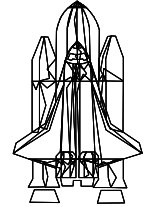


A tutorial on next generation systems engineering Systems Engineering, Life Cycle Management, and ISO/IEC 15288



*In every affair, consider what precedes and what follows, and then undertake it. – Epictetus
We are what we repeatedly do. Excellence, then, is not an act but a habit. – Aristotle*

There is a system to it! Be it natural, such as an atom or the Universe, or a DNA molecule or a human. Be it human-made, such as the Pyramid, an engine, the Space Station, or an organization. These are systems.

The system is constituted of elements. The system comes “alive” by the interactions among its elements. These interactions, for example, are in photosynthesis in a plant, the Carnot cycle of an engine, or the dynamics of an organization. These are processes.

By process there is system; in system there is process. Processes create and change the system in space-time. Every system is born, journeys through its destined states, expires, and is recycled. That is, the system goes through the states of its life cycle. Even our Sun is destined to follow this route. So, the system has elements, comes alive by processes, and goes through its life cycle.

Humans, as Nature, must depend on systems to function. Natural systems are absolutely essential but not enough; humans must make and use their own systems for survival and evolution. Humans created a discipline, called systems engineering, to address and process their own systems. Systems engineering is the systematic application of management and scientific means to provide solutions, products, and services for the system as it is evolved through its life cycle states – from conceptualization through development, production, operations, maintenance, support, and phase-out. Systems engineering is interdisciplinary. The system engineer, therefore, in order to be effective, needs: Basic understanding of the underlying disciplines, including system science, operations research, communications, and computers; Education in systems engineering, system analysis, and program management; and Proficiency in listening, reading, writing, and briefing.

For the common benefit of all, humans establish norms for addressing and processing systems. These are standards, which serve as the means for normalization and communication. On systems engineering there are several local standards. One such MIL-STD-499B (*Systems Engineering*) and its predecessors served the defense-industrial complex well. ANSI/EIA-632 (*Processes for engineering a system*), which began as a commercial adaptation of MIL-STD-499B, focuses well on the development state of the system. A relatively recent standard, ISO/IEC 15288 (*Systems engineering – System life cycle processes*), addresses most processes in the life cycle of the system and has the potential of serving international communities in global trade and economy. These standards could well be timely for the *System Age*!

ISO/IEC 15288. The standard is intended to be employed in the acquisition, supply, development, production, operations, maintenance, support, and disposal of [human-made] systems. The standard is a suitable but supplementary medium for interested parties to form agreements regarding the tasks which they need to perform within the constraints of requirements, technology, cost, and time. The standard may serve as a reference model for the processes implemented in systems engineering environments.

Tutorial. It presents an advanced introduction to systems engineering and life cycle management. ISO/IEC 15288:2008, ISO/IEC 15288:2002, MIL-STD-499B, real life cycle models, text books on system science and systems engineering, several articles, and the tutor’s experience serve as the source material. It includes guidance on how to apply the standard.

In five days, the tutorial will cover the following major chapters:

- Day 1, 2: Concepts and topics from sciences, engineering, systems engineering, and program management.
- Day 2: Life cycle states.
- Day 3, 4: Life cycle processes.
- Day 4, 5: Applications.

Syllabus. The tutorial has the following chapters. Appendix and Documentation formats will be brought up as needed.

1. Background. History, scope, and purpose of systems engineering and of ISO/IEC 15288.

2. Concepts. To instill life cycle outlook and system approach, the following concepts, *inter alia*, will be introduced:

- Process;
- System;
- Life cycle;
- System approach;
- Systems engineering;
- Life cycle management;
- Organization, enterprise, acquirer, supplier;
- Program, project, service, product;
- Architectures of system, process, and life cycle;
- Life cycle states and communication matrix;
- Life cycle modeling and management;
- Conformance and compliance; and
- Humans and systems.

3. Preparatory topics. To prepare and diversify the system engineer's portfolio, the following topics, *inter alia*, will be presented in respectively appropriate details:

- Program management for system engineers;
- Acquisition-supply models;
- Management indicators (value function, MOE, TPM, ROI, earned value, status indicators,);
- Project assessment and control;
- Life cycle models (real ones as examples);
- Systems engineering environment;
- System attributes (efficiency, reliability, availability, maintainability, complexity,);
- Development process;
- Development environment;
- Developmental models (Vee, fast track, incremental, evolutionary, re-engineering,);
- Engineering test and evaluation;
- Developmental, Operational, and Live-fire test and evaluation;
- Reviews, audits, and baselines;
- (Independent) Verification and Validation;
- Quality assurance;
- Risks and Risk management;
- Configuration and change management;
- Production/manufacturing/construction process;
- Operations process;
- Maintenance and Repair process;
- Logistics support process;

- Disposal process;
- Modeling and simulation;
- System analysis and Trade studies;
- Operations research; Optimization; and Queuing;
- Human factors and Ergonomics;
- Cybernetics & Automation;
- Safety;
- Security;
- Computers (analog, electromechanical, binary-digital electronic, neural network, hybrid,);
- Software engineering;
- Information technology; and
- Tailoring.

System development process. This is the primary focus of the tutorial. Its primary functions (requirements analysis, functional analysis, synthesis, design, implementation, integration, and engineering testing and evaluation) will be explained in significant depth. This process is the cornerstone of systems engineering: it could be employed anywhere in a life cycle as an analytical/modeling aid or to (re)engineer a system into being. Elementary Vee and complex developmental models will be discussed.

Acquisition-supply models. Acquisition-supply models facilitate understanding and negotiation between an acquirer and a supplier of system products and services. A generic model and the ISO/IEC 15288 model will be presented. An agreement may range from informal to formal to legal. The models, with suitable customization, may be employed in the following modes: an agreement by an individual with the self; an assignment by a supervisor to a subordinate; an agreement between branches of an organization; or a contract between separate organizations.

Program management for system engineers. Key functions of the system engineer *in programs* will be explained. The system engineer supports the program manager in budgeting, developing and executing program management plans (PMPs), soliciting or selecting suppliers, preparing or responding to requests-for-proposal or statements-of-work, and monitoring cost, schedule and progress. The system engineer develops and executes system engineering management plans (SEMPs), prepares data and documentation requirements, prepares and manages change notices, forms and directs integrated teams, convenes concurrent engineering forums, and monitors and influences progress. (There are two separate, coordinated PMP-SEMP sets: one on the acquisition side and the other on the supply side.)

Tailoring process. *Tailoring is adjudicating applicable pieces of current human knowledge to work the problem at hand.* This process will be explained carefully, for absent or improper tailoring will lead to shortchanging, gold plating, or both. As no two systems are the same, as the pressure to harness new findings is incessant, as the system must comply with government regulations and industry codes, as no program could earn unlimited budget and schedule, and as no model or standard could ever suffice, *tailoring* is become necessary and crucial to the program.

4. System life cycle states. States (phases or stages) through which the system is evolved:

- Generic life cycle phases: Research & Discovery; Need determination; Concept definition and demonstration; Development; Production/manufacturing/construction; Operations; Maintenance; Support; and Phase-out;
- Life cycle stages in 15288:2002: Concept; Development; Production; Utilization; Support; and Retirement;
- Activities and decisions in the life cycle states; and
- Decision gates and Milestone reviews.

The life cycle of a system is its *master* process. The organization employs a life cycle model when it sponsors a program and directs the evolution of the system through its life cycle states. Program management, systems engineering, and everything else are brought in to *support* the organization there. System life cycle processes (next chapter) are employed in implementing the decisions which the organization makes in each life cycle state. The tutor will discuss the aforementioned life cycle states in sufficient detail and show *real* life cycle models as examples.

5. System life cycle processes. ISO/IEC 15288:2008 processes employed in implementing the life cycle decisions:

- Agreement processes: Acquisition and Supply;
- Organizational project-enabling processes: Life cycle model management; Infrastructure management; Project portfolio management; Human resource management; and Quality Management;
- Project processes: Project planning; Project assessment and control; Decision management; Risk management; Configuration management; Information management; and Measurement;
- Technical processes: Stakeholder requirements definition; Requirement analysis; Architectural design; Implementation; Integration; Verification; Transition; Validation; Operation; Maintenance; and Disposal; and
- Tailoring.

The tutor will discuss the tasks in these processes and give comments and recommendations. Each student should have a copy of the standard. The standard normatively invokes ISO/IEC 12207 (*Software life cycle processes*) for binary-digital-electronic computer software in the system. It is, however, not necessary for system engineers to receive training in ISO/IEC 12207; the software engineering topic covered in the Preparatory chapter is adequate.

6a. Application. Guidance on how to apply such as a standard based on issues and questions which are expected to be addressed when conducting modern systems engineering in a program. The following four application modes will be discussed:

- On an organization – as if it were a system in itself;
- On a business/mission – as if it were a system in itself;
- On a program/project – to provide solutions, products and services in it; and
- In an acquirer-supplier agreement – related to products and services.

6b. Demonstrations. Two applications will be demonstrated: one by the tutor and the other jointly by the students and the tutor. In addition, the students are requested to bring in a statement of work that they themselves will use in applying the standard; the statement of work should be long enough for the exercise to fit in the tutorial schedule.

For the sake of time, only ISO/IEC 15288 processes will be considered during the sessions. The tutor recommends that, in practice, the following be considered as a minimum:

- ISO/IEC 15288;
- A local standard, such as ANSI/EIA 632, IEEE 1220, or other;
- Specialty standards, as applicable: health, safety, security, privacy, environment, quality, ...;
- Organizational instructions and system engineering environments; and
- Industry codes; and
- Government regulations.

7. Conclusion. Synopses of related areas and issues: certification of products and processes; comparison of ISO/IEC 15288 with ISO 9001; recommendations to organizations, National Bodies, and ISO/IEC; *et al.* Finally, the summary.

8. Appendix. Over 150 supplementary and additional topics. Exercises.

9. Documentation. These formats are in a separate Microsoft Word 2003 folder:

- Operational Concept Document;
- System Engineering Management Plan (SEMP);
- Test & Evaluation Management Plan;
- System/Subsystem Specifications;
- Interface Requirements Specifications;
- System/Subsystem Design Description;
- Interface Design Description; and
- Integrated Logistics Support Plan.

These documentation formats should be used as guidance for recording the results of system activities, or for customizing in-house documentation standards. (Acquirers are advised to ask for a draft SEMP in their request-for-proposal/tender. Suppliers are advised to improve their chances by including a draft SEMP in their proposals. ANSI/EIA-632 has a better SEMP format.)

Note 1. The life cycle processes from 15288 will be revised when the standard itself is revised in the future. Other topics come from various sources and will be adjusted only as needed.

Note 2. Students are urged to go through the tutorial after the session and complete the exercises. Should questions arise, the tutor will try to answer them – without any further obligation whatsoever. Cheers!

Note 3. Please note that there is no such person as a universal system engineer. A prospective system engineer receives lessons in common systems engineering courses but with *specialization* with respect to a specific area/industry, such as administration, engineering, business, health, military, manufacturing, etc.

ANNEX. Systems engineering curriculum

A sample set of graduate-level courses is listed below. SE100 courses are meant for all students; all other courses should be prudently elected to meet a student's career goals. Some courses may be given by other departments.

Recommend text book: B. S. Blanchard and W. J. Fabrycky, *Systems Engineering and Analysis*, Prentice Hall, 2006.

SE 101 System Science
SE 102 System Metrics & Measurements
SE 103 System Life Cycle and Models
SE 104 System Analysis and Control
SE 105 Program Management for system engineers
SE 106 System Development
SE 107 System Integration
SE 108 System Test & Evaluation
SE 109 System Production, Manufacturing and Construction
SE 110 System Maintenance
SE 111 System Logistics Support
SE 112 System Operations
SE 113 System Disposal

SE 600 Seminar series on selected topics: Listening, Reading, Writing, and Briefing; Systems engineering environment; Safety; Security; Risks; Ergonomics; Human factors; Cybernetics & automation; Accidents; Operations research; Trade studies; Computer science; Software engineering; Information technology; Problem/conflict resolution; Decision making; Configuration management; Quality assurance & control; Verification & Validation; Reviews & Audits; *et al.*

SE 701 Mathematics, Statistics, and Numerical analysis for system engineers
SE 702 Physics and physical systems for system engineers
SE 703 Chemistry and chemical systems for system engineers
SE 704 Biology and biological systems for systems engineers
SE 705 Economics and business systems for system engineers

SE 801 Organizational directives and instructions
SE 802 Systems engineering standards (e.g., ISO/IEC 15288, ANSI/EIA 632, IEEE 1220, ...)
SE 803 Quality management guides (e.g., ISO 9000 series)

SE 901 Thesis for M.S. in SE
SE 902 Thesis for Ph.D. in SE.

The problem is not that you aim high and you miss it; the problem is that you aim low and you achieve it.
– Leonardo daVinci