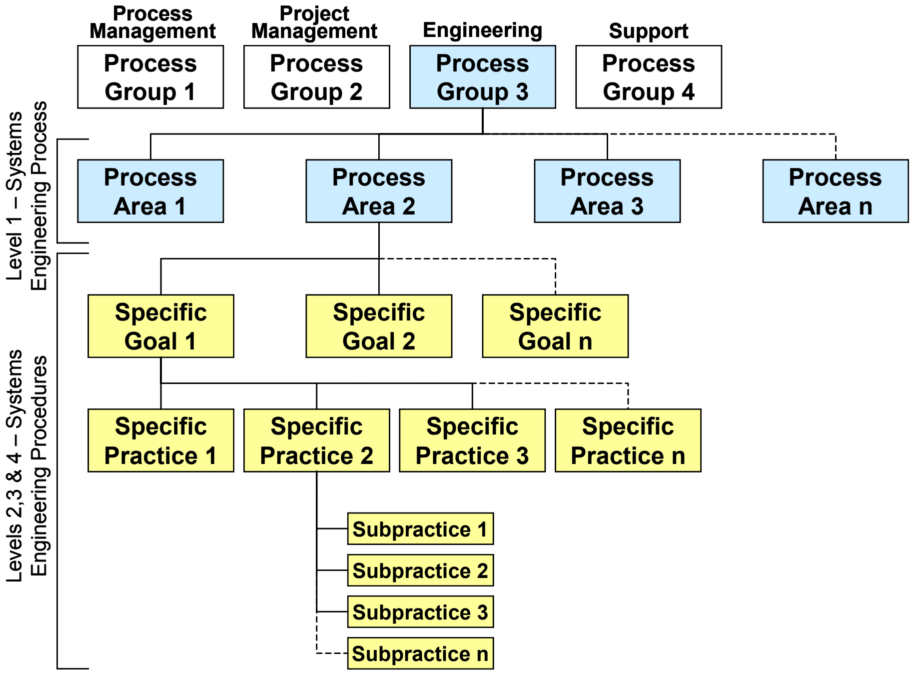

Figure 3: Hierarchy of Process Components in CMMI

There is obviously a need to some tailoring to adapt the "standard" recommendations of CMMI to the development of organizational specific documentation. This process can also be supplemented by consulting other Bodies of Knowledge such as the Project Management Handbook [2], EIA-632 Standard: Engineering a System [3], the INCOSE Handbook on Systems Engineering [4], ISO-IEC 15288 System Life Cycle Processes [5], and the Rational Unified Process ® [6].

An Example – Requirements Development Procedure

Applying the above process to the development of an Engineering Procedure for Requirements Development based on the CMMI goals and specific practices for the process we have a hierarchy as defined in Figure 4 below.

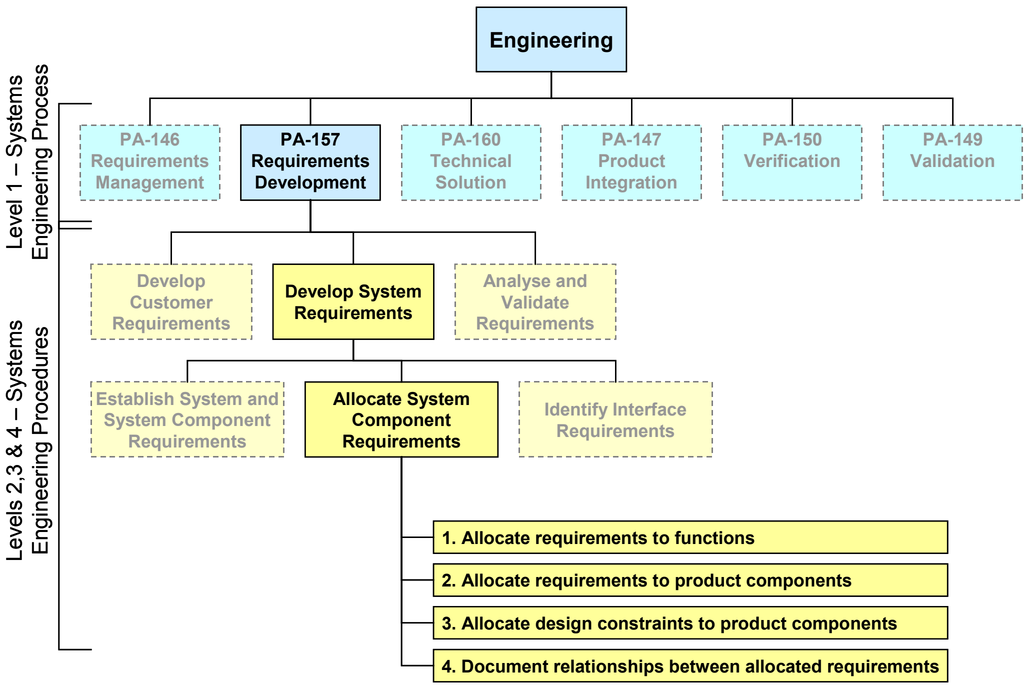

Figure 4: Hierarchy of Requirements Development Process – Example

Building on this understanding of what are the recommendations and expectations, and also on the initial top level process flows that have been defined in the Systems Engineering Manual so far, it is possible to keep evolving the proposed process to include lower level detail such as show below. At this level the procedures start to take shape, in other words "how" to implement the recommended process in the domain and technology environments that the system must be developed and integrated for.

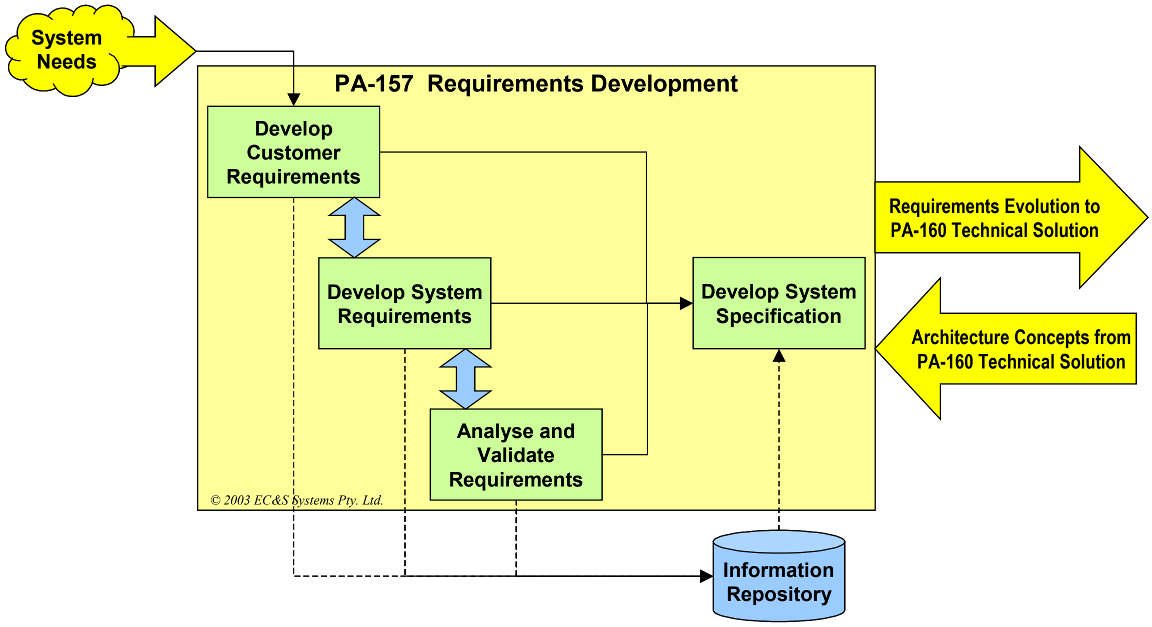

Figure 5: Sections of a Requirements Development Procedure

CMMI recommends a set of "Work Products" resulting from the application of each of the "subpractices". Those provide a good indication of what needs to be done in order to produce the outputs. For example, in the above example, under the subpractice "Allocate Product Component Requirements" the following Work Products are suggested:

- *Requirement allocation sheets;*
- *Provisional requirement allocations;*
- *Design constraints;*
- *Derived requirements;*
- *Relationships between derived requirements; and*
- *Specifications.*

There is adequate information in the supporting text of the CMMI document to enable the development of a suitable procedure that will communicate to a projects team "how" the organization implements this part of the process.

Procedure Detail

Based on the ideas developed above, the organization's Systems Engineering Manual will be supported by at least one procedure for each PA, and each procedure will have several inter-related sections that will describe the method used to "transform" certain inputs to produce outputs or work products. For the development of procedures in support of the process descriptions, CMMI suggests the following contents:

Process Area	e.g., *Requirements Development: Develop System Requirements*
Process Roles The roles, aims and objectives of the process. What are the expected outcomes and how they fit in the overall Systems Engineering process described in the manual to contribute to the overall scheme.	
Applicable Standards The external and internal published standards that are relevant and referred to in the procedure.	**Applicable Tools & Resources** Specific sets of tools and other special resources that will enhance the effectiveness of the application of this procedure.
Performance Objectives The performance objectives required by the process in order to integrate seamlessly with the other processes it interfaces with.	**Measures** The performance metrics that will be set in place and gathered in order to assess the process performance and plan continuous improvements.
Entry Criteria States of being that must be present before an effort can begin successfully.	**Exit Criteria** States of being that must be present before an effort can end successfully.
Inputs All the Work Products produced by other processes that will be required to be present at the start of the process.	**Outputs** All the Work Products that are developed as a result of the application of the process. (In the Rational Unified Process (RUP) language those are the "Artefacts" produced by the process.
Interfaces with other PAs As most of the processes are of a Recursive nature, there is a need to define how the process relates to other processes on either side of the Life Cycle.	**Verification Points** The progressive reviews, gates and checkpoints that will be used to control the correct and effective implementation of the process.
Method What is to be done, how and by whom during the action of transforming the Inputs to the Outputs of this process? The development of the method can follow the hierarchical structure inherent in the Specific Goals-Specific Practices-Subpractices structure. This is the focus of the procedure.	

Figure 6: Suggested Structure for Procedure

CMMI Limitations

CMMI focuses on some of the "developmental and delivery" areas of the overall capability, in particular project related processes. In the construction, definition and documentation of a complete capability there is therefore a need to draw information from other Bodies of Knowledge. Areas not well addressed by CMMI include:

- *Human Resource Management;*
- *Business Development;*
- *Contract Management;*
- *Logistic Support (note that "Support" in CMMI is not related to Logistic Support).*

Conclusion

For an organization that has not yet developed mature Operational Manuals, it does make sense to base the content and depth of the manuals on a well-accepted and complete Body of Knowledge. The intelligence that has been captured in CMMI appears to be exhaustive enough to be used in that way, although for specific areas such as listed above, it should be supplemented by other Bodies of Knowledge and Standards, such as those listed in References [2] to [6] below.

About the Author

Hervé completed his HSC (University of Cambridge) in 1967 in Mauritius before migrating to Australia in 1968. In 1973 Hervé graduated in Electrical Engineering at the Caulfield Institute of Technology in Melbourne. He subsequently worked for Thomson CSF over a period of 13 years at several international locations, including Australia, France, Saudi Arabia and Taiwan, mainly on Civil and Military Air Traffic Control/Air Defence Radar Systems. Hervé later worked in Melbourne for Rockwell Systems Australia for 4 years as Engineering Manager, and for Telstra (Telecom Australia) for six years as Manager, Systems Engineering in their Applied Technologies Group. Hervé completed a Post-Graduate Diploma in Business Management in 1993, and an MBA (Deakin University) in Technology Management in 1994.

Between 1997 and 2001 Hervé was the Engineering Manager of Adacel Technologies Limited in Melbourne during which time he led and completed several large defence and commercial systems integration projects. He was based for 10 months in Montréal at Adacel Canada as Director of Operations to set up the Air Traffic Management Business Unit, and also implemented several Air Traffic Management System Integration projects in the US, UK, Europe, New Zealand and North Africa. In 2001 Hervé created his own Systems Engineering consultancy organization, EC&S System Pty. Ltd., to provide technical assistance to complex & software intensive projects, process improvement services and Systems Engineering training.

Hervé's main professional interests are the promotion of leading edge Technology Management techniques, Systems Engineering Business Development, and Software Management in large System Integration projects. In 1994 Hervé led the foundation of SESA (Systems Engineering Society of Australia) – a Technical Society of the Institution of Engineers, Australia (IEAust). SESA is affiliated with the International Council On Systems Engineering (INCOSE). During his SESA Presidency period (1995 to 1998) Hervé represented Australia on the INCOSE Board of Directors. In 2001 Hervé was the Symposium Chair for the 11th annual international symposium of INCOSE, held in Australia (Melbourne) for the first time. Hervé has published several papers in international forums (Australia, US, UK, Canada, Germany, France & South Africa) with INCOSE, the IEEE, the IEAust, SESA and other major conferences on Systems Engineering.

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