



# **The MITRE Systems Engineering Guide**

## ***Practical Guidance for Systems Engineering***

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# An Initiative of the Office of the Corporate Chief Engineer (OCCE)

OCCE ...

- Formed to enhance corporate-wide practice of systems engineering
- Enhance technical quality of MITRE work
- Promote cross-cutting integration
- Champion enterprise engineering

Today's focus



# The MITRE SE Guide

- **Practical guidance on MITRE systems engineering**
  - Like having a discussion with a MITRE expert available 24/7
- **Primary Audience**
  - MITRE staff leading or performing an FFRDC SE activity
  - Individuals who want to learn SE from this perspective
- **Purpose**
  - Convey accumulated wisdom on systems engineering practice
  - Accelerate individuals up the learning curve
  - Hit the ground running with that knowledge in customer environment
- **Sources of wisdom**
  - MITRE experience (> 130 senior contributors across the Corporation)
  - Other sources – when they provide practical advice for MITRE SEs
- **Complements, does not duplicate, other resources**
- **Guide organization & focus based on MITRE SE Competency Model**
- **101 articles posted, more in the works**

# SE Guide – A Resource for the Customer, Too

- **Best practices & lessons learned relevant to program manager & other government member roles & responsibilities**
  - **Systems Engineering & Acquisition a team sport**
  - **Tips on specific subjects, ideas for program planning**
- **Brings to bear wisdom accumulated from across all MITRE customers & sponsors for the benefit of a government program**

*Dedicated to capturing & sharing our SE knowledge & expertise across the Corporation for the benefit of all our customers*

# 5 Major SEG Sections

The screenshot shows the MITRE Systems Engineering Guide website. The browser title is "Home - Systems Engineering Guide - Windows Internet Explorer provided by MITRE". The URL is "https://partners.mitre.org/sites/SEG/default.aspx". The page header includes "MITRE Community Share Partners" and "Systems Engineering Guide". The main content area is titled "Systems Engineering at MITRE" and features a search bar. Below the header, there are navigation links for "Home" and "Articles". The main content area is divided into several sections, each with a callout box:

- Engineering IT-intensive Enterprises:** A callout box pointing to the "Enterprise Engineering" section, which includes links for "Comprehensive Viewpoint", "Engineering Information-Intensive Enterprises", "Enterprise Governance", and "Other Enterprise Engineering Articles".
- Fundamental SE building blocks:** A callout box pointing to the "SE Life-Cycle Building Blocks" section, which includes links for "Concept Development", "Implementation, O and M, and Transition", "Other Life-Cycle Building Blocks Articles", "Requirements Engineering", "System Architecture", "System Design and Development", "Systems Integration", and "Test and Evaluation".
- How fit in government acquisition:** A callout box pointing to the "SE Planning and Management" section, which includes links for "Acquisition Program Planning", "Configuration Management", "Continuous Process Improvement", "Contractor Evaluation", "Integrated Logistics Support", "MITRE FFRDC Independent Assessments", "Other Planning and Management Articles", "Program Acquisition Strategy Formulation", "Quality Assurance and Measurement", "Risk Management", "Source Selection Preparation and Evaluation", and "Transformation Planning and Organizational Change".
- Definition(s) of SE & its evolution:** A callout box pointing to the "The Evolution of Systems Engineering" section, which includes a link for "More >".
- Expectations - sponsors & our own:** A callout box pointing to the "The Essence of MITRE Systems Engineering" section, which includes a link for "More >".

At the bottom of the page, there is a "Browse Guide Topics" section with a link for "View all articles". The footer of the page includes the MITRE logo, the text "Approved for public release. Distribution unlimited. Case no. 10-4072", and the copyright notice "© 2010 The MITRE Corporation. All rights Reserved.".

# SEG Section Page (1/2)

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https://partners.mitre.org/sites/SEG/Sections%20and%20Topics/SE%20Life-Cycle%20Building%20Blocks.aspx

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Home - Systems Engineering

## Systems Engineering at MITRE

This Site: Systems Engineering

Home Articles

Systems Engineering Guide > Life-Cycle Building Blocks

### SE Life-Cycle Building Blocks

Intro & Background

List of topics

#### Introduction

MITRE systems engineers (SEs) orchestrate the complete development of a system, from a need through operations to retirement, by applying a set of life-cycle building blocks. SEs are expected to understand and work with fundamental building blocks for engineering systems, regardless of the specific life-cycle methodology used. They are expected to define systems conceptually, transform user needs into system requirements, and develop and assess architectures. They are expected to compose and assess alternative design and development approaches; develop test and certification strategies; monitor and assess contractor efforts in design, development, integration, and test; and assist with field deployment, operations, and maintenance.

#### Background

All systems engineering models and processes are organized around the concept of a life cycle. Although the detailed views, implementations, and terminology used to articulate the SE life cycle differ across MITRE's processes and customers, they all share fundamental elements:

#### Topics in this Section

Name
Concept Development
Implementation, O and M, and Transition
Other Life-Cycle Building Blocks Articles
Requirements Engineering
System Architecture
System Design and Development
Systems Integration
Test and Evaluation

#### Sections and Topics

Enterprise Engineering Section

- Comprehensive Viewpoint
- Engineering Information-Intensive Enterprises
- Enterprise Governance
- Other Enterprise Engineering Articles

SE Life-Cycle and Building Blocks Section

- Concept Development
- Requirements Engineering
- System Architecture
- System Design and Development
- Systems Integration
- Test and Evaluation

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## Concept Development

This first phase is concerned with transforming a user's expression of an operational need into a well-defined concept of operations, a high-level conceptual definition, and a set of initial operational requirements. This Systems Engineering Guide (SEG) topic contains the following articles: [Operational Needs Assessment](#), [Concept of Operation](#), [Operational Requirements](#), and [High-Level Conceptual Definition](#).

## Requirements Engineering

In this phase, detailed system requirements are elicited from the user and other stakeholders, the requirements are further analyzed and refined, and plans and processes for managing the requirements throughout the rest of the system life cycle are developed. With today's complex systems, there is always a degree of instability and uncertainty with the requirements, so methods to accommodate this are included as well during this phase. This SEG topic contains articles entitled [Eliciting Requirements](#), [Analyzing and Defining Requirements](#), and [Special Considerations for Conditions of Uncertainty: Prototyping and Experimentation](#).

## System Architecture

Once the requirements are expressed and folded into a management process, a system architecture can be described. The architecture will be the foundation for further development, integration, testing, operation, interfacing, and improvement of the system as time goes on. In the system architecture articles, we discuss various architecture patterns (e.g., service-oriented architecture), architectural frameworks (e.g., DoDAF [architectural framework]), and formal processes for developing architectures. This SEG topic contains articles called [Architectural Patterns](#); [Architectural Frameworks, Models, and Views](#); and [Approaches to Architecture Development](#).

## System Design and Development

At this point in the system life cycle, a complete and comprehensive description of what and how the system is expected to perform has been developed along with an architectural representation to guide the actual design and development of the hardware, software, and interfaces. This SEG topic contains the following articles: [Develop System-Level Technical Requirements](#), [Assess a Design's Ability to Meet the System Requirements](#), and [Develop a Top-Level System Design](#).

## Systems Integration

During the design and development phase, all of the system's sub-systems are complete. In this next system integration phase, the system's components and its interfaces with other systems are integrated into an operational whole. This SEG topic contains articles entitled [Identify and Assess Integration and Interoperability Challenges](#), [Develop and Evaluate Integration and Interoperability Solution Strategies](#), [Assess Integration Testing Approaches](#), and [Interface Management](#).

## Test and Evaluation

Since the system is completely designed at this point, it is now necessary to test the system to see if it fulfills the users' needs (verification) and all of the defined

Program Acquisition Strategy Formulation  
Acquisition Program Planning  
Source Selection Preparation and Evaluation  
Contractor Evaluation  
Risk Management  
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Integrated Logistics Support  
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Management  
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Assessments  
Planning and Management Articles

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Short Intro to each topic

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# SEG Topic Page

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## Concept Development

**Definition:** *Concept development is a set of activities that are carried out early in the systems engineering life cycle to collect and prioritize operational needs and challenges, develop alternative concepts to meet the needs, and select a preferred one as the basis for subsequent system or capability development and implementation.*

**Keywords:** *analysis, concept, definition, development, exploration, requirements, systems engineering*

### Context

Concept development takes place early in the systems engineering life cycle. The success of the subsequent development of a system or capability can be critically dependent on the soundness of the foundation that is laid during the concept development stage. In their definitions of concept development, Kossiakoff and Sweet [1] highlight phases of needs analysis (valid need and practical approach), concept exploration (performance to meet the need, feasible cost-effective approach), and concept definition (key characteristics that balance capability, operational life, and cost).

In this guide, concept development is described as four activities that identify and characterize user needs:

- Operational Needs Assessment**—The application of operational experience to identify and characterize gaps in existing capabilities that are significant impediments to achieving the mission area objectives.
- Concept of Operations**—A description of a proposed system characteristics in terms of the needs it will fulfill from a user's perspective.
- Operational Requirements**—Statements that formally, unambiguously, and as completely as possible, identify the essential capabilities and associated performance measures.
- High-Level Conceptual Definition**—A clear description or model of the characteristics or attributes needed to address a specific set of requirements or capabilities.

MITRE systems engineers (SEs) should understand that, like the environment, operational needs and requirements cannot be viewed as static. User needs change, their priorities change, and the technology to enable them change. This means that requirements cannot be viewed as cast-in-stone with subsequent system engineering aligned to an inflexible baseline. Trade-off analyses may be required more or less continuously to ensure effective capabilities are delivered to meet user's immediate and evolving needs.

### Articles in this Topic

Title	#	Comments
- Operational Needs Assessment	0	
- Concept of Operations	0	
- Operational Requirements	0	
- High-Level Conceptual Definition	0	

### Sections and Topics

- Enterprise Engineering Section
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  - Engineering Information-Intensive Enterprises
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  - Other Enterprise Engineering Articles
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  - Configuration Management
  - Integrated Logistics Support
  - Quality Assurance and Measurement

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Definition & key words

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Systems Engineering Guide > Life-Cycle Building Blocks > Concept Development > Operational Requirements

## Operational Requirements

**Definition:** Operational requirements are those statements that "identify the essential capabilities, associated requirements, performance measures, and the process or series of actions to be taken in effecting the results that are desired in order to address mission area deficiencies, evolving applications or threats, emerging technologies, or system cost improvements [1]." The operational requirements assessment is a part of Operations (CONOPS) and goes to a greater level of detail in identifying mission performance assumptions and constraints, and identifying areas of or enhancements needed for operations and mission success. Operational requirements are the basis for system requirements.

**Keywords:** concept definition, concept development, operational requirements, requirements attributes, system requirements, user requirements, users

**MITRE SE Roles & Expectations:** MITRE systems engineers (SEs) are expected to be able to understand the users' needs based on the operational needs assessment (i.e., what mission area capability gaps need to be addressed). They must be able to analyze the needs identified by the capability gaps, and develop or assist in defining the operational and top-level characteristics or requirements of the system. They also should utilize the concept of operations (CONOPS) to understand the operational needs, desires, visions, expectations, performance requirements, and challenges of the system. MITRE SEs, together with the users, developers, and integrators, assist in defining the system operational requirements, ensuring the requirements map to the operational needs assessment and CONOPS. They work closely with the users to define and develop operational requirements that are reasonable and testable. The MITRE SE is expected to be able to lay out an evolutionary strategy for the requirements that identify and prioritize initial capabilities and subsequent capability increments to be implemented over time. This approach allows for the delivery of initial capabilities and enables agility in delivering future capabilities that are responsive to changes in the operational environment. The MITRE SE is responsible for identifying and assessing conditions, constraints, conflicting requirements, and organizational issues, including safety and security for system resolution. The MITRE SE will typically work to gain user agreement on the operational requirements, including refining and changing requirements as part of the system development process. For more information on CONOPS, see "Concept Development" in the SE Life-Cycle Building Blocks section of the SEG.

**Background**

A key process in the concept development phase is analysis to define the operational requirements of the system. Operational requirements are typically prepared by a team of users, user representatives, developers, integrators, and MITRE systems engineers and are based on the identified user need or capability gaps (refer to the "Operational Needs Assessment" article in this section of the Guide). Establishing operational requirements forms the basis for subsequent system

MITRE SE Roles & Expectations

Where article subject fits; MITRE SE fits.

**Sections and Topics**

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  - Transformation Planning and Organizational Change
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# Competitive Prototyping Article - Best Practices & Lessons Learned

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### CP Best Practices and Lessons Learned [4, 5, 6, 7]

- **When size (and skill) matters:** Acquisition program offices that employ CPs successfully tend to require a larger contingent of government systems engineers with greater than average technical competence. While this may appear counterintuitive, remember that CPs offer advantages to programs that use them, but they must be skillfully planned, monitored, and managed by the government team.
- **Right-sizing CP requirements:** CP is an investment that buys information to reduce uncertainty and risk. But CP adds up-front costs to a program right at a time when funding may be scarce and support for the program is often weak. A CP may run into opposition from the least expected stakeholders—staunch advocates of a program who believe that it must be pushed at great speed to fill capability gaps. To navigate these external forces on CP efforts, the program CP requirements must be right-sized. They must focus on areas that have substantial risk or offer a high reward-risk ratio, whatever and wherever those areas may be—high-level capabilities/levels-of-service, low-level detailed requirements at the subsystem level, or issues in between. It is also important to make sure that likely performance bottlenecks are identified in the prototype process that are measurable and measured as part of prototype testing.
- **Make sure your CP learns from antecedent activities:** One focus of recent government acquisition reform initiatives is on the importance of early systems engineering. Some departments and agencies are strongly recommending or mandating prototyping in advance of technology development, during materiel solution analysis (see figure 1, above). Results or lessons learned from these very early prototypes should be used to shape and inform CP activities.
- **Have your CP do double duty:** The primary purpose of CP is to illuminate and eliminate technology maturity risks. But don't lose sight of the fact that a CP can give important insight into other risk areas such as contractor manufacturing processes (if the CP is resourced appropriately) and undiscovered operational user requirements. Look for and collect information on all issues and areas that a CP can illuminate, especially important downstream system engineering activities and assessments for which CP information can form the basis of refined government assessments of system design or estimates of program cost.
- **Ensure persistent, active engagement of all stakeholders:** CP is not a competition between two gladiators in an arena slugging it out until one gives in, at which time everyone else in the coliseum looks up and applauds the winner. CP efforts must be structured to encourage active participation of end-users and other stakeholders throughout the CP lifecycle. To facilitate that involvement, CP efforts should emphasize frequent demonstrations of progress and evidence that a prototype can scale. Ideally, CPs should be developed iteratively or in an evolutionary fashion and be able to demonstrate interim operational capabilities. Active operational user stakeholder engagement is particularly critical to CPs intended to address requirements discovery and refinement.
- **Remember those without "skin in the game":** Important stakeholders in the eventual outcome of a program, like certification and accreditation authorities, are frequently forgotten during CP. Identify and bring these stakeholders into CP planning early so they can advise on "non-starters" and be engaged through the

From Competitive Prototyping article

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# To Obtain your Account ... (active duty military, civilian government and FFRDC employees)

First ....

- Send an email from your government or FFRDC email account to [segteam@mitre.org](mailto:segteam@mitre.org) that:
  - Requests access to the “SEG-LR extranet site”
  - References “George Rebovich – 13<sup>th</sup> Annual NDIA SE Conference”

Next ...

- You’ll receive an email asking you to set up a password

Then ...

- You’ll receive an email with a link to the site that you can access with your email address and password

A final note ...

- Once in the site, you can suggest ideas for additional topics to cover or recommend your own best practices & lessons learned

# Contact Information

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