

CHAPTER 1

INTRODUCTION TO SYSTEMS ENGINEERING MANAGEMENT

1.1 PURPOSE

The overall organization of this text is described in the Preface. This chapter establishes some of the basic premises that are expanded throughout the book. Basic terms explained in this chapter are the foundation for following definitions. Key systems engineering ideas and viewpoints are presented, starting with a definition of a system.

1.2 DEFINITIONS

A System Is ...

Simply stated, a system is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective.

Systems Engineering Is...

Systems engineering consists of two significant disciplines: the technical knowledge domain in which the systems engineer operates, and systems engineering management. This book focuses on the process of systems engineering management.

Three commonly used definitions of systems engineering are provided by the best known technical standards that apply to this subject. They all have a common theme:

- A logical sequence of activities and decisions that transforms an operational need into a description of system performance parameters and a preferred system configuration. (MIL-STD-

499A, *Engineering Management*, 1 May 1974. Now cancelled.)

- An interdisciplinary approach that encompasses the entire technical effort, and evolves into and verifies an integrated and life cycle balanced set of system people, products, and process solutions that satisfy customer needs. (EIA Standard IS-632, *Systems Engineering*, December 1994.)
- An interdisciplinary, collaborative approach that derives, evolves, and verifies a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability. (IEEE P1220, *Standard for Application and Management of the Systems Engineering Process*, [Final Draft], 26 September 1994.)

In summary, systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions that satisfy customer needs.

Systems Engineering Management Is...

As illustrated by Figure 1-1, systems engineering management is accomplished by integrating three major activities:

- Development phasing that controls the design process and provides baselines that coordinate design efforts,
- A systems engineering process that provides a structure for solving design problems and

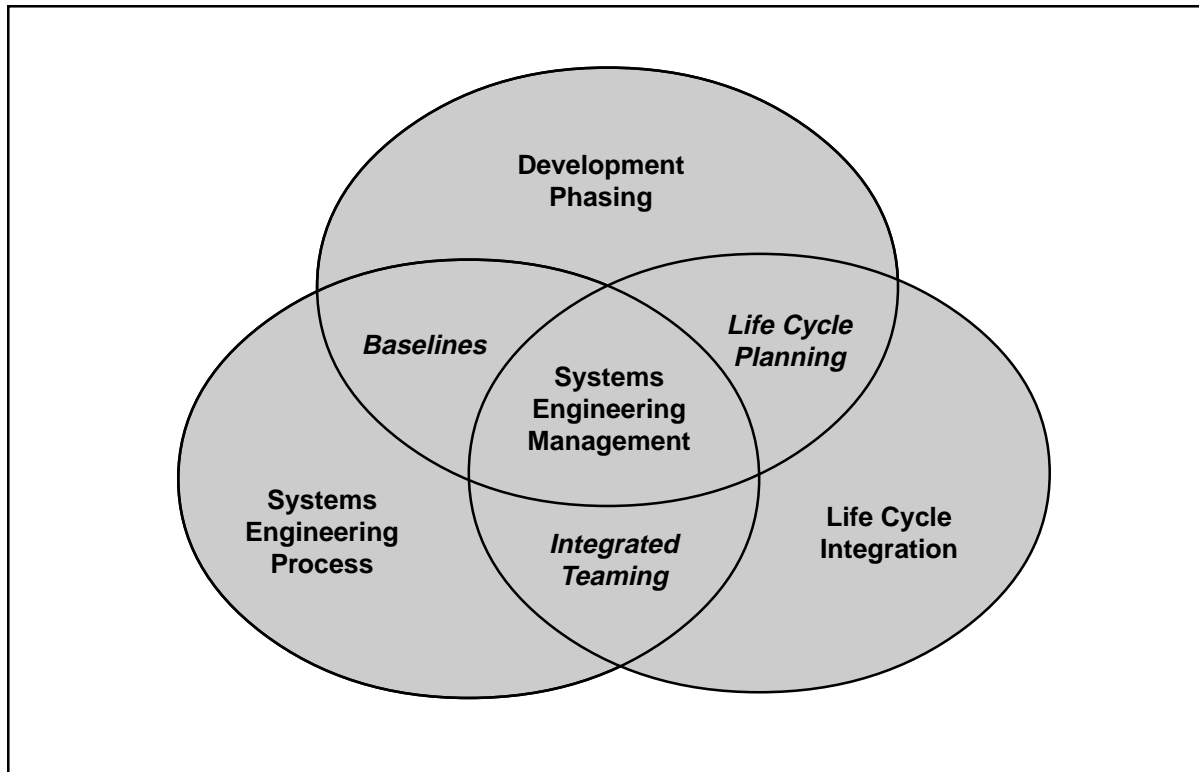


Figure 1-1. Three Activities of Systems Engineering Management

tracking requirements flow through the design effort, and

- Life cycle integration that involves customers in the design process and ensures that the system developed is viable throughout its life.

Each one of these activities is necessary to achieve proper management of a development effort. Phasing has two major purposes: it controls the design effort and is the major connection between the technical management effort and the overall acquisition effort. It controls the design effort by developing design baselines that govern each level of development. It interfaces with acquisition management by providing key events in the development process, where design viability can be assessed. The viability of the baselines developed is a major input for acquisition management Milestone (MS) decisions. As a result, the timing and coordination between technical development phasing and the acquisition schedule is critical to maintain a healthy acquisition program.

The systems engineering process is the heart of systems engineering management. Its purpose is to provide a structured but flexible process that transforms requirements into specifications, architectures, and configuration baselines. The discipline of this process provides the control and traceability to develop solutions that meet customer needs. The systems engineering process may be repeated one or more times during any phase of the development process.

Life cycle integration is necessary to ensure that the design solution is viable throughout the life of the system. It includes the planning associated with product and process development, as well as the integration of multiple functional concerns into the design and engineering process. In this manner, product cycle-times can be reduced, and the need for redesign and rework substantially reduced.

1.3 DEVELOPMENT PHASING

Development usually progresses through distinct levels or stages:

- Concept level, which produces a system concept description (usually described in a concept study);
- System level, which produces a system description in performance requirement terms; and
- Subsystem/Component level, which produces first a set of subsystem and component product performance descriptions, then a set of corresponding detailed descriptions of the products' characteristics, essential for their production.

The systems engineering process is applied to each level of system development, one level at a time, to produce these descriptions commonly called configuration baselines. This results in a series of configuration baselines, one at each development level. These baselines become more detailed with each level.

In the Department of Defense (DoD) the configuration baselines are called the functional baseline for the system-level description, the allocated baseline for the subsystem/ component performance

descriptions, and the product baseline for the subsystem/component detail descriptions. Figure 1-2 shows the basic relationships between the baselines. The triangles represent baseline control decision points, and are usually referred to as technical reviews or audits.

Levels of Development Considerations

Significant development at any given level in the system hierarchy should not occur until the configuration baselines at the higher levels are considered complete, stable, and controlled. Reviews and audits are used to ensure that the baselines are ready for the next level of development. As will be shown in the next chapter, this review and audit process also provides the necessary assessment of system maturity, which supports the DoD Milestone decision process.

1.4 THE SYSTEMS ENGINEERING PROCESS

The systems engineering process is a top-down comprehensive, iterative and recursive problem

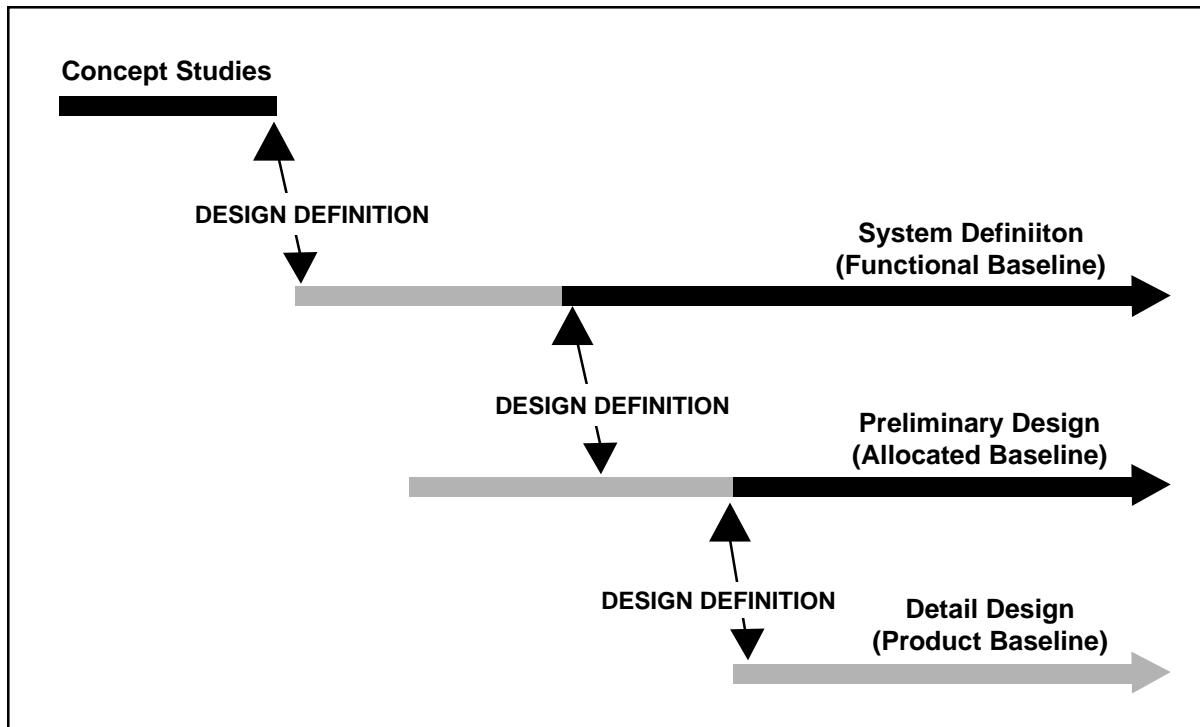


Figure 1-2. Development Phasing

solving process, applied sequentially through all stages of development, that is used to:

- Transform needs and requirements into a set of system product and process descriptions (adding value and more detail with each level of development),
- Generate information for decision makers, and
- Provide input for the next level of development.

As illustrated by Figure 1-3, the fundamental systems engineering activities are Requirements Analysis, Functional Analysis and Allocation, and Design Synthesis—all balanced by techniques and tools collectively called System Analysis and Control. Systems engineering controls are used to track decisions and requirements, maintain technical baselines, manage interfaces, manage risks, track cost and schedule, track technical performance, verify requirements are met, and review/audit the progress.

During the systems engineering process architectures are generated to better describe and understand the system. The word “architecture” is used in various contexts in the general field of engineering. It is used as a general description of how the subsystems join together to form the system. It can also be a detailed description of an aspect of a system: for example, the Operational, System, and Technical Architectures used in Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR), and software intensive developments. However, Systems Engineering Management as developed in DoD recognizes three universally usable architectures that describe important aspects of the system: functional, physical, and system architectures. This book will focus on these architectures as necessary components of the systems engineering process.

The *Functional Architecture* identifies and structures the allocated functional and performance requirements. The *Physical Architecture* depicts the

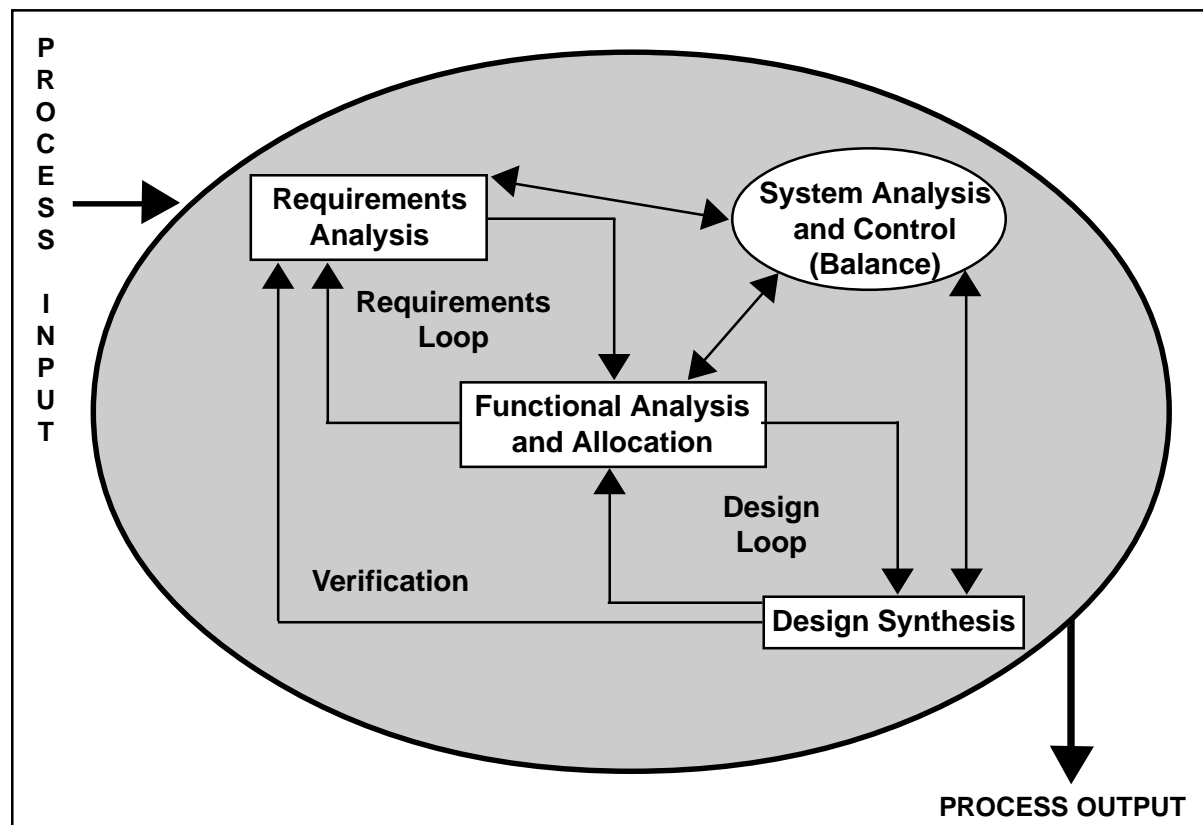


Figure 1-3. The Systems Engineering Process

system product by showing how it is broken down into subsystems and components. The *System Architecture* identifies all the products (including enabling products) that are necessary to support the system and, by implication, the processes necessary for development, production/construction, deployment, operations, support, disposal, training, and verification.

Life Cycle Integration

Life cycle integration is achieved through integrated development—that is, concurrent consideration of all life cycle needs during the development process. DoD policy requires integrated development, called Integrated Product and Product Development (IPPD) in DoD, to be practiced at all levels in the acquisition chain of command as will be explained in the chapter on IPPD. Concurrent consideration of all life cycle needs can be greatly enhanced through the use of interdisciplinary teams. These teams are often referred to as Integrated Product Teams (IPTs).

The objective of an Integrated Product Team is to:

- Produce a design solution that satisfies initially defined requirements, and
- Communicate that design solution clearly, effectively, and in a timely manner.

Multi-functional, integrated teams:

- Place balanced emphasis on product and process development, and
- Require early involvement of all disciplines appropriate to the team task.

Design-level IPT members are chosen to meet the team objectives and generally have distinctive competence in:

- Technical management (systems engineering),
- Life cycle functional areas (eight primary functions),

- Technical specialty areas, such as safety, risk management, quality, etc., or
- When appropriate, business areas such as finance, cost/budget analysis, and contracting.

Life Cycle Functions

Life cycle functions are the characteristic actions associated with the system life cycle. As illustrated by Figure 1-4, they are development, production and construction, deployment (fielding), operation, support, disposal, training, and verification. These activities cover the “cradle to grave” life cycle process and are associated with major functional groups that provide essential support to the life cycle process. These key life cycle functions are commonly referred to as the eight primary functions of systems engineering.

The customers of the systems engineer perform the life-cycle functions. The system user’s needs are emphasized because their needs generate the requirement for the system, but it must be remembered that all of the life-cycle functional areas generate requirements for the systems engineering process once the user has established the basic need. *Those that perform the primary functions also provide life-cycle representation in design-level integrated teams.*

Primary Function Definitions

Development includes the activities required to evolve the system from customer needs to product or process solutions.

Manufacturing/Production/Construction includes the fabrication of engineering test models and “brass boards,” low rate initial production, full-rate production of systems and end items, or the construction of large or unique systems or subsystems.

Deployment (Fielding) includes the activities necessary to initially deliver, transport, receive, process, assemble, install, checkout, train, operate, house, store, or field the system to achieve full operational capability.

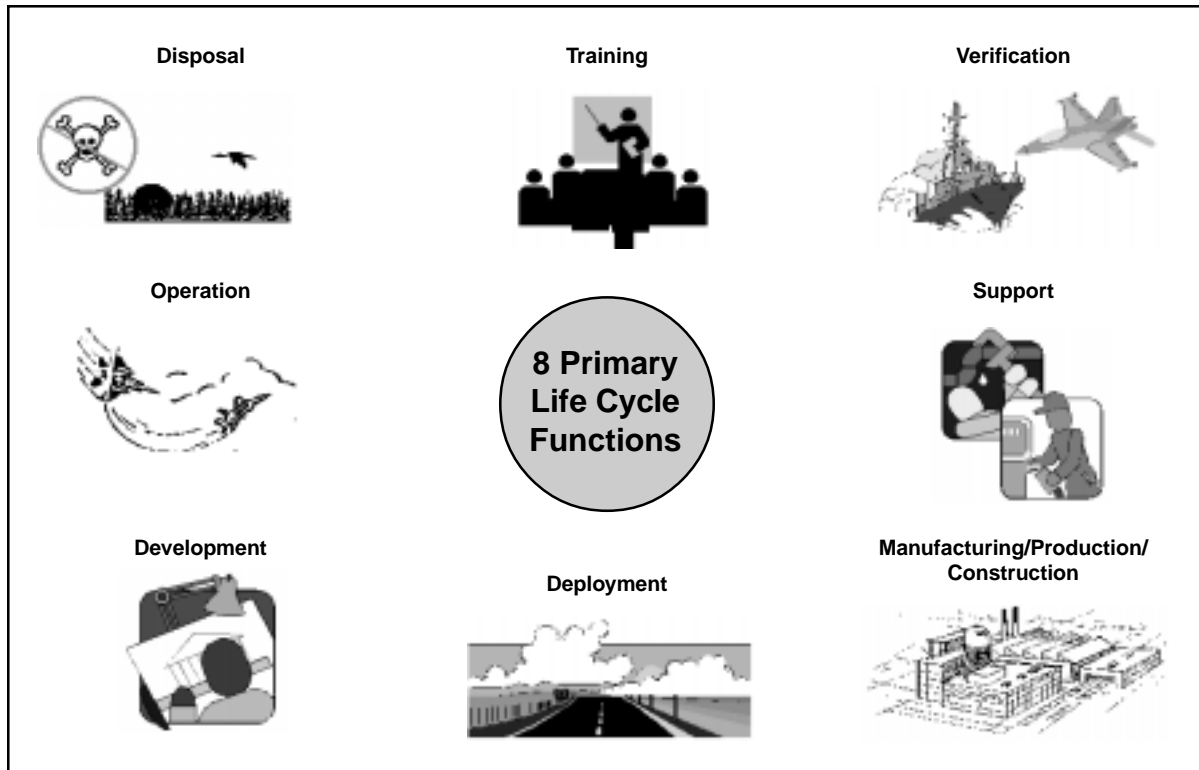


Figure 1-4. Primary Life Cycle Functions

Operation is the user function and includes activities necessary to satisfy defined operational objectives and tasks in peacetime and wartime environments.

Support includes the activities necessary to provide operations support, maintenance, logistics, and material management.

Disposal includes the activities necessary to ensure that the disposal of decommissioned, destroyed, or irreparable system components meets all applicable regulations and directives.

Training includes the activities necessary to achieve and maintain the knowledge and skill levels necessary to efficiently and effectively perform operations and support functions.

Verification includes the activities necessary to evaluate progress and effectiveness of evolving system products and processes, and to measure specification compliance.

Systems Engineering Considerations

Systems engineering is a standardized, disciplined management process for development of system solutions that provides a constant approach to system development in an environment of change and uncertainty. It also provides for simultaneous product and process development, as well as a common basis for communication.

Systems engineering ensures that the correct technical tasks get done during development through planning, tracking, and coordinating. Responsibilities of systems engineers include:

- Development of a total system design solution that balances cost, schedule, performance, and risk,
- Development and tracking of technical information needed for decision making,
- Verification that technical solutions satisfy customer requirements,

- Development of a system that can be produced economically and supported throughout the life cycle,
- Development and monitoring of internal and external interface compatibility of the system and subsystems using an open systems approach,
- Establishment of baselines and configuration control, and
- Proper focus and structure for system and major sub-system level design IPTs.

1.5 GUIDANCE

DoD 5000.2-R establishes two fundamental requirements for program management:

- It requires that an Integrated Product and Process approach be taken to design wherever practicable, and
- It requires that a disciplined systems engineering process be used to translate operational needs and/or requirements into a system solution.

Tailoring the Process

System engineering is applied during all acquisition and support phases for large- and small-scale systems, new developments or product improvements, and single and multiple procurements. The process must be tailored for different needs and/or requirements. Tailoring considerations include system size and complexity, level of system definition detail, scenarios and missions, constraints and requirements, technology base, major risk factors, and organizational best practices and strengths.

For example, systems engineering of software should follow the basic systems engineering approach as presented in this book. However, it must be tailored to accommodate the software development environment, and the unique progress

tracking and verification problems software development entails. In a like manner, all technology domains are expected to bring their own unique needs to the process.

This book provides a conceptual-level description of systems engineering management. The specific techniques, nomenclature, and recommended methods are not meant to be prescriptive. Technical managers must tailor their systems engineering planning to meet their particular requirements and constraints, environment, technical domain, and schedule/budget situation.

However, the basic time-proven concepts inherent in the systems engineering approach must be retained to provide continuity and control. For complex system designs, a full and documented understanding of what the system must do should precede development of component performance descriptions, which should precede component detail descriptions. Though some parts of the system may be dictated as a constraint or interface, in general, solving the design problem should start with analyzing the requirements and determining what the system has to do before physical alternatives are chosen. Configurations must be controlled and risk must be managed.

Tailoring of this process has to be done carefully to avoid the introduction of substantial unseen risk and uncertainty. Without the control, coordination, and traceability of systems engineering, an environment of uncertainty results which will lead to surprises. Experience has shown that these surprises almost invariably lead to significant impacts to cost and schedule. Tailored processes that reflect the general conceptual approach of this book have been developed and adopted by professional societies, academia, industry associations, government agencies, and major companies.

1.6 SUMMARY POINTS

- Systems engineering management is a multi-functional process that integrates life cycle functions, the systems engineering problem-solving process, and progressive baselining.

- The systems engineering process is a problem-solving process that drives the balanced development of system products and processes.
- Integrated Product Teams should apply the systems engineering process to develop a life cycle balanced-design solution.
- The systems engineering process is applied to each level of development, one level at a time.
- Fundamental systems engineering activities are Requirements Analysis, Functional Analysis/Allocation, and Design Synthesis, all of which are balanced by System Analysis and Control.
- Baseline phasing provides for an increasing level of descriptive detail of the products and processes with each application of the systems engineering process.
- Baseline in a nut shell is a concept description that leads to a system definition which, in turn, leads to component definitions, and then to component designs, which finally lead to a product.
- The output of each application of the systems engineering process is a major input to the next process application.