

The Road to Developing a World Class Automotive Systems Engineering Capability

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ABSTRACT

The Capability Maturity Model (CMM), originally developed as a software process evaluation tool for Department of Defense projects by the leadership of Carnegie Mellon University in the early 1990's, was quickly adapted for Systems Engineering. The resulting model, Systems Engineering Capability Maturity Model (SE-CMM) described the essential elements of an organization's Systems Engineering process that must exist to ensure superior performance (2). Its development was intended to first measure and then provide systematic step-by-step guidance for improvement to ensure that an organization effectively and accurately translate Customer needs into a compliant product.

The Delphi Thermal Systems Engineering Common Process (SECP) was designed to meet and grow by means of this process. Initial surveys were conducted to assess the existing status and identify needs and opportunities. From these needs, the SECP was established and future plans have been identified to grow this process to "World Class" as defined by the SE-CMM. This paper will identify and discuss Lessons Learned and best practices in developing an effective Systems Engineering organization using the process principles from the SE – Capability Maturity Model. Emphasis will be placed on the actions that are planned for levels 4 and 5, Quantitatively Controlled and Continuously Improving respectively. The author currently rates this process at level 3 - Well Defined.

"Systems Engineering is a **formal process** for the development of a complex system, driven by a set of established requirements, derived from the intended mission of the system throughout its life cycle."

What is of particular interest in this definition is "formal process". What will be discussed within this paper is how the author has utilized SE- Capability Maturity Model (SE-CMM), as a model, to develop and grow the Systems Engineering Common Process for Thermal Systems, Delphi. Before we delve into how this process was and will be utilized, more background on Systems Engineering methodology and the successful use thereof will be described to establish a consistent background(4) for the reader.

The basic premise of SE methodology is that requirements are initially derived and/or based upon Customer or user mission requirements and are then analyzed and allocated to synthesize a responsive system. These requirements are then further allocated to sub-systems, components and their interfaces that comprise the system. Requirements documentation and requirements management of Customer and internal product design changes are a must. Verification of these requirements is an integral part of the methodology.

The Systems Engineering process is usually explained by means of the following "V" diagram.

INTRODUCTION

A REVIEW OF SYSTEMS ENGINEERING – WHAT, HOW, WHO, AND WHY

While there are many different definitions for Systems Engineering, the following one summarizes and makes some of the key points that will be discussed throughout this paper.

Systems Engineering "V Diagram"

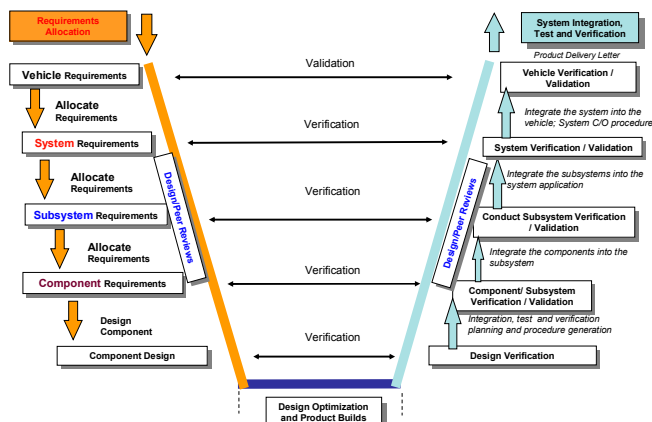


Figure A.

The left hand side of the "V Diagram" deals with the definition, analysis, development and allocation of requirements starting with the Customer and proceeding from system to subsystem all the way down to piece parts and software algorithms. The detailed design based upon the derivation of these requirements occupies the bottom of the diagram, while the right hand side deals with the verification and validation of these requirements. The left hand side is connected to the right hand side, using what we call a compliance matrix or verification cross reference index as each and every requirement must be verified.

Systems Engineers primary responsibilities are system oriented and provide the "glue" that binds the diverse system elements together. They aid in providing the up/down communication that allows flowing "down" Customer and system requirements and project perspectives, and flowing "up" component and subsystem problems, interface problems, issues and risks. The following figure summarizes the roles and responsibilities of the Systems Engineer.

So What is Systems Engineering?

◆ Technical Group/Individual that establishes an Integrated Systems Thinking

- Provide the Program with System Level Leadership
- Develop and Flow Requirements
- Balance the Design
- Plan the System Integration, Test and Validation
- Assist the Program Manager in Technical Planning, Managing, and Monitoring the Program
- Lead System Integration and Functional Test
- Lead the Sell-off of the System
- Lead system problem solving

◆ Key SE Elements:

- Systems Management & Architectural Development
- Requirements Management
- Develop and Evaluate Alternatives
- System and Subsystem Integration
- Test and Verification

Figure B.

So "Why have Systems Engineering," you might ask? The need for Systems Engineers is most apparent on large, complex systems. However, Systems Engineering contributions are also important in the development, production, deployment and support of much smaller systems. While Systems Engineers perform essential tasks throughout a project's lifetime, most managers consider their role during the development phase as the most value added.

While it is common for naive product development teams to think that they can save money by eliminating systems help, many studies and experiences have shown that such resulting products will not meet their system level performance or interface requirements. This can result in significant cost and schedule overruns and insufficient performance. The following figure illustrates a quantitative study conducted by the International Council on Systems Engineering (INCOSE) that was published in their latest Systems Engineering Handbook (1) that substantiates the minimum Systems Engineering support required to minimize the probability of cost over runs and schedule slips.

How much Systems Engineering is enough for each Project* ?!

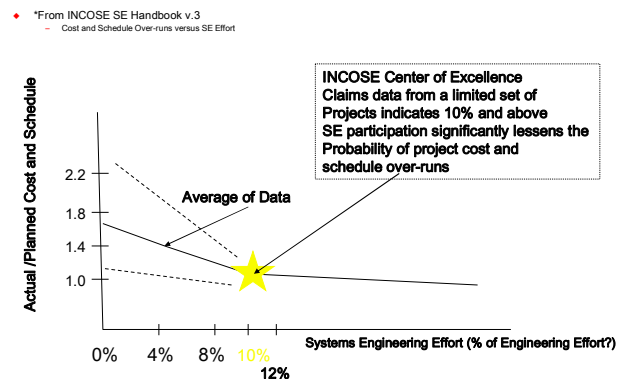


Figure C.

The data shown here, from a limited data set, indicates there is a minimum critical SE participation of 10-12% of the engineering resources. Other supporting studies that are well documented throughout industry is that 35-50% of all projects that fail to meet their imperatives of cost, schedule and performance/quality are due in some part to missing, incomplete, and mismanaged Requirements and changing Requirements. This is indeed what Systems Engineering is all about – designing and verifying to Requirements!

THE SYSTEMS ENGINEERING – CAPABILITY MATURITY MODEL (2, 3) – WHAT IS IT AND WHY USE IT?

Capability Maturity Model (CMM) (3) broadly refers to a process improvement approach that is based upon a process model. A process model is a structured collection of practices that describe the characteristics of

effective processes with practices that have proven to be effective. CMM was originally developed by the Carnegie Mellon Software Engineering Institute (SEI) for the United States Air Force to create a model for the military to use as an objective evaluation for software subcontractors. It was then rapidly adapted and used for the evaluation of Systems Engineering. It has since been successfully used throughout various commercial and military aerospace companies.

The Capability Maturity Model is a roadmap of the journey to competence with metrics to gage your progress. A maturity model is a structured collection of elements that describe characteristics of effective processes. The CMM can be used to assess an organization against a scale of five process maturity levels. Each level ranks the organization according to its standardization of processes in the subject area being assessed. The maturity levels provide a layered framework of a progression to the discipline that is directed toward continuous improvement.

The six step process, with each level having measurable criteria known as Key Process areas (18 for the CMM shown in Appendix A), consists of:

- Not Performed (or Zero Level)
 1. Performed Informally
 2. Planned and Tracked
 3. Well Defined
 4. Quantitatively Controlled
 5. Continuously Improving.

Level 5 is commonly known as “World Class” which few corporations, either aerospace or commercial, have yet to achieve. The benefits to improvement by consulting organizations that evaluate and guide such improvements indicate that a typical 10-20% improvement in cost, schedule and quality is achieved for each level gained (or matured). The following figure illustrates the characteristics of each step that the author utilized to develop the SE Common Process.

♦ The Road to Improvement – Process Wise

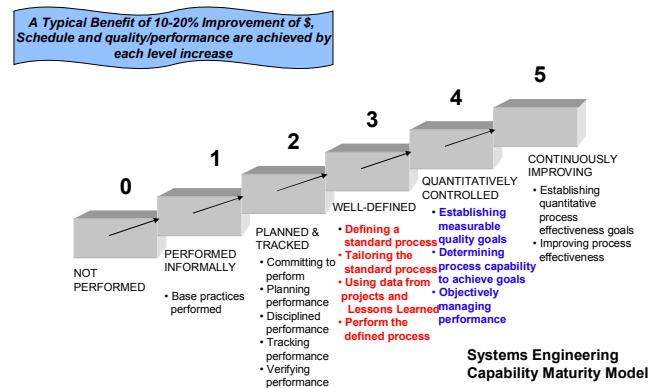


Figure D.

DISCUSSION OF THE MATURITY LEVELS OF CMM –

Level 1 (Performed Informally) –

While the base areas are generally performed, their performance may not be rigorously planned or tracked. Performance depends upon an individual's or the organization's tribal knowledge and application. There is general agreement within the organization that the action should be performed and that there are identifiable work products. In spite of this ad hoc, chaotic environment, level 1 organizations often produce products and services that work; however, at the expense of typically exceeding project schedule and budget.

Level 2 (Planned and Tracked) –

The base practices of the process are planned and tracked and performance to specified procedures are verified. Work products conform to specified standards and requirements. The organization is committed to track process area performance enabling it to manage its activities based upon actual performance. The primary distinction from level 1 is that of planned and tracked.

Level 3 (Well Defined) –

Base practices are performed according to a well-defined process using approved, tailored versions of standard, documented processes. These standard processes establish consistency across the organization. Data is collected and Lessons Learned is used throughout to help manage the process. The primary distinction from the previous level is that the process is planned and managed using an organization-wide standard process.

Level 4 (Quantitatively Controlled) –

Detailed measures of performance are collected and analyzed to lead to a quantitative understanding of process capability and an improved ability to predict performance. Performance can then be objectively