Chapter 1 Systems Engineering Overview

The systems engineering management process is intended to ensure that development cost, schedule, and technical performance objectives are met. Typical management activities include planning the technical effort, monitoring technical performance, managing risk, and controlling the system technical baseline.

The System Specification and Design process is used to specify system requirements that will meet the needs of the stakeholders.

- It then allocates the requirements to the components of the system
- The components are designed, implemented, and tested to ensure they satisfy the requirements
- The System Integration and Test process includes activities to integrate the components into the system and verify that the system satisfies its requirements
- Maintain traceability from the system goals to the system and component requirements and verification results to ensure that requirements and stakeholder needs are addressed
- Perform analysis to evaluate and select a preferred system solution that satisfies the system requirements and maximizes the effectiveness measures
- Synthesize alternative system solutions by partitioning the system design into components that can satisfy the system requirements

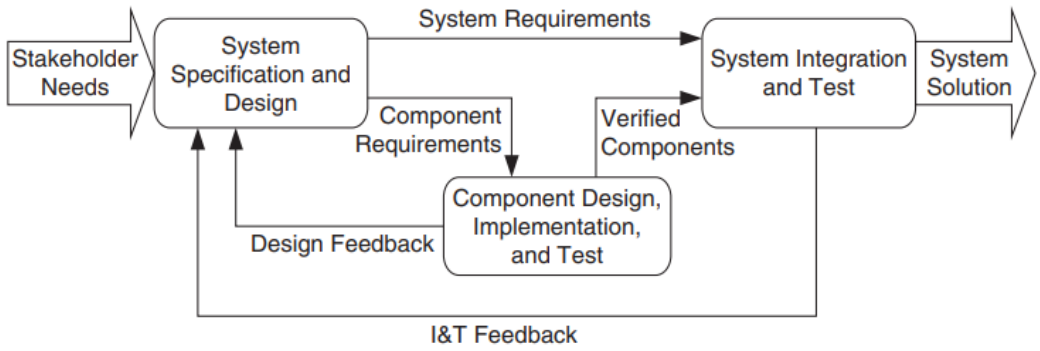

FIGURE 1.1

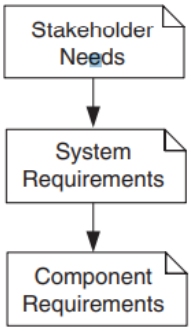

FIGURE 1.7

Stakeholder needs flow down to system and component requirements.

Stakeholders

- addressing the needs of other stakeholders who may be affected throughout the system's lifecycle
- Less obvious stakeholders are organizations and governments that express their needs via laws, regulations, and standards
- Analysis is performed to understand the needs of each stakeholder and to define effectiveness measures and target values
    - In terms of an automobile effectiveness measures may relate to the primary goal of addressing the transportation needs, such as the availability of transportation
    - the time to reach a destination, safety, comfort, environmental impact
    - costs associated with purchasing and owning an automobile

system boundary

- gas pump and maintenance equipment, road

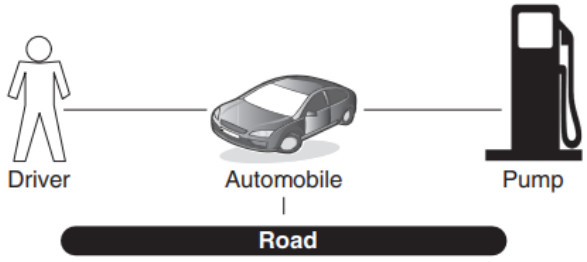

FIGURE 1.2

Defining the system boundary.

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Functional requirements

- analyzing what the system must do to support its overall goals, such as functional requirements to meet transportation needs
- must perform functions related to accelerating, braking, and steering
- functional analysis identifies the inputs and outputs for each function
- must also be evaluated to determine the level of performance required for each function
- Additional requirements are specified to address other concerns of each stakeholder as defined by the system goals and effectiveness measures

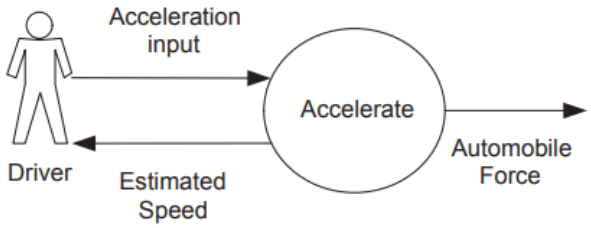

FIGURE 1.3

- Specifying the functional requirements.

System Requirements

- must be clearly traceable to stakeholder needs and validated to ensure that the requirements address those needs
- involves identifying system components and specifying the component requirements so that the system requirements will be met
- may involve first developing a logical system design that is independent of the technology used, and then a physical system design that reflects specific technology selections.
- system's physical components include the engine, transmission, differential, body, chassis, brakes, and so on
- Systems engineers should validate the assumptions that drive the constraints and perform the analysis to understand their impact on the design.

System Design Overview

- alternatives are evaluated to determine the system solution that achieves a balanced design while addressing multiple competing requirements
- The component requirements are input to the Component Design, Implementation, and Test process from Figure 1.1.
- Some components may be procured rather than developed, so designers need to understand the difference between what has been specified and what can be supplied
- The system test cases are defined to verify that the system satisfies its requirements

Multidisciplinary Systems Engineering Team

- The Requirements Team analyzes stakeholder needs, develops the concept of operations, and specifies and validates the system requirements
- The Architecture Team is responsible for synthesizing the system architecture by partitioning the system into components and defining their interactions and interconnections
- The Systems Analysis Team is responsible for performing the engineering analysis on different aspects of the system, such as performance and physical characteristics, reliability, maintainability, and cost, to provide the rationale for the technical specifications

- The Integration and Test Team is responsible for developing test plans and procedures and for conducting tests to verify the requirements are satisfied

Codifying Systems Engineering Practice Through Standards

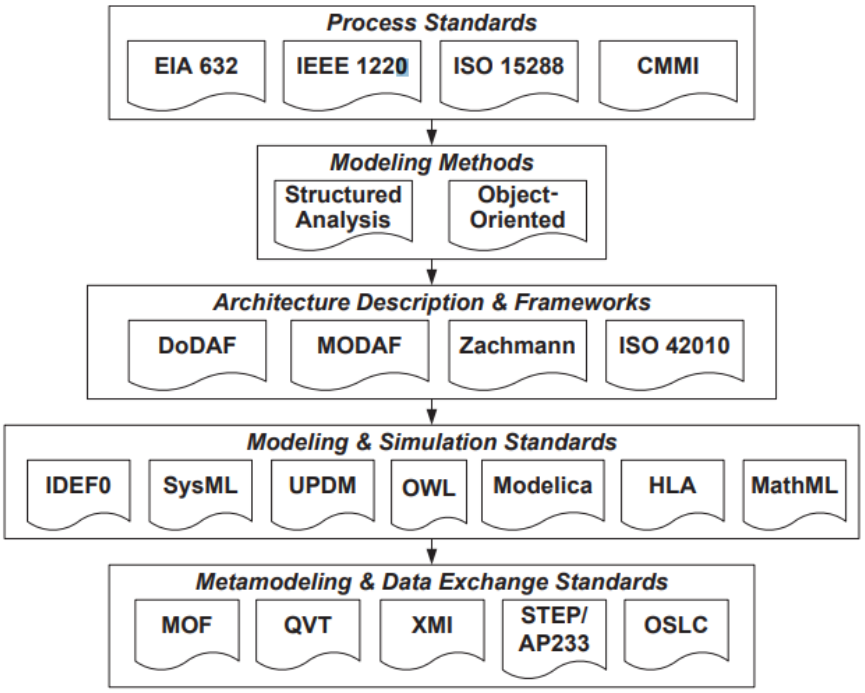

FIGURE 1.9

A partial systems engineering standards taxonomy.

- A particular systems engineering approach may implement one or more standards from each layer of this taxonomy
- The systems engineering process defines what activities are performed but does not generally give details on how they are performed.
- A systems engineering method describes how the activities are performed and the kinds of systems engineering artifacts that are produced
- The concept of operations defines what the system is intended to do from the user's perspective.
- Criteria for selecting a method include its ease of use, its ability to address the relevant systems engineering concerns, and the level of tool support.
- The C4ISR framework [16] was introduced in 1996 to provide a framework for architecting information systems for the US Department of Defense
- The OMG SysML specification—the subject of this book—was adopted in 2006 by the Object Management Group as a general-purpose graphical systems modeling language that extends the Unified Modeling Language (UML).
- Model and data exchange standards is a critical class of modeling standards that supports model and data exchange among tools.

Chapter 2 Model-Based Systems Engineering

- applies systems modeling as part of the systems engineering process described in Chapter 1 to support analysis, specification, design, and verification of the system being developed

Document-Based Systems Engineering Approach

- System Function Decomposition: Utilize drawing tools such as functional flow diagrams and schematic block diagrams to decompose system functions and allocate them to respective components.
- Engineering Trade Studies: Conduct analyses and trade studies across various disciplines to evaluate and optimize alternative designs, considering aspects like performance, reliability, safety, and mass properties.
- Requirements Traceability: Establish and maintain requirements traceability by linking specifications at different levels of the hierarchy. Utilize requirements management tools to parse and capture requirements in a database, ensuring traceability between requirements and design elements.
- Document-Based Approach Limitations: While document-based approaches can be rigorous, they suffer from limitations such as difficulties in assessing completeness, consistency, and relationships between different aspects (requirements, design, analysis). This can lead to poor synchronization, hindering system understanding, traceability, and change impact assessments. Additionally, maintaining and reusing information for evolving systems is challenging, potentially impacting cost, schedule, and system quality.

Model-Based Systems Engineering Approach

- MBSE is the formalized application of modeling to support system activities from conceptual design through development and later lifecycle phases.
- It utilizes models for system requirements, design, analysis, verification, and validation.
- Model elements represent requirements, design, test cases, design rationale, and their interrelationships.
- It specifies hardware and software components, their interconnections, interfaces, interactions, functions, and performance characteristics.
- Model elements are stored in a model repository and presented through diagrams with graphical symbols.
    - The repository enables querying, analysis, and document generation from the system model.
- Model-Based Approach Benefits
    - Enhanced communication and shared understanding across development teams.
    - Reduced development risk through ongoing requirements validation and design verification.
    - Improved quality with more complete and traceable requirements.
- Increased Productivity with MBSE:
    - Faster and more comprehensive impact analysis of requirements and design changes.
    - Reuse of existing models for design evolution and automated document generation.
- Challenges and Considerations

- Transitioning to MBSE requires upfront investment in processes, methods, tools, and training.
- MBSE may coexist with document-based approaches during the transition, tailoring the approach based on project needs.