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A Systems Process Lifecycle Standard for Very Small Entities: Development and Pilot Trials

Claude Y. Laporte¹ Rory V. O'Connor^{2,3}

¹ École de technologie supérieure, Montréal, Canada

² Lero, the Irish Software Engineering Research Centre, Ireland

³ Dublin City University, Dublin, Ireland

Claude.Y.Laporte@etsmtl.ca, roconnor@computing.dcu.ie

Abstract. Very small entities, organizations with up to 25 people, are very important to the worldwide economy. The products they develop are either developed specifically for a customer or are integrated into products made by larger enterprises. To address the needs of Very small entities, a set of standards and guides have been developed using the systems engineering lifecycle standard ISO/IEC/IEEE 15288 as the main framework. The systems engineering handbook, developed by the International Council on Systems Engineering (INCOSE), is used as the reference for the development of a set of systems engineering deployment packages. Two pilot projects, using the new ISO/IEC 29110 guide for systems engineering, are presented as well as a cost and savings analysis. Finally, the certification scheme is discussed as well as the future developments.

Keywords: VSE, ISO/IEC 29110, ISO, Standards

1 Introduction

Today, the ability of organizations to compete, adapt, and survive depends increasingly on software. In 2010 a cellular phone contained 20 million lines of code and some cars had up to 100 million lines of code. Manufacturers depend increasingly on the components produced by their suppliers. A manufacturing chain of large mass-market products often has a pyramidal structure, for example, a large mass product manufacturer recently integrated into one of its products a part with an unknown software error that was produced by one of its 6,000 lower-level producers. This defective part resulted in a loss of over \$200 million by the mass product manufacturer.

The term Very Small Entities (VSEs) has been defined as being “*an enterprise, organization, department or project having up to 25 people*” [1]. VSEs have unique characteristics, which make their business styles different to SMEs and therefore most of the management processes are performed through a more informal and less documented manner [2]. Furthermore there is an acknowledged lack of adoption of standards in small and very small companies, as the perception is that they have been developed for large software companies and not with the small organisation in mind

[3]. Accordingly the new standard ISO/IEC 29110 “Lifecycle profiles for Very Small Entities” is aimed at meeting the specific needs of VSEs [4]. The overall objective of this new standard is to assist and encourage small software organization in assessing and improving their software process and it is predicted that this new standard could encourage and assist small software companies in assessing their software development process. The approach [5] used to develop ISO/IEC 29110 started with the pre-existing international standards ISO/IEC 12207 and ISO/IEC 15504.

The working group behind the development of this standard is advocating the use of pilot projects as a mean to accelerate the adoption and utilization of ISO/IEC 29110 by VSEs [6]. Pilot projects are an important mean of reducing risks and learning more about the organizational and technical issues associated with the deployment of new software engineering practices [7]. To date a series of pilot projects for the software engineering profile standard have been completed in several countries with the results published in a variety of literature [8, 9, 10].

2 The Development of Systems Engineering Standards for VSEs

In 2008, after a presentation at the annual International Council on Systems Engineering (INCOSE) symposia it was agreed by the INCOSE Board of Directors, to setup a working group to develop a set of standards and guides, for systems engineering VSEs, similar to the one developed for software VSEs. A new INCOSE working group, the Very Small and Medium-sized Enterprise (VSME) working group, was mandated in 2009 to apply systems engineering to product development for small and very small entities. The working group, created in April 2009, co-chaired by one co- author, is composed of INCOSE members from mainly from Canada, France, Germany, and the US. At the first meeting of the INCOSE WG, the project editor of ISO/IEC 29110 proposed an approach similar to that developed by WG24, i.e. the conducting of a survey, the development of a set of requirements, the creation of profiles (e.g. roadmaps), the development of deployment packages to facilitate the implementation of the standards and guides, and the conduct of pilot projects. The members of the working group agreed with this proposition. The initial goals of the INCOSE WG were to [11]:

- Improve or make product development efficient by using systems engineering methodology,
- Elaborate tailored practical guidance to apply to VSMEs in the context of the prime contractor or subcontractor of commercial products,
- Contribute to standardization

At the SC7 Plenary meeting in France in May 2011, the ISO/IEC 29110 project editor submitted, on behalf of Canada, a formal project proposal to develop a set of systems engineering standards for VSEs similar to the set developed for software VSEs. A draft systems engineering Management and Engineering guide for the Basic profile was attached to the formal proposal. The scope of this work includes the current scope of ISO/IEC/IEEE 15288, the associated guidance documents and other relevant SC7 Standards such as ISO/IEC/IEEE 15289 and ISO/IEC 29110. The project will produce Standards and Technical Reports (Guides), similar to the

ISO/IEC 29110 set of Software documents for the Generic profile group (i.e. for VSEs developing non critical system), which establishes a common framework for describing assessable system engineering life cycle profiles for Very Small Entities (VSEs).

In August 2011, the proposal, as well as a draft systems engineering management and engineering guide for the Basic profile, were circulated for approval by the members of SC7. In September 2011, the proposal to develop SE standards for VSEs has been accepted by twenty countries. Nine countries made a commitment to participate in the development of the new ISO Systems Engineering standard.

Instead of developing a complete set of 5 documents, as illustrated in table 3, similar to the ones developed for software, it was proposed by the project editor to broaden scope of existing Part 1- Overview, Part 2- Framework and Part 3- Assessment guide to cover also systems engineering while Part 4- Profile specifications and Part 5- Management and engineering guide would be specific to systems engineering.

In November 2011, WG24 met in Ireland to launch the official development of the systems engineering ISs and TRs for VSEs. Delegates from Brazil, Canada, France, Japan, Thailand, United States and INCOSE participated to the first meeting. A draft was sent for a round of review within ISO in January 2012. More than 450 comments have been submitted by seven countries. A new version was sent for a second round of review in December 2012. Less than 150 comments have been submitted. The Management and engineering guide for the Basic Profile has been published by ISO in 2014.

The Basic profile, as illustrated in Figure 1, is composed of two processes: a Project Management (PM) process and a System definition and Realization (SR) process. The PM process uses the Acquirer's Statement of Work to elaborate the Project Plan. If there is no statement of work available from the customer, the PM, in collaboration with the Work Team, has to clarify the basis to develop the Statement of Work. The PM project assessment and control tasks compare the project progress against the Project Plan and actions are taken to eliminate deviations or incorporate changes to the Project Plan. The PM project closure activity ensures delivery of the product (new or modified product), produced by SR (System definition and Realization) process, and gets the Acquirer's acceptance to formalize the end of the project. A Project Repository is established to save the work products and to control its versions during the project.

It is to be noted that the ISO/IEC 29110 SE standards and guides are not intended to dictate the use of different lifecycles such as: waterfall, iterative, incremental, evolutionary or agile. The ISO/IEC 29110 systems engineering standards and guides have been developed to work hand-in-hand with the published ISO/IEC 29110 software engineering standards and guides.

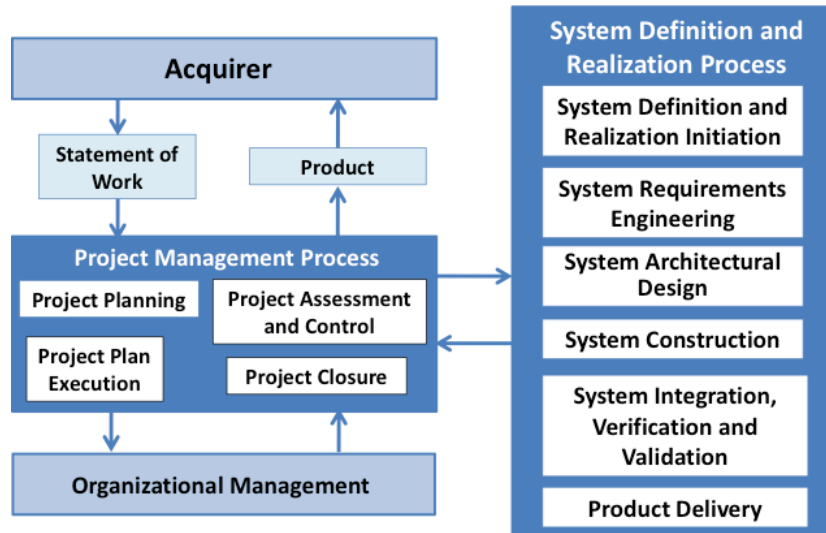


Fig 1. Processes of the systems engineering Basic Profile

2.1 Project Management Process of the Systems Engineering Basic Profile

As defined in ISO/IEC 29110, the purpose of the Project Management (PM) process is to establish and carry out in a systematic way the tasks of the system development, which allows complying with the project's objectives in the expected quality, time and cost. The objectives of the ISO/IEC 29110-5-62 Project Management Process of the Basic profile are:

- **PM.O1.** The Project Plan, the Statement of Work (SOW) and commitments are reviewed and accepted by both the Acquirer and the Project Manager. The Tasks and Resources necessary to complete the work are sized and estimated.
- **PM.O2.** Progress of the project is monitored against the Project Plan and recorded in the Progress Status Record. Corrections to remediate problems and deviations from the plan are taken when project targets are not achieved. Closure of the project is performed to get the Acquirer acceptance documented in the Acceptance Record.
- **PM.O3.** Change Requests are addressed through their reception and analysis. Changes to system requirements are evaluated by the project team for cost, schedule, risks and technical impact.
- **PM.O4.** Review meetings with the Work Team and the Acquirer, suppliers are held. Agreements are registered and tracked.
- **PM.O5.** Risk Management Approach is developed. Risks are identified, analyzed, prioritized, and monitored as they develop and during the conduct of the project. Resources to manage the risks are determined.
- **PM.O6.** A Product Management Strategy is developed. Items of Product are identified, defined and baselined. Modifications and releases of the items are

controlled and made available to the Acquirer and Work Team. The storage, handling and delivery of the items are controlled.

- **PM.O7.** Quality Assurance is performed to provide assurance that work products and processes comply with the Project Plan and System Requirements Specifications.
- **PM.O8.** A Disposal Management Approach is developed to end the existence of a system entity.

To show the links between ISO/IEC/IEEE 15288 and the objectives of the PM process, we illustrate in table 1 the outcomes of the project planning process and the measurement process of ISO15288 used to develop objective 1 of the PM Process of ISO/IEC 29110. Notice that just a subset of the Project Planning and Measurement processes of ISO 15288 has been selected for the Basic profile.

Table 1. Links between the ISO15288 outcomes and the PM.01 process

6.3.1 Project Planning Process a) Project plans are available; e) Plans for the execution of the project are activated. 6.3.7 Measurement Process a) The information needs of technical and management [ISO/IEC 15288, 6.3.1, 6.3.7]

2.2 Modifications to the Software PM process of the ISO 29110 Software Engineering Basic Profile

Few modifications/additions were made to the Software engineering Basic profile to develop the PM process of the SE Basic profile. The role of Customer was replaced by the role of Acquirer. Two tasks were added: *Define the system breakdown structure* and *Identify and document a disposal management approach*. Two tasks were modified: *Identify and document risks* was replaced by *Identify and document a Risk Management Approach*; the *Version Control Strategy* was replaced by *Configuration Management Strategy*.

2.3 System Definition and Realization Process of the Systems Engineering Basic Profile

The purpose of the System Definition and Realization (SR) process is the systematic performance of the analysis, design, construction, integration, verification, and validation activities for new or modified system according to the specified requirements. The seven objectives of the SR process are [12]:

- **SR.O1.** Tasks of the activities are performed through the accomplishment of the current Project Plan.
- **SR.O2.** System requirements are defined, analyzed for correctness and testability, approved by the Acquirer, baselined and communicated.

- **SR.O3.** The System architectural design is developed and baselined. It describes the System elements and internal and external interfaces of them. Consistency and traceability to system requirements are established.
- **SR.O4.** System elements defined by the design are produced or acquired. Acceptance tests are defined and performed to verify the consistency with requirements and the design. Traceability to the requirements and design are established.
- **SR.O5.** System elements are integrated. Defects encountered during integration are corrected and consistency and traceability to System Architecture are established.
- **SR.O6.** A System Configuration, as agreed in the Project Plan, and that includes the engineering artifacts is integrated, baselined and stored at the Project Repository. Needs for changes to the Product are detected and related change requests are initiated.
- **SR.O7.** Verification and Validation Tasks of all required work products are performed using a defined criteria to achieve consistency among output and input products in each activity. Defects are identified, and corrected; records are stored in the Verification/Validation Reports.

2.4 Modifications to the Software Implementation process of the ISO 29110 Software Basic Profile

Some significant changes were made to the software implementation (SI) process of the ISO 29110 basic profile to produce the System Definition and Realization process (SR) of the SE basic profile: new system activities and tasks were added, irrelevant SW activities were suppressed, new system roles were defined. Also, new system documents were added as the result of the addition/modification to the tasks.

2.5 Roles for Systems Engineering and Management

The Analyst role was replaced by the Systems Engineer role. The Customer was replaced by the Acquirer and the Stakeholders. The Programmer was replaced by the Developer. Two new roles were also defined: the IVV (Integration, Verification and Validation) Engineer and the Supplier.

2.6 Product description

Product descriptions are based on ISO/IEC/IEEE 15289 [13] Information Items with some exceptions. Nine product descriptions were added to the software basic profile: Data Model, Disposed System, Integration Report, IVV Plan, IVV Procedure, Justification Document, Systems Engineering Management Plan, System Design Document, System Element, System Element Requirements Specification, and

System Maintenance Document. The product descriptions were modified to align them with the system engineering context.

2.7 Deployment Packages to Support the Systems Engineering Basic Profile

Members of the INCOSE VSME working group defined a set of guidelines explaining in more detail the processes defined in the Basic profile. These guidelines are freely accessible to VSEs on the internet as a collection of Deployment Packages. Since the INCOSE Handbook is a 'how to' document, it has been used to develop the set of DPs. Figure 8 illustrates the proposed set of SE Deployment Packages for the Basic Profile which are available, at no cost to members of INCOSE, on the Internet and on the INCOSE VSME working group page.

A first commercial software solution, using the deployment packages, has been developed to facilitate the implementation of the Basic Profile. The tool is based on the well-known Atlassian tool suite. The solution facilitates the role of the project manager and enhances team collaboration. It has the following characteristics:

- Project artifacts shared in one place
- Project documentation is managed
- Project progress dashboard can be generated
- Integrated with Model-based solutions

The solution provides project artifacts and documentation templates. It enforces the project management process, the system definition, the realization process and it facilitates progress tracking. When using a model-based approach, project artifacts such as: requirements, tests, changes and model artifacts, can be integrated and traced. The solution is already available in different languages such as English, French and Spanish.

4 Pilot Projects conducted in Engineering Enterprises

So far, two systems engineering organizations implemented the ISO/IEC 29110. We shortly describe below two applications of the Engineering and Management Guide: one in a start-up VSE and one in a large engineering firm.

A first implementation project has been conducted in a start-up VSE specialized in the integration of interactive, communication systems such as Public Address, Visual Information and Media, Vehicle Wayside Communications, Networking and Radio and safety systems such as CCTV, Fire Management, Access Control and Intrusion Detection, Perimeter Protection, Emergency Intercom, in the public transportation field such as trains and buses. In this domain, customers often require a CMMI[®] maturity level (SEI 2010), such as a CMMI level 2 for sub-system suppliers. In 2012, the VSE was composed of just 4 professionals. It was felt that implementing the process areas of the level 2 of CMMI was too demanding at that time. The company decided to implement the draft version of ISO/IEC 29110 systems engineering Basic profile as a foundation for its development work. It was felt that, once the processes

would have been documented and implemented in a few projects, the VSE could, if required, perform a gap analysis between the CMMI level 2 practices and the Basic profile and implement the practices needed for a level 2 assessment.

A large engineering firm has implemented a program to define and implement project management processes for their small-scale and medium-scale projects. The firm already had a robust and proven process to manage their large-scale projects. Their projects are classified into three categories as illustrated in Table 2.

Table 2. Classification of projects by the engineering firm [10]

	Small project	Medium project	Large project
Duration	< 2 months	>2 and <8 months	>8 months
Team size	<= 4 people	4-8 people	>8 people
No. engineering specialties	1	>1	Many
Engineering fees	\$5,000 - \$70,000	\$50,000 - \$350,000	>\$350,000

The engineering firm documented the business goals, as illustrated in Table 3, as well as the problems that one division of the company wished to solve. The division used the project management process of the Entry profile of ISO/IEC 29110 to document their small-scale project management process and they used the project management process of the Basic profile to document their medium-scale project management process.

Table 3. Division's business goals [10]

ID No.	Description
O-1	Facilitate the integration of new project managers
O-2	Achieve a global customer satisfaction level of 80 %.
O-3	Meet the deadlines and costs planned for the projects, within a margin of 5%.
O-4	Reduce resource overload by 10 %.
O-5	Reduce time delays to one week and cost overruns to 5 % of the initial budget.
O-6	Reduce corrective work during the quality control phase by 10 %.
O-7	Reduce non-chargeable time for resources by 10 %.

ISO has developed "The ISO Methodology to assess and communicate the economic benefits of standards" [14]. This methodology was used, by the engineering firm, to estimate the anticipated costs and benefits over a period of three years. The estimates were made by the sponsors of this process definition project. Figure 2 illustrates the value chain of the company.

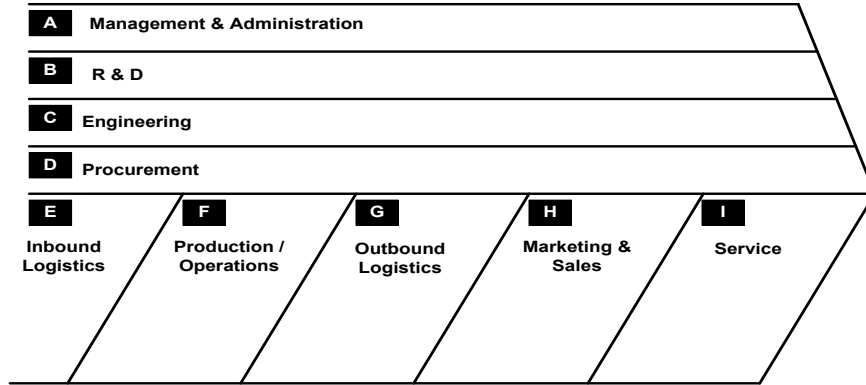


Fig 2. Value chain of the company

An estimate of anticipated costs and benefits over a period of three years was made by the improvement program project sponsors. Table 4 shows the results for the first three years of this cost/benefit estimation.

Table 1. Costs (in \$CAD) and benefits estimations from implementing ISO/IEC 29110 [10]

	Year 1	Year 2	Year 3	Total
Cost to implement & maintain	59,600	50 100	50,100	159,800
Net benefits	255,500	265,000	265,000	785,500

The engineering firm is planning to document and implement their systems engineering processes for the small-scale and medium scale projects once the ISO/IEC 29110 systems engineering guide of the Basic profile gets published by ISO.

5 ISO/IEC 29110 Certification of VSEs

For most enterprises, but in particular for VSEs, international certifications can enhance credibility, competitiveness and access to national and international markets. Brazil has led the development of an ISO/IEC 29110 certification process. An ISO/IEC 29110 auditor should be competent in auditing techniques, have expertise in ISO/IEC 29110 and have experience in systems or software development. For VSEs, such a certification should not be too expensive and short. The certification process has been successfully piloted in a few Brazilian VSEs. For these pilots, it took about 4 staff-days of work by the auditors. A first auditor course was conducted in English in Dublin in November 2013.

The certification scheme, described in ISO/IEC 29110-3-2 document [15] is based on ISO Standards on Conformity Assessment. As illustrated in figure 3, it is a four-stage certification process.

WG24 has initially developed the Systems Engineering and Management Guide since this document describes in a useful way for VSEs wishing to implement the project management and system definition and realization processes. WG24 has started, in 2014, the development of the Systems Engineering Basic profile specification document, i.e. ISO/IEC 29110-4-6. This document will be an international standard and will be required by the auditors when they perform an ISO/IEC 29110 audit. This standard should reach publication stage in 2015.

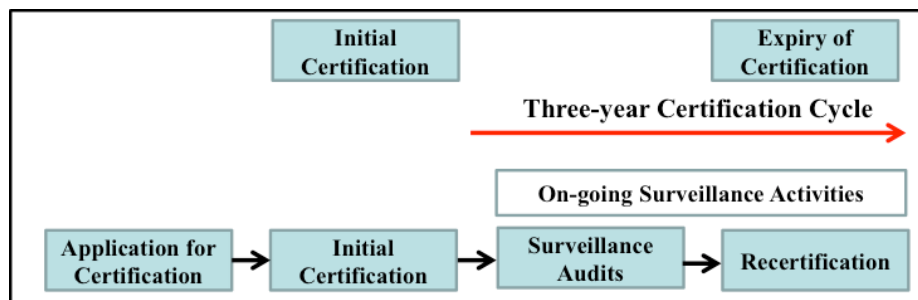


Fig 3. ISO/IEC 29110 Four-Stage Certification Process (adapted [15])

6 Development of the Entry Profile for Systems Engineering

VSEs targeted by the Entry Profile are VSEs working on small projects (e.g. at most six person-months effort) and for start-up VSEs. The approach used by WG24 to develop this profile was to use, as the baseline, the published software Entry Profile and the published systems engineering Basic profile keeping in mind that the 2 Entry profiles should be about of the same size and should have the same structure. Also, if a VSE develops a system having a software component, it could use the SE Entry profile to guide the development of the system and use the software Entry profile to guide the development of the software component.

At the November 2013 WG24 meeting in Dublin, the delegates, of the systems engineering sub-working group of ISO WG24, have reviewed the 2 tables and made modifications based on consensus. Then, they analyzed the PM and SR processes of the SE Basic profile and deleted/added/modified text of the activities, tasks, roles and products to produce a first draft of the SE Engineering and Management guide Entry profile. The document has been sent for a first review cycle within ISO at the beginning of 2014. The comments received have been processed at the May 2014 meeting of WG24 in Australia. A new version of the Entry profile will be sent for a second review cycle in August 2014. We expect this second review cycle to generate only minor comments. These comments will be processed and the document should be ready for publication by ISO in 2015.

6 Conclusions and Future Work

Industry recognizes the contribution of VSEs in terms of the valuable products and services they offer. A large majority of organisations worldwide have up to 25 people. The collection of ISO/IEC JTC1 SC7 standards was not easily applied in VSEs, which generally found standards difficult to understand and implement.

After having developed ISs and TRs for VSEs involved in the development of software, WG24 developed the ISO/IEC 29110 systems engineering Basic profile management and engineering guide. Then members of the INCOSE VSME WG developed a set of Deployment Packages to help implement the Basic profile. WG24 started the development of the Entry profile for systems engineering. Once a stable version of the SE Entry profile is available, the INCOSE VSME working group will be able to start the development of the deployment packages to support the Systems Engineering Entry Profile. Once the ISO/IEC 29110 software Intermediate and Advanced profiles are ready, the development of the two matching systems engineering profiles for VSEs will start [16].

Since many VSEs developing systems are also involved in the development of critical systems, WG24 and the INCOSE VSME Working Group will conduct an analysis to determine if a set of systems/software engineering standards for VSEs developing critical systems should be developed.

Additional information: The following website provides more information, as well as articles by WG24 members and deployment packages for software and systems engineering: <http://profs.logti.etsmtl.ca/claporte/English/VSE/index.html>

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