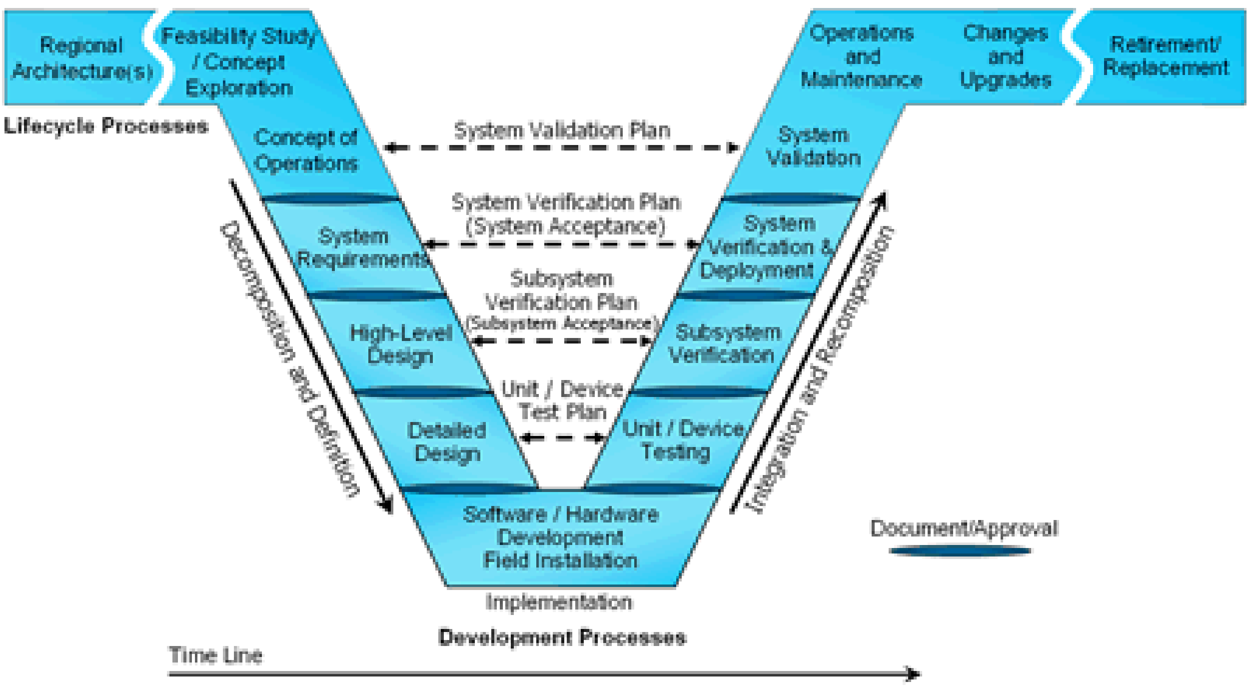
# Overview of the System Engineering Process

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## Introduction

This document provides a high level look at the Systems Engineering Process for ITS projects. More detailed information of the System Engineering process is available through FHWA's publication, "System Engineering for Intelligent Transportation Systems". The systems engineering should be viewed as an extension to the traditional project development process that is already established in the department. As the NDDOT gains experience with ITS projects and the systems engineering approach, we will find that we can weave the systems engineering processes and best practices into our overall project development process.

## What is Systems Engineering?

Since the term was coined in the 1950s, systems engineering has evolved from a process focused primarily on large-scale defense systems to a broader discipline that is used in all kinds of project development. Systems engineering can be applied to any system development, so whether you are developing a household appliance, building a house, or implementing a sophisticated transportation management system, systems engineering can be used. INCOSE defines systems engineering like this:

> *Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.*
>
> *Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.*

Note that this definition is very broad – it covers the project life cycle from needs definition to system disposal. It includes technical activities like requirements and design, as well as project activities like risk management and configuration management. Systems engineering provides a systematic process and tools that directly support project management.

## What is an ITS Project?

In order to apply systems engineering to ITS projects in accordance with the FHWA Rule/FTA Policy, it is important to define an *ITS project*. Rule 940 defines ITS projects quite broadly:

> *ITS Project means any project that in whole or in part funds the acquisition of technologies or systems of technologies that provide or significantly contribute to the provision of one or more ITS user services as defined in the National ITS Architecture.*

This definition encompasses a wide range of projects. Smaller ITS projects might be limited to the purchase and installation of field equipment – controllers, environmental sensors, signals, etc. Larger ITS projects support integration of multiple systems and development of custom software – for example, transportation management centers (TMC's) and 511 traveler information systems. These ITS projects are

**§ 23 CFR 940.11 Project implementation.**
(a) All ITS projects funded with highway trust funds shall be based on a systems engineering analysis.
(b) The analysis should be on a scale commensurate with the project scope.
(c) The systems engineering analysis shall include, at a minimum:
(1) Identification of portions of the regional ITS architecture being implemented (or if a regional ITS architecture does not exist, the applicable portions of the National ITS Architecture);
(2) Identification of participating agencies' roles and responsibilities;
(3) Requirements definitions;
(4) Analysis of alternative system configurations and technology options to meet requirements;
(5) Procurement options;
(6) Identification of applicable ITS standards and testing procedures; and
(7) Procedures and resources necessary for operations and maintenance

vastly different in complexity and in the amount of systems engineering that is needed. The FHWA Division/FTA Regional Offices establish and monitor how systems engineering analysis requirements are levied on specific ITS projects.

# Systems Engineering Principles

### Start with Your Eye on the Finish Line

You should reach consensus at the very beginning of the project on what will constitute success at the end. This means that the stakeholders should start with an agreement of what the project should accomplish and the metrics that will be used to measure the success of the project. This initial focus on the finish line must be sustained by project management as project development progresses and competing interests and project complexities begin to dominate the day-to-day work.

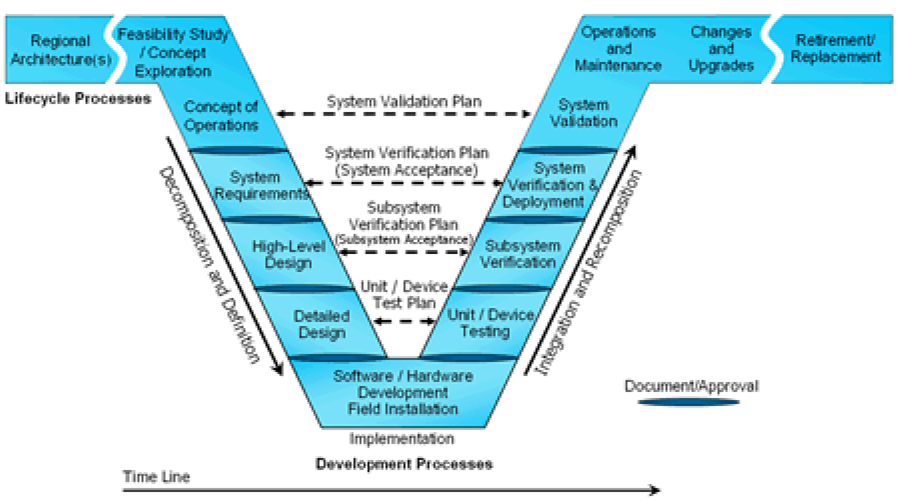
### Stakeholder Involvement is Key

Successful projects involve the customer, users, operators, and other stakeholders in the project development. Systems engineering is a systematic process that includes reviews and decision points intended to provide visibility into the process and encourage stakeholder involvement. The systems engineering process includes stakeholders through all stages of the project, from initial needs definition through system verification and acceptance. The stakeholders who are involved in any particular step will vary, providing managers, operators, and technical personnel with an opportunity to contribute to the steps in the process where their input is needed.

## *The "V" Systems Engineering Model*

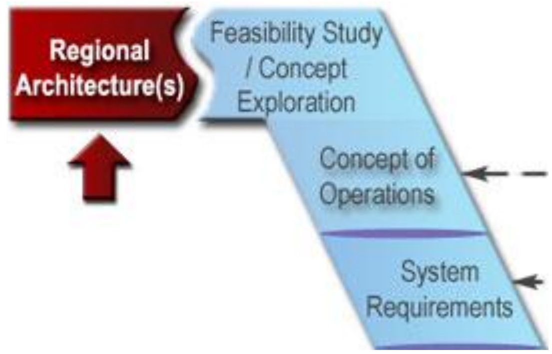
Many different process models have been developed over the years that specify a series of steps that make up the systems engineering approach[6]. Among these models, the "V" model, shown in Figure 7, is merging as the de facto standard way to represent systems engineering for ITS projects. Don't be surprised if you come across different spellings for the "V" model. Some books, guides, and other resources refer to the same V-shaped model as the "Vee" model. If it looks like a "V" and it sounds like a "V", then it is a reference to the same basic model, whether it is spelled "V" or "Vee".

Since it was first developed in the 1980s, the "V" model has been refined and applied in many different industries. Wings have been recently added to the "V" as part of its adaptation for ITS to show how project development fits within the broader ITS project life cycle. The left wing shows the regional ITS architecture, feasibility studies, and concept exploration that support initial identification and scoping of an ITS project based on regional needs. A gap follows the regional architecture(s) step because the regional architecture is a broader product of the planning process that covers all ITS projects in the region. The following steps in the "V" are for a specific ITS project. The central core of the "V" shows the project definition, implementation, and verification processes. The right wing shows the operations and maintenance, changes and upgrades, and ultimate retirement of the system. The wings are a key addition to the model since it is important to consider the entire life cycle during project development.



# What are the Parts of the “V” Diagram

## *Using the Regional ITS Architecture*




**In this step:** The portion of the regional ITS architecture that is related to the project is identified. Other artifacts of the planning and programming processes that are relevant to the project are collected and used as a starting point for project development. This is the first step in defining your ITS project.

**OBJECTIVES**

- Define the project scope while considering the regional vision and opportunities for integration
- Improve consistency between ITS projects and identify more efficient incremental implementation strategies
- Improve continuity between planning and project development

**INPUT**

**Sources of Information**

- Relevant regional ITS architecture(s)
- Regional/national resources supporting architecture use
- Other planning/programming products relevant to the project

**PROCESS**

**Key Activities**

- Identify regional ITS architecture(s) that are relevant to the project
- Identify the portion of the regional ITS architecture that applies
- Verify project consistency with the regional ITS architecture and identify any necessary changes to the regional ITS architecture

**OUTPUT**

**Process Results**

- List of project stakeholders and roles and responsibilities
- List of inventory elements included in or affected by the project
- List of requirements the proposed system(s) must meet
- List of interfaces and the information to be exchanged or shared by the system(s)
- Regional ITS architecture feedback as necessary

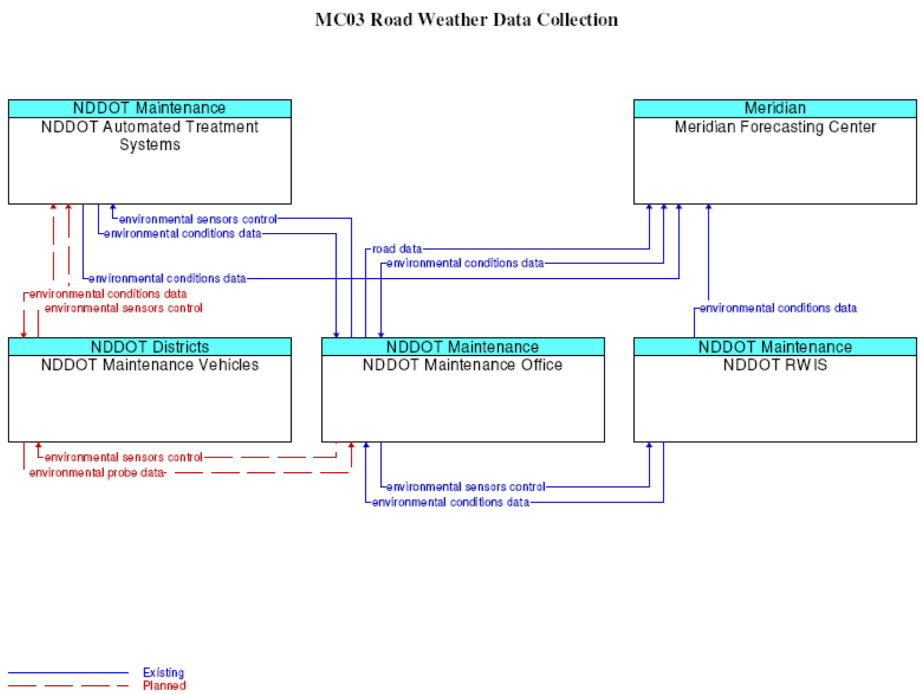
**REVIEW**

**Proceed only if you have:**

- Demonstrated consistency with the regional ITS architecture and identified needed changes to the regional ITS architecture, if applicable
- Extracted the relevant portion of the regional ITS architecture that can be used in subsequent steps
- Reached consensus on the project/system scope

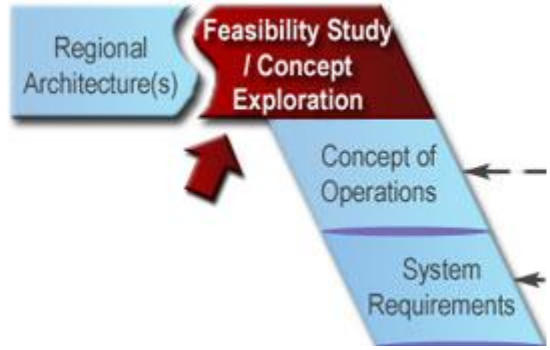
## Overview

The regional ITS architecture provides a good starting point for systems engineering analyses that are performed during ITS project development. It provides region-level information that can be used and expanded in project development. When an ITS project is initiated, there is a natural tendency to focus on the programmatic and technical details and to lose sight of the broader regional context. Using the regional ITS architecture as a basis for project implementation provides this regional. It provides each project sponsor with the opportunity to view their project in the context of surrounding systems. It also prompts the sponsor to think about how the project fits within the overall transportation vision for the region. Finally, it identifies the integration opportunities that should be considered and provides a head start for the systems engineering analysis.




**Example: NDDOT Architecture Subset; Weather Data**

## *Feasibility Study/Concept Exploration*




**In this step:** A business case is made for the project. Technical, economic, and political feasibility is assessed; benefits and costs are estimated; and key risks are identified. Alternative concepts for meeting the project's purpose and need are explored, and the superior concept is selected and justified using trade study techniques.

**OBJECTIVES**

- Identify superior, cost-effective concept, and document alternative concepts with rationale for selection
- Verify project feasibility and identify preliminary risks
- Garner management buy-in and necessary approvals for the project

**INPUT**

**Sources of Information**

- Project goals and objectives
- Project purpose and need
- Project scope/subset of the regional ITS architecture

**PROCESS**

**Key Activities**

- Define evaluation criteria
- Perform initial risk analysis
- Identify alternative concepts
- Evaluate alternatives
- Document results

**OUTPUT**

**Process Results**

- Feasibility study that identifies alternative concepts and makes the business case for the project and the selected concept

**REVIEW**

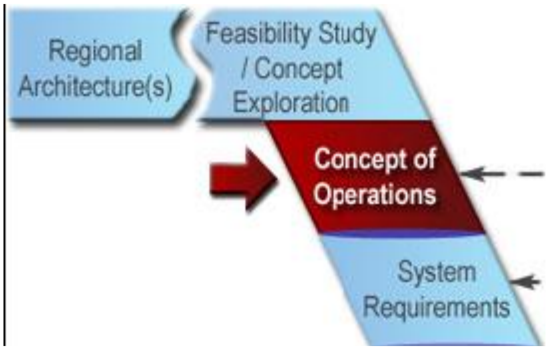
**Proceed only if you have:**

- Received approval on the feasibility study from project management, executive management, and controlling authorities, as required
- Reached consensus on the selected alternative

## Overview

In this step, the proposed ITS project is assessed to determine whether it is technically, economically, and operationally viable. Major concept alternatives are considered, and the most viable option is selected and justified. While the concept exploration should be at a fairly high level at this early stage, enough technical detail must be included to show that the proposed concept is workable and realistic. The feasibility study provides a basis for understanding and agreement among project decision makers – project management, executive management, and any external agencies that must support the project, such as a regional planning commission.

## *Concept of Operations*




**In this step:** The project stakeholders reach a shared understanding of the system to be developed and how it will be operated and maintained. The Concept of Operations (ConOps) is documented to provide a foundation for more detailed analyses that will follow. It will be the basis for the system requirements that are developed in the next step.

**OBJECTIVES**

- High-level identification of user needs and system capabilities in terms that all project stakeholders can understand
- Stakeholder agreement on interrelationships and roles and responsibilities for the system
- Shared understanding by system owners, operators, maintainers, and developers on the who, what, why, where, and how of the system
- Agreement on key performance measures and a basic plan for how the system will be validated at the end of project development

**INPUT**

**Sources of Information**

- Stakeholder lists, roles and responsibilities, and other components from the regional ITS architecture
- Recommended concept and feasibility study from the previous step
- Broad stakeholder input and review

**PROCESS**

**Key Activities**

- Identify the stakeholders associated with the system/project
- Define the core group responsible for creating the Concept of Operations
- Develop an initial Concept of Operations, review with broader group of stakeholders, and iterate
- Define stakeholder needs
- Create a System Validation Plan

**OUTPUT**

**Process Results**

- Concept of Operations describing the who, what, why, where, and how of the project/system, including stakeholder needs and constraints
- System Validation Plan defining the approach that will be used to validate the project delivery

**REVIEW**

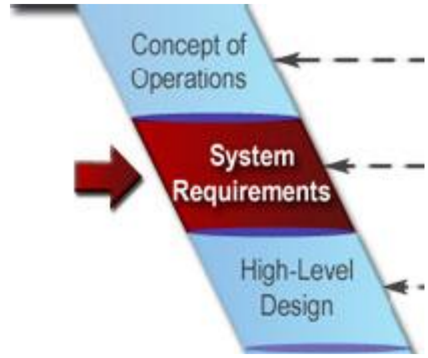
**Proceed only if you have:**

- Received approval on the Concept of Operations from each stakeholder organization
- Received approval on the System Validation Plan from each stakeholder organization

## Overview

The Concept of Operations (ConOps) is a foundation document that frames the overall system and sets the technical course for the project. Its purpose is to clearly convey a high-level view of the system to be developed that each stakeholder can understand. A good ConOps answers who, what, where, when, why, and how questions about the project from the viewpoint of each stakeholder.

- Who – Who are the stakeholders involved with the system?
- What – What are the elements and the high-level capabilities of the system?
- Where – What is the geographic and physical extent of the system?
- When – What is the sequence of activities that will be performed?
- Why – What is the problem or opportunity addressed by the system?
- How – How will the system be developed, operated, and maintained?




## *System Requirements*

**In this step:** The stakeholder needs identified in the Concept of Operations are reviewed, analyzed, and transformed into verifiable requirements that define *what* the system will do but not *how* the system will do it. Working closely with stakeholders, the requirements are elicited, analyzed, validated, documented, and baselined.

**OBJECTIVES**

- Develop a validated set of system requirements that meet the stakeholders' needs

**INPUT**

**Sources of Information**

- Concept of Operations (stakeholder needs)
- Functional requirements, interfaces, and applicable ITS standards from the regional ITS architecture
- Applicable statutes, regulations, and policies
- Constraints (required legacy system interfaces, hardware/software platform, etc.)

**PROCESS**

**Key Activities**

- Elicit requirements
- Analyze requirements
- Document requirements
- Validate requirements
- Manage requirements
- Create a System Verification Plan
- Create a System Acceptance Plan

**OUTPUT**

**Process Results**

- System Requirements document
- System Verification Plan
- Traceability Matrix
- System Acceptance Plan

**REVIEW**

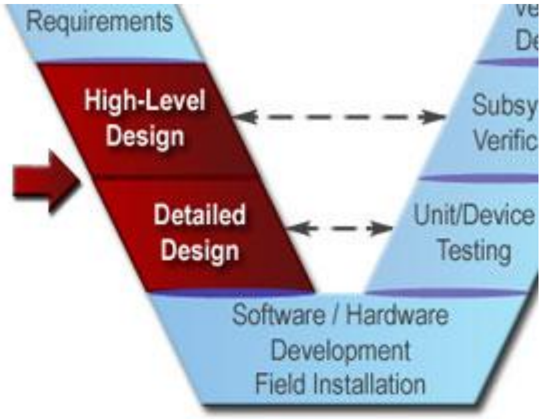
**Proceed only if you have:**

- Received approval on the System Requirements document from each stakeholder organization, including those that will deploy, test, install, operate, and maintain the new system
- Received approval on the System Verification Plan from the project sponsor, the test team, and other stakeholder organizations
- Received approval on the System Acceptance Plan from the project sponsor, the Operations & Maintenance (O&M) team, and other stakeholder organizations

## Overview

One of the most important attributes of a successful project is a clear statement of requirements that meet the stakeholders' needs. Unfortunately, creating a clear statement of requirements is often much easier said than done. The initial list of stakeholder needs that are collected will normally be a jumble of requirements, wish lists, technology preferences, and other disconnected thoughts and ideas. A lot of analysis must be performed to develop a good set of requirements from this initial list.

# *System Design*




**In this step:** A system design is created based on the system requirements including a high-level design that defines the overall framework for the system. Subsystems of the system are identified and decomposed further into components. Requirements are allocated to the system components, and interfaces are specified in detail. Detailed specifications are created for the hardware and software components to be developed, and final product selections are made for off-the-shelf components.

**OBJECTIVES**

- Produce a high-level design that meets the system requirements and defines key interfaces, and that facilitates development, integration, and future maintenance and upgrades
- Develop detailed design specifications that support hardware and software development and procurement of off-the-shelf equipment

**INPUT**

**Sources of Information**

- Concept of Operations
- System Requirements document
- Off-the-shelf products
- Existing system design documentation
- ITS standards
- Other industry standards

**PROCESS**

**Key Activities**

- Evaluate off-the-shelf components
- Develop and evaluate alternative high-level designs
- Analyze and allocate requirements
- Document interfaces and identify standards
- Create Integration Plan, Subsystem Verification Plans, and Subsystem Acceptance Plans
- Develop detailed component-level design specifications

**OUTPUT**

**Process Results**

- Off-the-shelf evaluation and alternatives summary reports
- High-level (architectural) design
- Detailed design specifications for hardware/software
- Integration Plans, Subsystem Verification Plans, Subsystem Acceptance Plans, and Unit/Device Test Plans

**REVIEW**

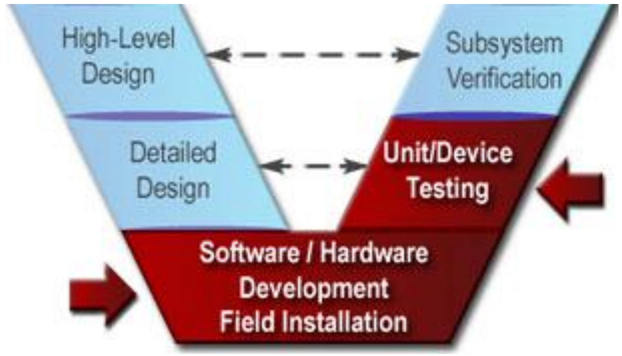
**Proceed only if you have:**

- Approved high-level design for the project
- Defined all system interfaces
- Traced the system design specifications to the requirements
- Approved detailed specifications for all hardware/software components

## Overview

In the systems engineering approach, we define the problem before we define the solution. The previous steps in the "V" have all focused primarily on defining the problem to be solved. The system design step is the first step where we focus on the solution. This is an important transitional step that links the system requirements that were defined in the previous step with system implementation that will be performed in the next step. There are two levels of design that should be included in your project design activities; High-level design and Detail design.

## *Software/Hardware Development and Testing*




**In this step:** Hardware and software solutions are created for the components identified in the system design. Part of the solution may require custom hardware and/or software development, and part may be implemented with off-the-shelf items, modified as needed to meet the design specifications. The components are tested and delivered ready for integration and installation.

**OBJECTIVES**

-  Develop and/or purchase hardware and software components that meet the design specifications and requirements with minimum defects
-  Identify any exceptions to the requirements or design specifications that are required

**INPUT**

**Sources of Information**

-  System and subsystem requirements
-  System design
-  Off-the-shelf products
-  Industry standards
-  Unit/Device Test Plans

**PROCESS**

**Key Activities**

-  Plan software/hardware development
-  Establish development environment
-  Procure off-the-shelf products
-  Develop software and hardware
-  Perform unit/device testing

**OUTPUT**

**Process Results**

-  Software/hardware development plans
-  Hardware and software components, tested and ready for integration
-  Supporting documentation (e.g., training materials, user manuals, maintenance manuals, installation and test utilities)

**REVIEW**

**Proceed only if you have:**

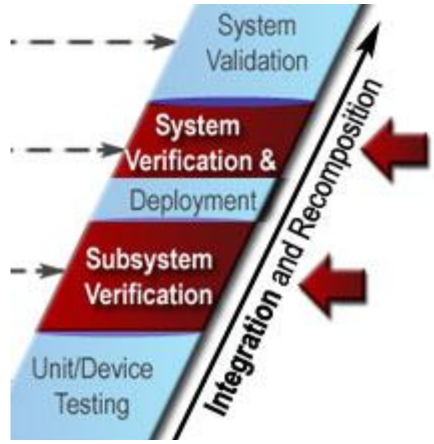
-  Conducted technical reviews of the hardware/software
-  Performed configuration/quality checks on the hardware and software
-  Received all supporting documentation
-  Verified that unit/device testing has been successfully completed

## Overview

Although hardware and software development may be the first task that comes to mind when thinking about an ITS project, the systems engineering approach focuses on the preceding requirements and design steps and on the integration, verification, and validation steps to follow.  This is where the investment in a clear set of requirements and a good system design should begin to pay dividends. The systems engineering process now provides technical oversight as an implementation team of specialists fabricates the hardware and writes the software. This is a highly iterative process, particularly for software, where key features may be incrementally implemented, tested, and incorporated into the baseline over time. Progress is monitored through a planned series of walkthroughs, inspections, and reviews.

## *Integration and Verification*

**In this step:** The software and hardware components are individually verified and then integrated to produce higher-level assemblies or subsystems. These assemblies are also individually verified before being integrated with others to produce yet larger assemblies, until the complete system has been integrated and verified.




**OBJECTIVES**

-  Integrate and verify the system in accordance with the high-level design, requirements, and verification plans and procedures
-  Confirm that all interfaces have been correctly implemented
-  Confirm that all requirements and constraints have been satisfied

**INPUT**

**Sources of Information**

-  System Requirements document
-  High-level design specifications
-  Detailed design specifications
-  Hardware and software components
-  Integration plan
-  System and Subsystem Verification Plans
-  Subsystem Acceptance Plans

**PROCESS**

**Key Activities**

-  Add detail to integration and verification plans
-  Establish integration and verification environment
-  Perform integration
-  Perform verification

**OUTPUT**

**Process Results**

-  Integration plan (updated)
-  Verification plan (updated)
-  Integration test and analysis results
-  Verification results, including corrective actions taken

**REVIEW**

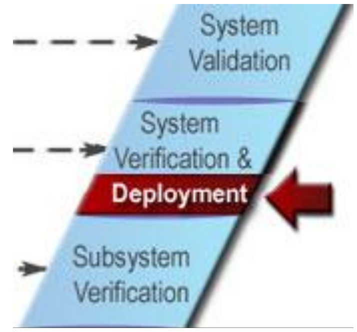
**Proceed only if you have:**

-  Documented evidence that the components, subsystems, and system meet the allocated requirements
-  Documented evidence that the external and internal interfaces are working and consistent with the interface specifications

## Overview

In this step, we assemble the system components into a working system and verify that it fulfills all of its requirements. Assembling a puzzle is a nice, simple analogy for this step, but the challenge in an ITS project "puzzle" is that you may find that not all of the pieces are available at the same time, some won't fit together particularly well at first, and there will be pressure to change some of the pieces after you have already assembled them. The systems engineering approach provides a systematic process for integration and verification that addresses the challenges and complexity of assembling an ITS system.

## *Initial Deployment*




**In this step:** The system is installed in the operational environment and transferred from the project development team to the organization that will own and operate it. The transfer also includes support equipment, documentation, operator training, and other enabling products that support ongoing system operation and maintenance. Acceptance tests are conducted to confirm that the system performs as intended in the operational environment. A transition period and warranty ease the transition to full system operation.

**OBJECTIVES**

- Uneventful transition to the new system

**INPUT**

**Sources of Information**

- Integrated and verified system, ready for installation
- System Acceptance Plan

**PROCESS**

**Key Activities**

- Plan for system installation and transition
- Deliver the system
- Prepare the facility
- Install the system
- Perform acceptance tests
- Transition to operation

**OUTPUT**

**Process Results**

- Hardware and software inventory
- Final documentation and training materials
- Delivery and installation plan, including shipping notices
- Transition Plan with checklists
- Test issues and resolutions
- Operations and maintenance plan and procedures

**REVIEW**

**Proceed only if you have:**

- Formally accepted the system
- Documented acceptance test results, anomalies, and recommendations

## Overview

Up to this point, the system has been tested primarily in a lab environment. The next step is to ship the system to the actual deployment site(s), install and check it out, and make sure the system and personnel are ready to transition to system operations and maintenance (O&M).  Larger systems may be installed in stages. For example, a closed-circuit television (CCTV) camera network may be built out incrementally over the course of several years and several projects. This may be done to spread the costs across several fiscal years or to synchronize with other construction projects in the region. In other cases, phased deployment may be performed to mitigate risk by deploying the essential core of the system and then adding features over time. If it is necessary to deploy the system in stages, whether due to funding constraints, to mitigate risk, or to synchronize with other projects, it is important to understand the dependencies between successive deployments and to prioritize the projects accordingly.

## *System Validation*

**In this step:** After the ITS system has passed system verification and is installed in the operational environment, the system owner/operator, whether the state DOT, a regional agency, or another entity, runs its own set of tests to make sure that the deployed system meets the original needs identified in the Concept of Operations.


**OBJECTIVES**

-  Confirm that the installed system meets the user's needs and is effective in meeting its intended purpose

**INPUT**

**Sources of Information**

-  Concept of Operations
-  Verified, installed, and operational system
-  System Validation Plan

**PROCESS**

**Key Activities**

-  Update Validation Plan as necessary and develop procedures
-  Validate system
-  Document validation results, including any recommendations or corrective actions

**OUTPUT**

**Process Results**

-  System Validation Plan (update) and procedures
-  Validation results

**REVIEW**

**Proceed only if you have:**

-  Validated that the system is effectively meeting its intended purpose
-  Documented issues/shortcomings
-  Established ongoing mechanisms for monitoring performance and collecting recommendations for improvement
-  Made modifications to the Concept of Operations to reflect how the system is actually being used

## Overview

Some may be surprised to see that there is another step in the "V" between initial deployment and operations and maintenance. After all, we have already verified that the system meets all of its requirements, installed the system and trained the users, and the customer has successfully conducted acceptance tests and formally accepted the system. Aren't we done? The answer is: yes and no. Yes, the system has been put into operation and is beginning to be used for its intended purpose. No, we aren't done. Now that the system is beginning to be used in the operational environment, we have our first good opportunity to measure just how effective the system is in that environment (i.e., system validation). In systems engineering, we draw a distinction between *verification* and *validation*. **Verification** confirms that a product meets its specified requirements. **Validation** confirms that the product fulfills its intended use.

## *Operations and Maintenance*


**In this step:** Once the customer has accepted the ITS system, the system operates in its typical steady state. System maintenance is routinely performed and performance measures are monitored. As issues, suggested improvements, and technology upgrades are identified, they are documented, considered for addition to the system baseline, and incorporated as funds become available. An abbreviated version of the systems engineering process is used to evaluate and implement each change. This occurs for each change or upgrade until the ITS system reaches the end of its operational life.

**OBJECTIVES**

- Use and maintain the system over the course of its operational life

**INPUT**

**Sources of Information**

- System requirements (operations/maintenance requirements)
- Operations and Maintenance Plan and procedures
- Training materials
- Performance data
- Evolving stakeholder needs

**PROCESS**

**Key Activities**

- Conduct Operations and Maintenance Plan reviews
- Establish and maintain all operations and maintenance procedures
- Provide user support
- Collect system operational data
- Change or upgrade the system
- Maintain configuration control of the system
- Provide maintenance activity support

**OUTPUT**

**Process Results**

- System performance reports
- Operations logs
- Maintenance records
- Updated operations and maintenance procedures
- Identified defects and recommended enhancements
- Record of changes and upgrades
- Budget projections and requests

**REVIEW**

**Proceed only if you have:**

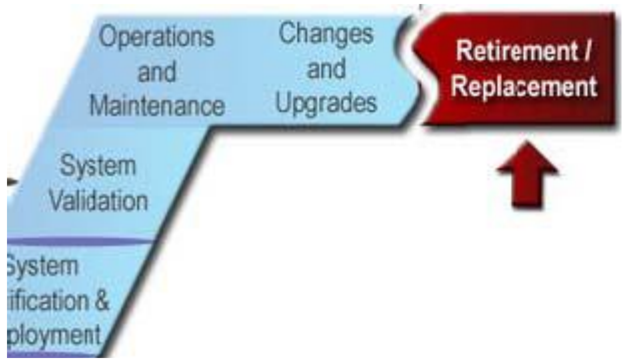
- Demonstrated that the system has reached the end of its useful life

## Overview

Now that the ITS system is up and running, it enters a “steady state” period that lasts until the system is retired or replaced.  During this period, operators, maintainers, and users of the system may identify issues, suggest enhancements, or identify potential efficiencies. New releases of hardware and software will be installed and routine maintenance will be performed.  Approved changes and upgrades are incorporated into the system baseline using the systems engineering process.  O&M personnel might also identify process changes that may streamline O&M activities. All changes to the processes should be documented.

## *Retirement/Replacement*

**In this step:** Operation of the ITS system is periodically assessed to determine its efficiency. If the cost to operate and maintain the system exceeds the cost to develop a new ITS system, the existing system becomes a candidate for replacement. A system retirement plan will be generated to retire the existing system gracefully.




**OBJECTIVES**

- Remove the system from operation, gracefully terminating or transitioning its service
- Dispose of the retired system properly

**INPUT**

**Sources of Information**

- System requirements (retirement/disposal requirements)
- Service life of the system and components
- System performance measures and maintenance records

**PROCESS**

**Key Activities**

- Plan system retirement
- Deactivate system
- Remove system
- Dispose of system

**OUTPUT**

**Process Results**

- System retirement plan
- Archival documentation

**REVIEW**

**Proceed only if you have:**

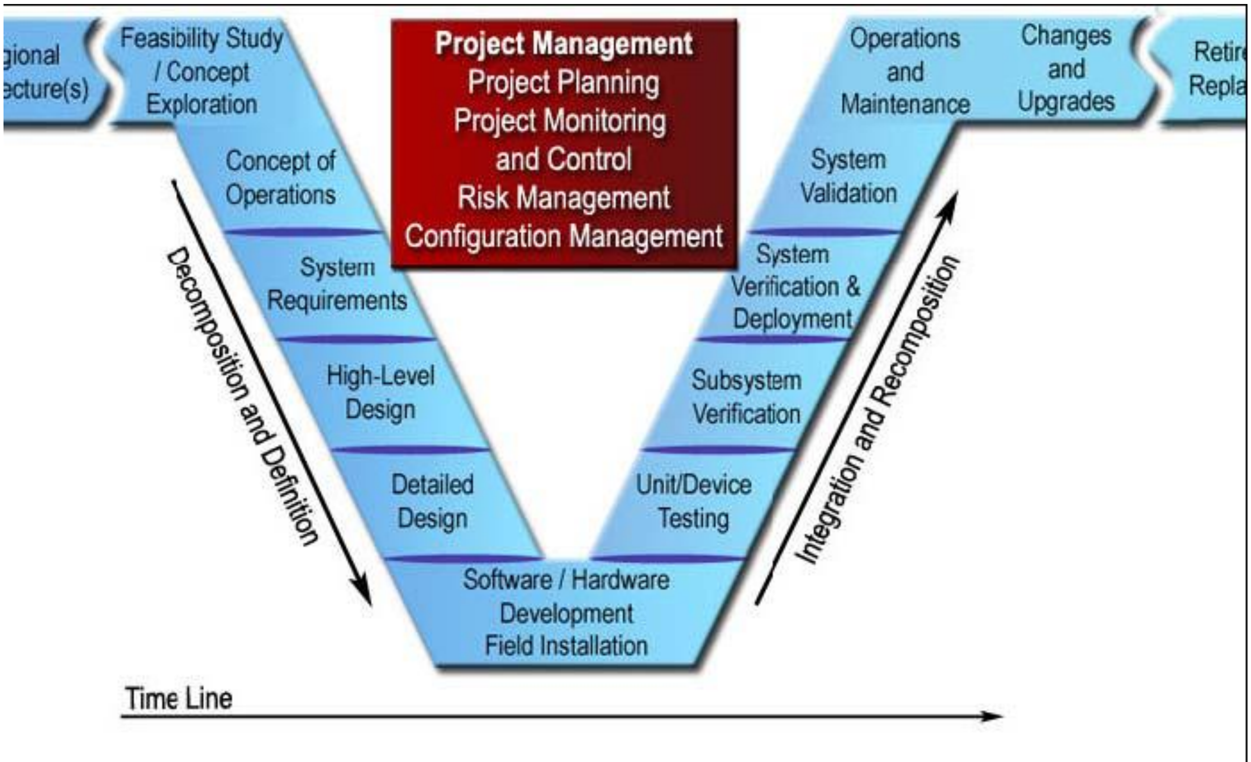
- Planned the system retirement
- Documented lessons learned
- Disposed of the retired system properly

## Overview

Systems are retired from service for a variety of reasons. Perhaps the system is being replaced by a newer system, or maybe the Concept of Operations has changed such that stakeholder needs are going to be met in an alternative manner that will no longer require use of the system. For example, the emergency call boxes that currently dot many of the nation's highways are beginning to be retired because their usage has decreased dramatically due to widespread use of cell phones. Many of the first-generation ITS systems are twenty years old and approaching the end of their useful life. Regardless of the reason for the retirement of the system, you should make sure that everything is wrapped up (e.g., hardware and software inventory identified for disposal is audited, final software images are captured, and documentation is archived), the contract is closed properly, and the disposal of the system is planned and executed.

# ITS Project Management Processes

In addition to the process steps identified in the “V”, there are several project management and control activities that are essential in order for a project to be successful. The project planning, project monitoring and control, risk management, and configuration management processes all support systems engineering. These activities will be discussed briefly here, additional resources and details can be found in FHWA’s publication, Systems Engineering for Intelligent Transportation Systems.




**Project Management Activities Cut Across 1Project Management Activities Cut Across All Steps of the “V”**

## *Project Planning*

Project planning lays out the activities, resources, budget, and timeline for the project. This effort, which begins early in the project life cycle, results in the creation of two major plans, the Project Plan (PP) and the Systems Engineering Management Plan (SEMP).

### Project Plan

The Project Plan (PP) documents how the project will be managed and controlled from a programmatic standpoint. It identifies the detailed work plans for both administrative and technical tasks. For each project task, the PP documents what is to be done, by whom, with what funds, when, how (processes to be used), and dependencies.

### Systems Engineering Management Plan

The Systems Engineering Management Plan (SEMP) is the top-level plan for managing the systems engineering effort to produce a final operational system from initial requirements. Just as the PP defines how the overall project will be executed, the SEMP defines how the engineering portion of the project will be executed and controlled. It describes how the efforts of system designers, test engineers, and other engineering and technical disciplines will be integrated, monitored, and controlled during the complete life cycle. For a small project, the SEMP might be included as part of the PP document, but for any project of greater size or complexity a separate document is recommended.

## *Project Monitoring and Control*

The plans discussed in the PP and in the SEMP include the steps that will be taken to monitor and control the project from a systems engineering standpoint. Two aspects of this monitoring and control, project tracking and project technical reviews, are discussed next.

### Project Tracking

The PP and the SEMP define the tasks and schedule for the project and the processes that will be followed to produce the deliverables. Once the project is underway, how can you track progress against the plan? When should you start to worry that the project is veering off track? Is the project on track as long as cost and schedule are meeting the plan?  It's tough to answer any of these questions without creating some means of measuring progress.

### Project Reviews

Project reviews provide a structured and organized approach to reviewing project products to determine if they are fit for their intended use. These reviews are a primary method of communicating progress, monitoring risk, and transferring products and knowledge between project team members. The reviews often occur at the completion of a "V" process step and represent *decision points* that must be passed successfully before moving to the next step in the process.

## *Risk Management*

Risk management is the identification and control of risks during all phases of the project life cycle. Murphy's Law is alive and well during most projects, so it's essential that you anticipate the risks and put plans in place for addressing them. The goal of risk management is to identify potential problems before they occur, plan for their occurrence, and monitor the system development so that early action can be taken if the risk occurs.

### Risk Identification

The objective of the risk identification step is to identify the key risks to project success *at the beginning of the project.* This will require that project managers, stakeholders, and possibly outside experts brainstorm about where the risks may lie. They should take a look at all potential risks, from initial development all the way out through operations and maintenance and eventual retirement of the system.

### Risk Analysis and Prioritization

Once risks have been identified, the next step in the process is to analyze and prioritize them by determining the impact should the risk occur, and the probability of its occurrence.

**How severe will the impact be if the risk occurs?**

For each risk identified, you should make an assessment of what will be impacted if the risk occurs. Risks typically fall into one or more of the following areas:

- Technical (risks affecting the quality of the resulting system)
- Schedule (risks that cause schedule slippage)
- Cost (risks that cause cost to exceed budget)

**What is the probability that the risk will occur?**
For each risk identified, assign a probability that the risk will occur (e.g., high, medium, or low). It's a good idea to define each of these probabilities quantitatively to make sure that everyone is analyzing the risks the same way (e.g., high = greater than 30% probability that the risk will occur).

### Risk Mitigation

The objective of risk mitigation is to identify and evaluate alternatives for handling the risks identified. From a project management standpoint, there are several ways to address risks:

- Avoid the risk altogether (e.g., change in requirements or design)
- Take actions to reduce the likelihood or severity of the risk (e.g., prototype a new technology or develop and deliver software incrementally)
- Accept the risk and do nothing, which is often the approach for risks with low impact and low probability of occurrence

### Risk Monitoring

Risks should be monitored throughout the life cycle to determine whether the mitigation steps are actually lessening the severity or probability of each risk. It's also possible that the nature of the risk has changed (e.g., the due date for delivery of the software code was extended because another project was delayed).

## *Configuration Management*

Configuration management (CM) can be defined as "*A management process for establishing and maintaining consistency of a product's performance, functional, and physical attributes with its requirements, design and operational information throughout its life.*" (From ANSI/EIA 649-1998)

Establishing the system baseline, or configuration, and managing change to that baseline, are key processes for ensuring that system integrity is maintained throughout the life of the system.

The configuration management process consists of five major activities:

### Configuration Management Planning

The processes and procedures to be used to manage the configuration of the system and changes to that system are documented in a Configuration Management (CM) Plan. The CM Plan may be a separate document (if the project is of sufficient size or complexity) or it may be part of another project planning document (e.g., PP or SEMP). The CM Plan is created at the beginning of the project life cycle.

### Configuration Identification

Configuration identification is the selection of the software, hardware, and documentation that will be tracked. These configuration items collectively represent the system baseline.

### Configuration Change Management

Once the configuration items have been identified, any changes to them must be handled in a controlled fashion. All changes must be clearly described and presented to the CCB to assess the technical, cost, and schedule impacts.

## Configuration Status Accounting

At any time during the system life cycle, you should always know the configuration of every item. From the time that a change is proposed and all the way through its approval cycle and final implementation in the deployed system, the change should be tracked. When it has been superseded by another change, the initial change should be archived. A complete history of all changes to all configuration items should be maintained throughout the life of the system and eventually archived.

## Configuration Auditing

How do you know that your project team members are following the documented CM processes to establish the baseline and control changes to it? You should periodically audit the processes and procedures that they're using against those in your CM Plan and also assess whether or not the CM processes are working effectively.