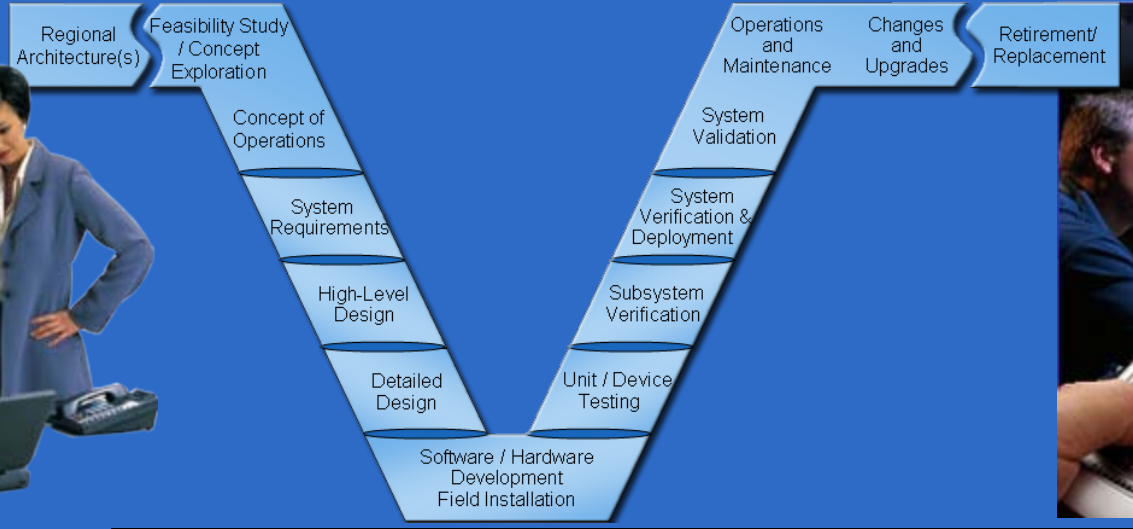


Welcome and Introductions

Process Overview

Systems Engineering "V"

Cross-Cutting Activities

Applying SE to a Project

Establishing SE in your Organization

Process Improvement Discussion

Wrap Up

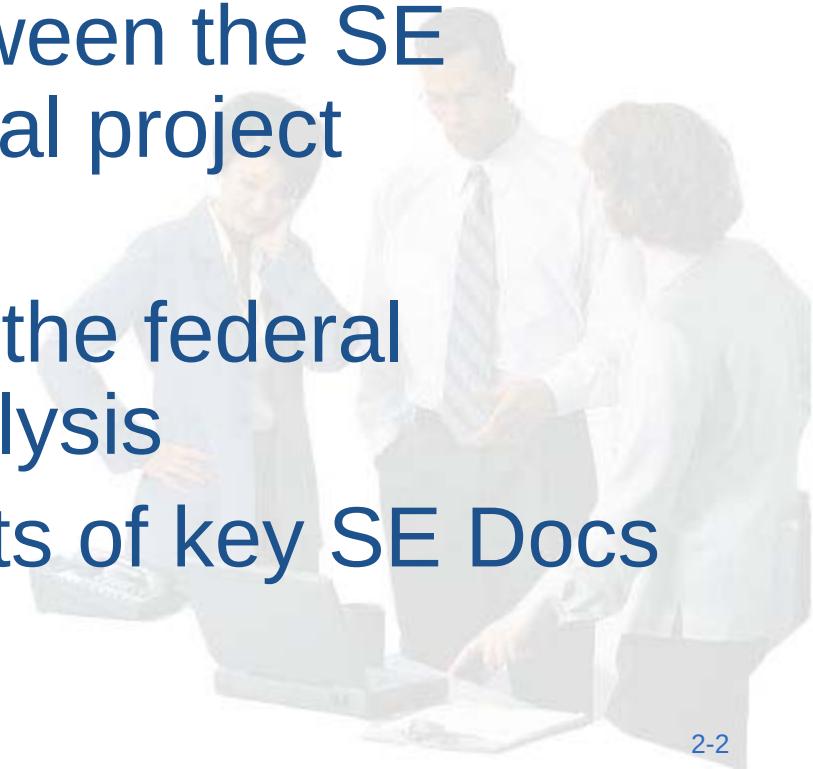
Session 2: Process Overview

These materials developed under the RITA National ITS Architecture Program

U.S. Department of Transportation
Research and Innovative Technology Administration

Learning Outcomes

- Identify the principles of systems engineering (SE)
- List benefits of using SE
- Describe similarities between the SE process and the traditional project development process
- Explain in general terms the federal requirements for SE Analysis
- Describe general contents of key SE Docs



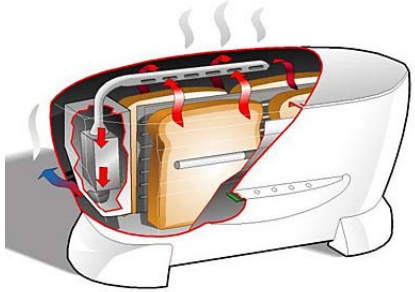
What Is a System?

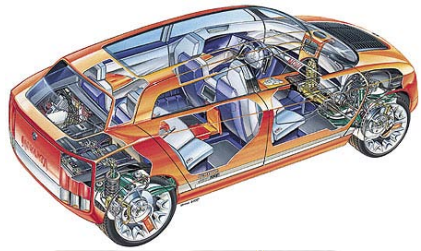
"A combination of interacting elements organized to achieve one or more stated purposes."

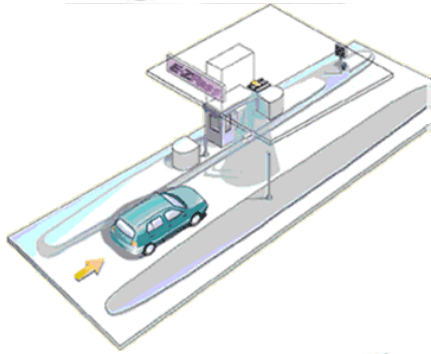
International Council of Systems Engineering

"An aggregation of end products and enabling products to achieve a given purpose"

Electronics Industry Association EIA-632

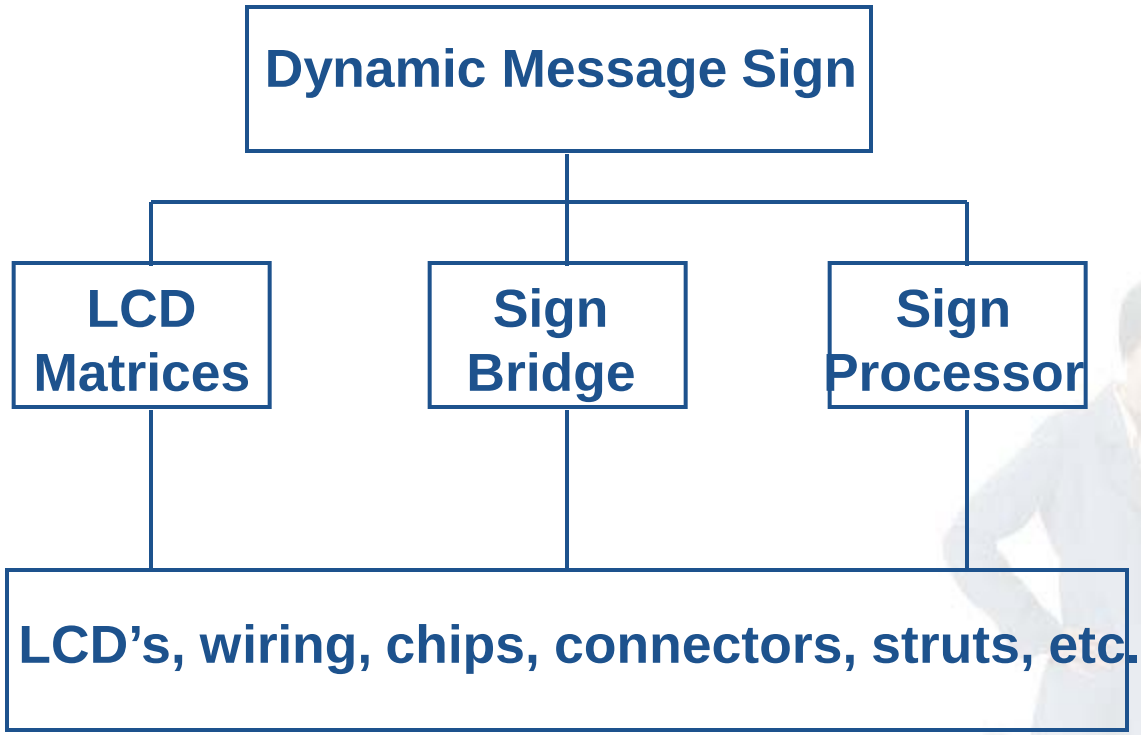






Is a Dynamic Message Sign a System?

To a sign manufacturer it is…

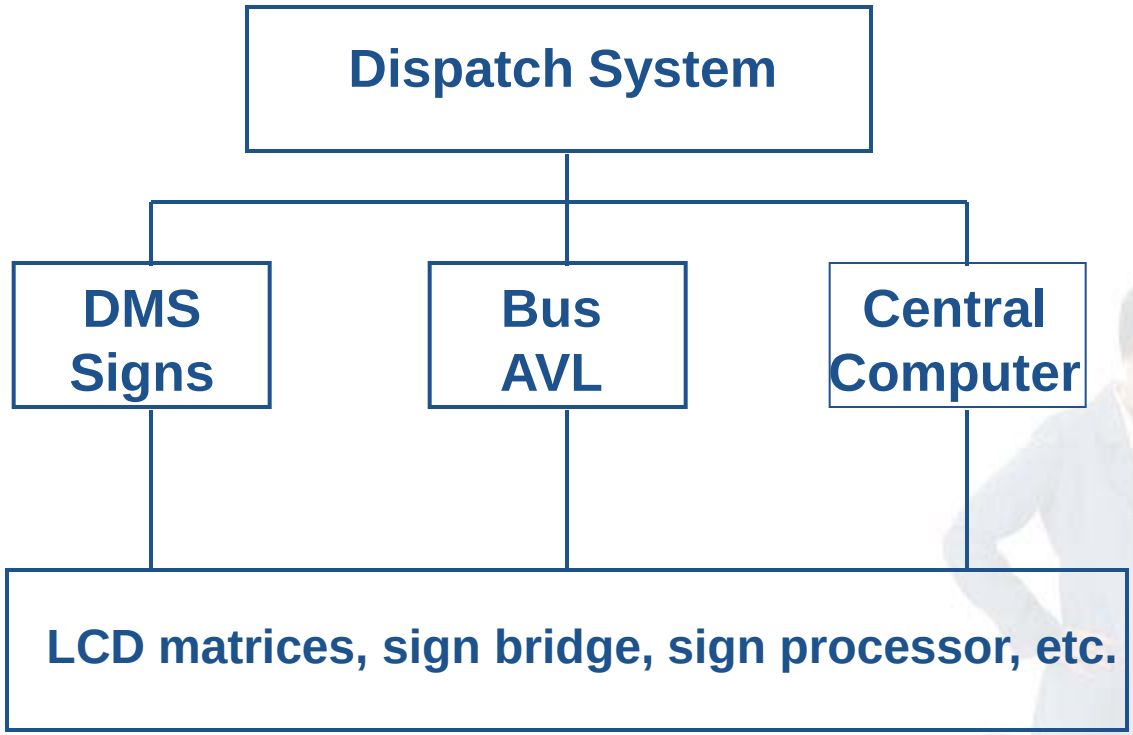


System

Subsystems

Components

But not to a Transit System Dispatcher



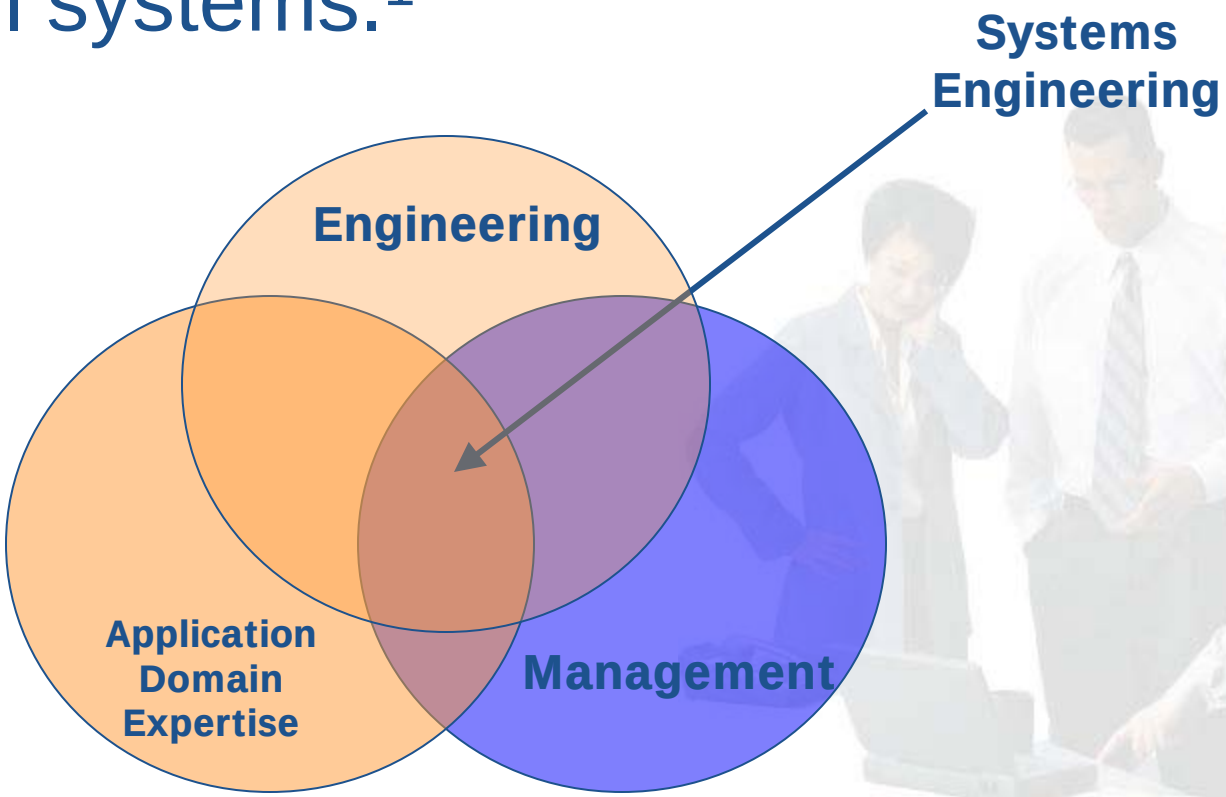
System

Subsystems

Components

What is Systems Engineering?

An ***inter-disciplinary approach*** and means to enable the realization of successful systems.[1]



Systems Engineering (cont.)

- Focuses on:
  - Defining customer needs and required functionality early in the development cycle
  - Documenting requirements
  - Then proceeding with design, implementation, and system validation while considering the complete problem

Systems Engineering Principles

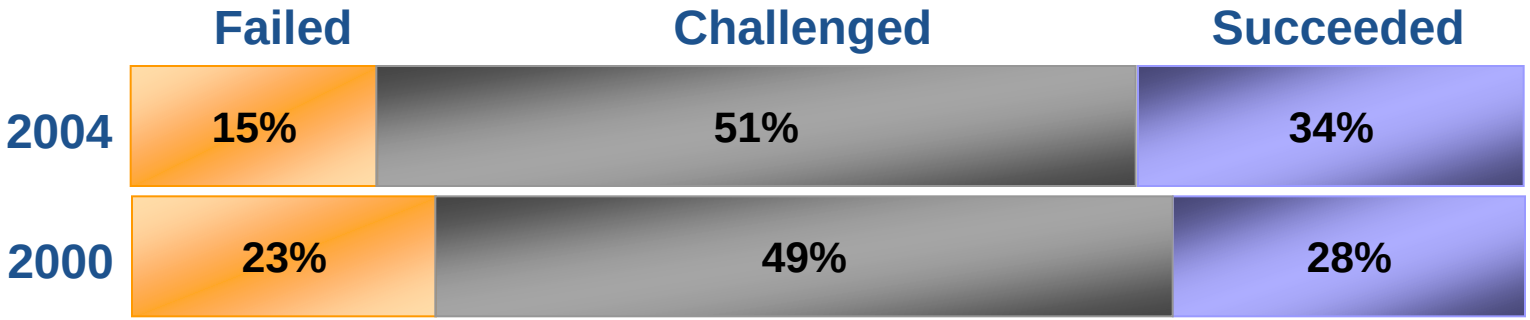
- Start with Your Eye on the Finish Line

- Stakeholder Involvement is Key

- Define the Problem before Implementing the Solution

- Delay Technology Choices

Project Success is Rare



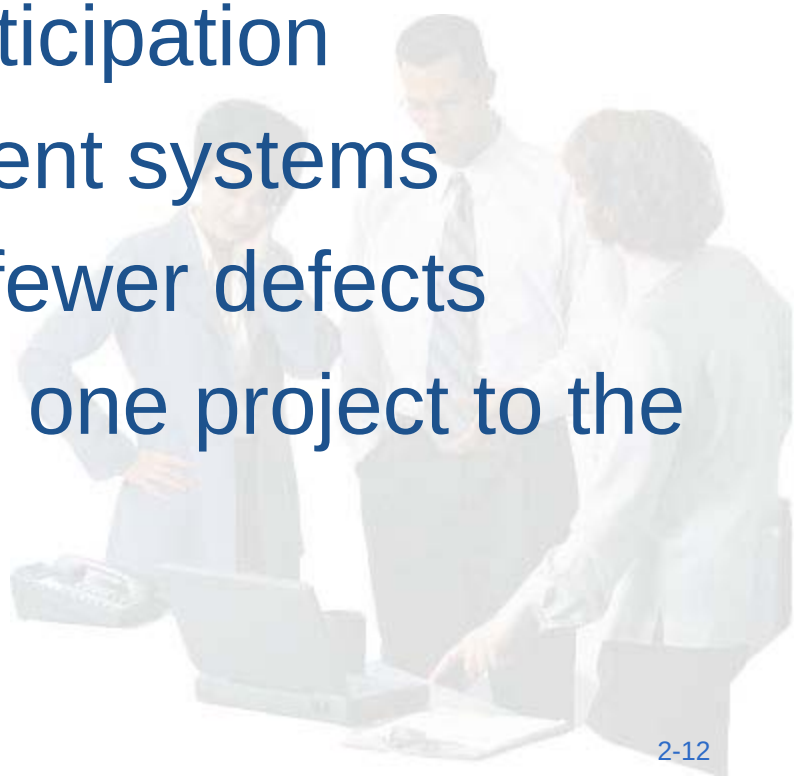
Source: The Standish Group International, *Extreme Chaos, The Standish Group International, Inc., 2000*

Average cost overrun:
45%
Time overrun:
63%
Functionality delivered on average:
67%
Standish Group

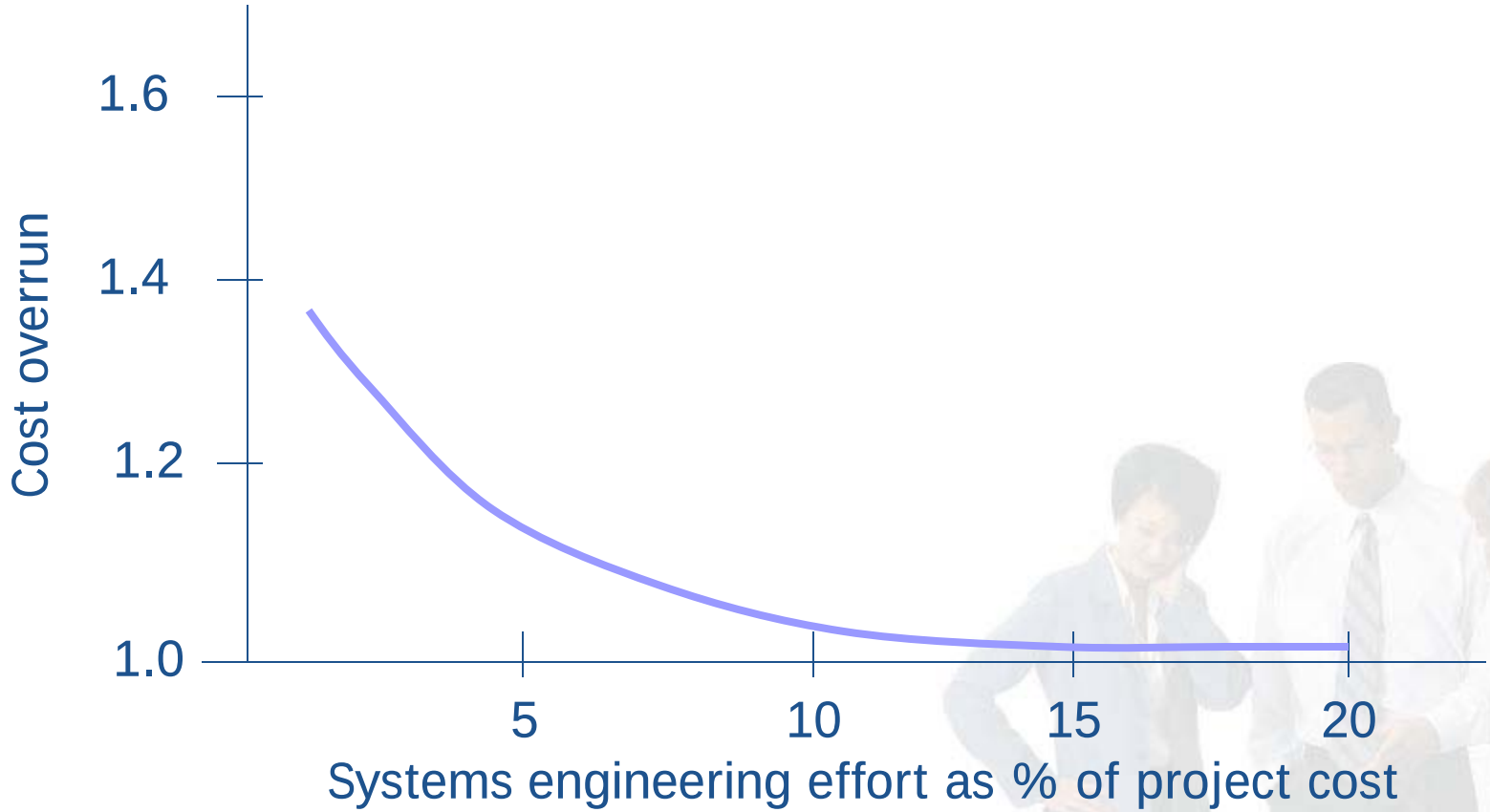
Project Failures are Visible

Benefits of Using SE

- Reduced risk of schedule and cost overruns
- Increased likelihood that implementation will meet users' needs
- Improved stakeholder participation
- More adaptable and resilient systems
- Verified functionality and fewer defects
- Higher level of reuse from one project to the next
- Better documentation



Systems Engineering Impact: Project Cost vs. SE Cost



Source: Honour, et al., 2004, *Value of Systems Engineering*, Honourcode, Inc., Pensacola, FL

A Lesson from the ‘Greatest Generation’

- Eisenhower Wants to Build Roads
  - How fast Germans moved armies during WWII
  - America embroiled in the Red Scare
  - Post war prosperity presented an opportunity

How Would We Use a New Roadway Network

- Move armies quickly
- Move people, goods & services efficiently

What slows armies down?

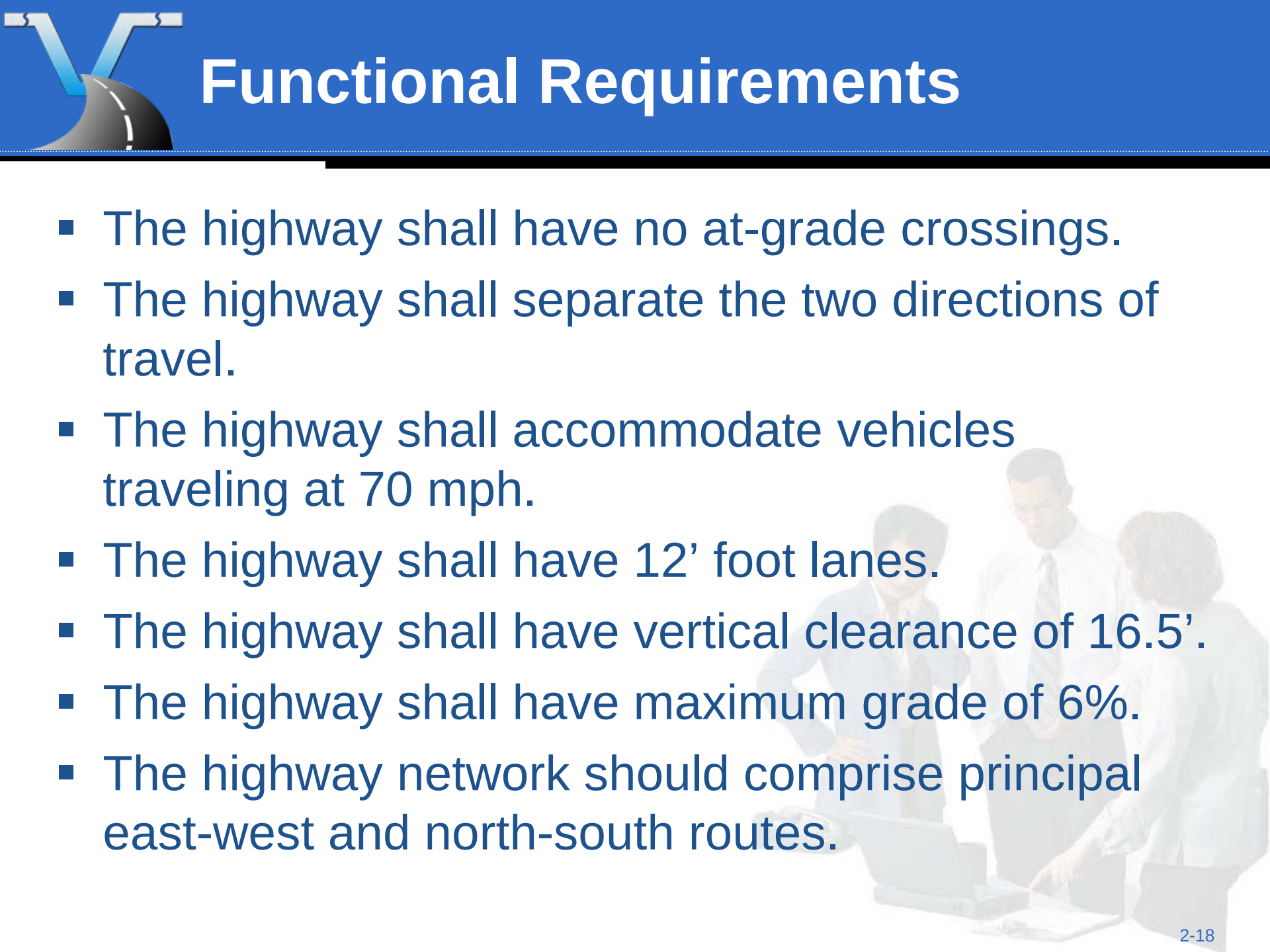
- Intersections
- Narrow roads
- Tight curves
- Incomplete network

Basic Requirements

- Limited access
- Wide lanes with shoulders
- Divided highway
- High design speed
- Comprehensive network

Functional Requirements

- The highway shall have no at-grade crossings.
- The highway shall separate the two directions of travel.
- The highway shall accommodate vehicles traveling at 70 mph.
- The highway shall have 12’ foot lanes.
- The highway shall have vertical clearance of 16.5’.
- The highway shall have maximum grade of 6%.
- The highway network should comprise principal east-west and north-south routes.



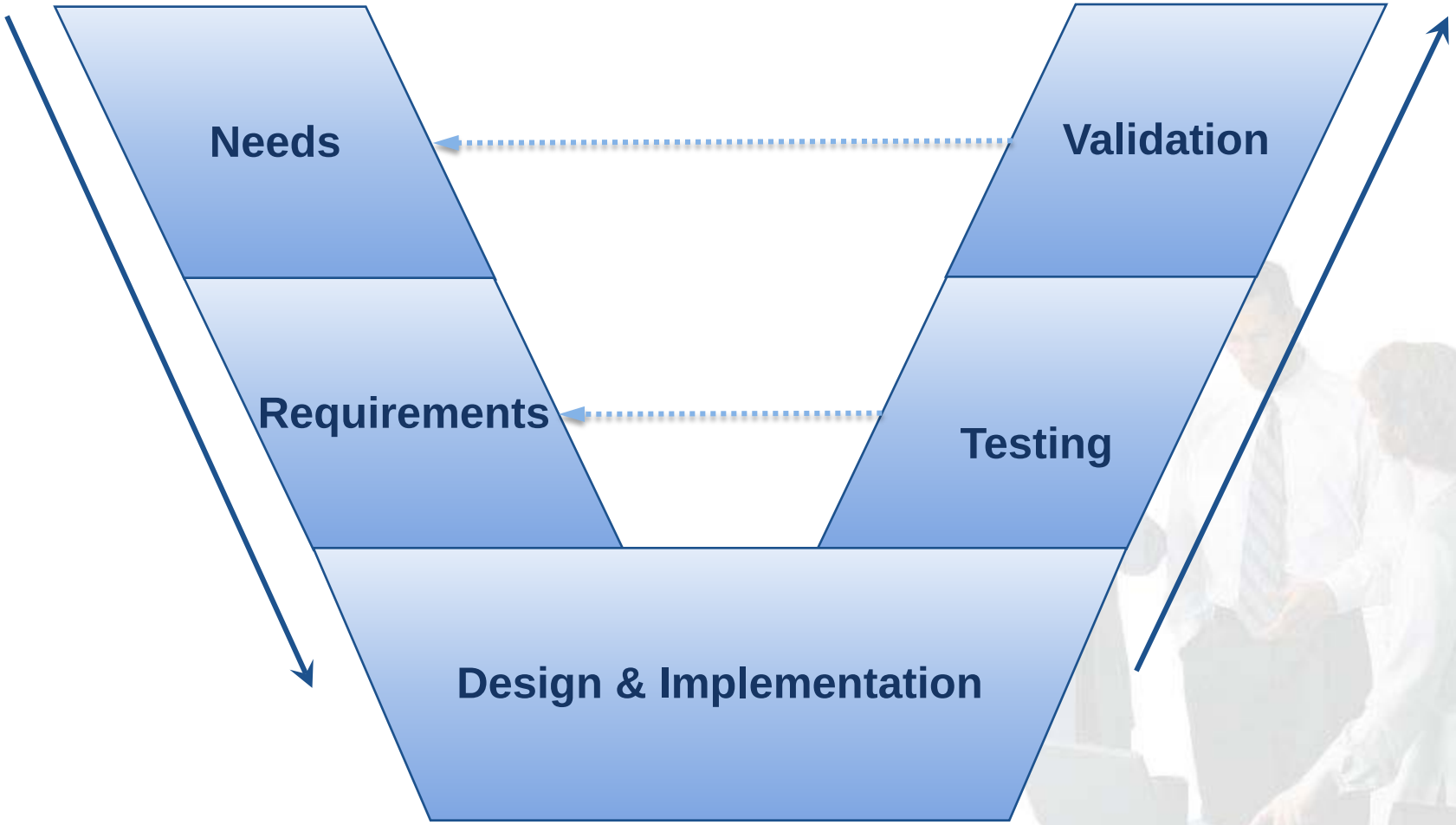
- Does Eisenhower know anything about building roads?
- Do road builders know anything about moving armies?

- Do they need to?

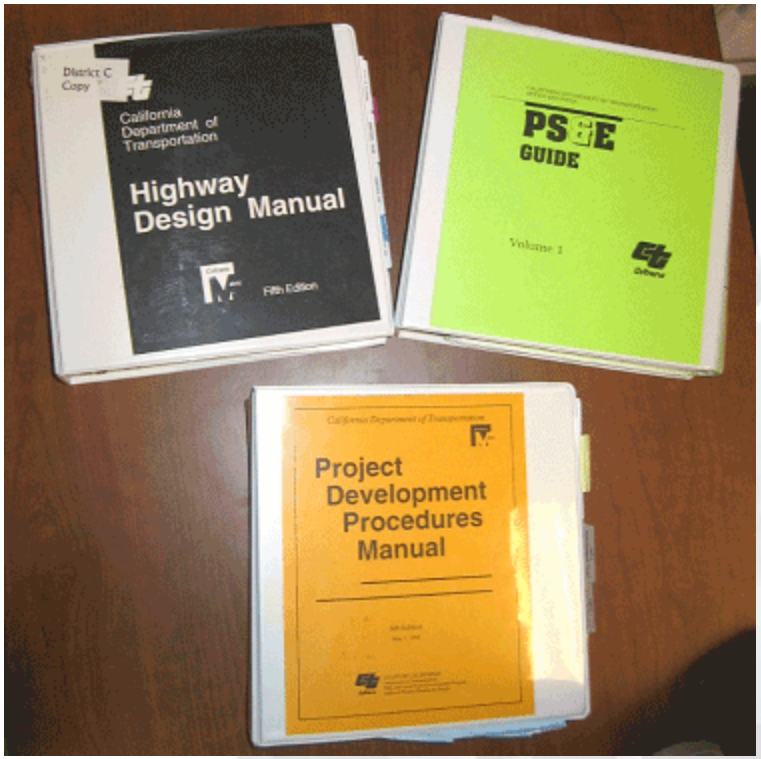
How did we do?

- Did we build the roads right?
- Did we build the right roads?

Systems Engineering Ties It All Together



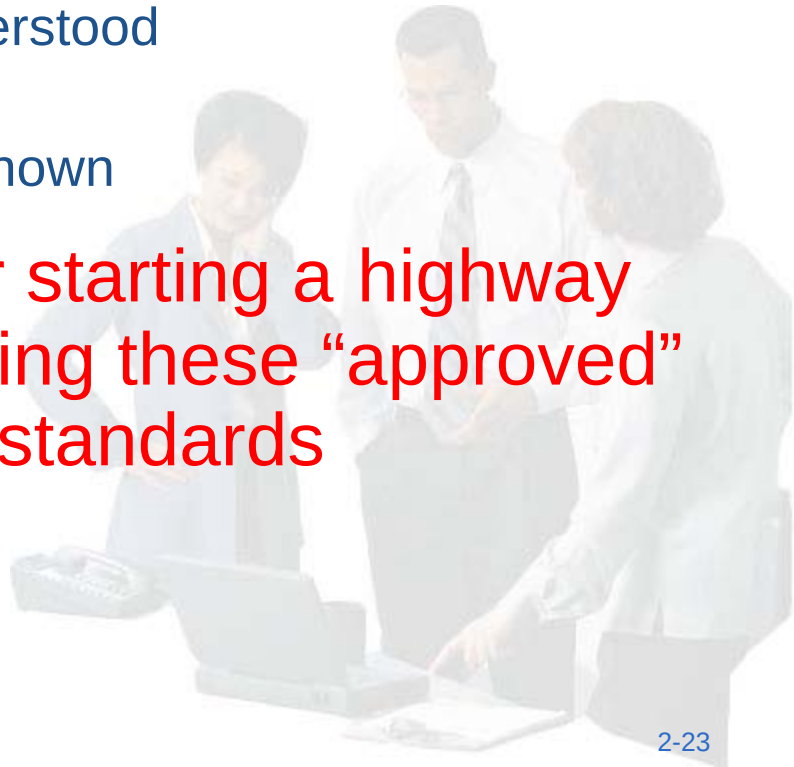
SE-like Processes ALREADY in Place!



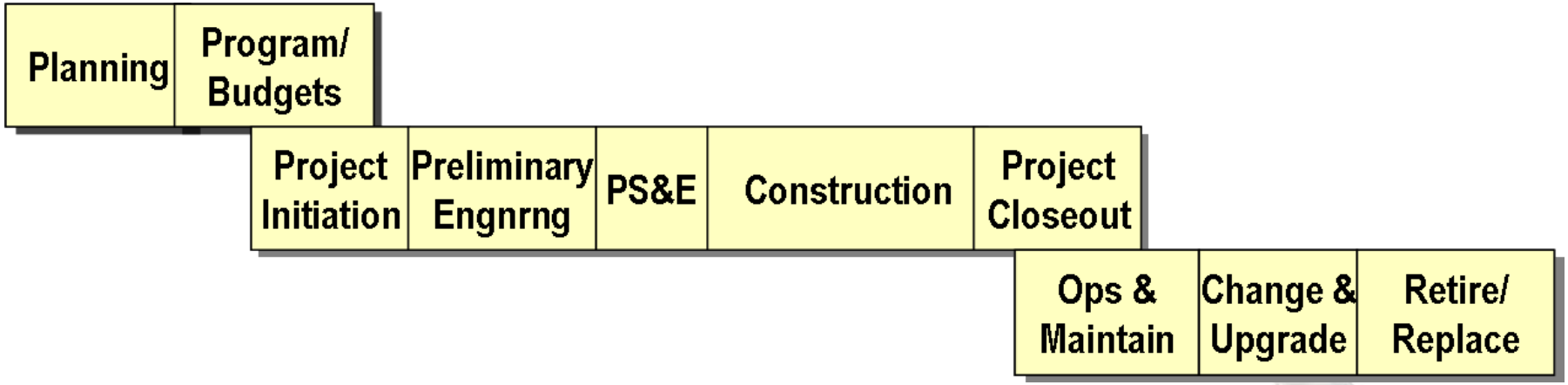
- ✓ Well Documented
- ✓ Highly Formalized
- ✓ Rigorously Followed
- ✓ Required by Management

What We Did Right

- DOTs have been building roads for many years
- DOTs have developed processes for design and construction of roads and bridges where:
  - Performance well understood
  - Requirements well defined and understood
  - Technology proven, well understood
  - Documented designs proven, well known
- No one would even consider starting a highway design project without following these “approved” processes, documents, and standards

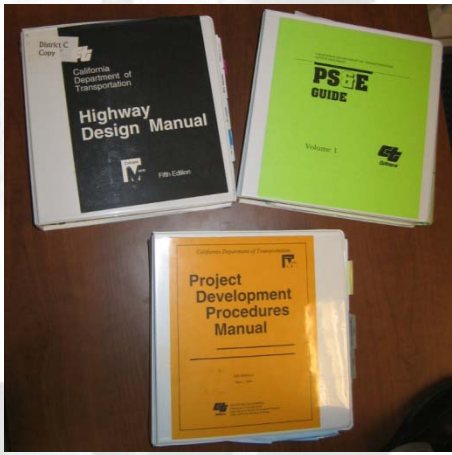


Traditional Project Development Process Has Led to This Success



Low Risk of Unsuccessful Implementation!

- ✓ Performance of products and materials well understood
- ✓ Requirements well defined and understood
- ✓ Proven, well-known technology
- ✓ Documented, proven designs



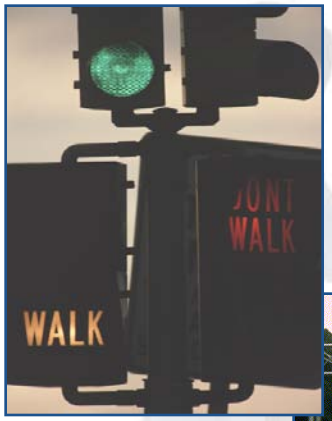
Result: Long-Lasting Highways Are Designed, Built, and Tested

Traditional Project Development ALSO Works for ITS Infrastructure Expansion

Planning	Program/ Budgets							
		Project Initiation	Preliminary Engnrng	PS&E	Construction	Project Closeout		
							Ops & Maintain	Change & Upgrade	Retire/ Replace

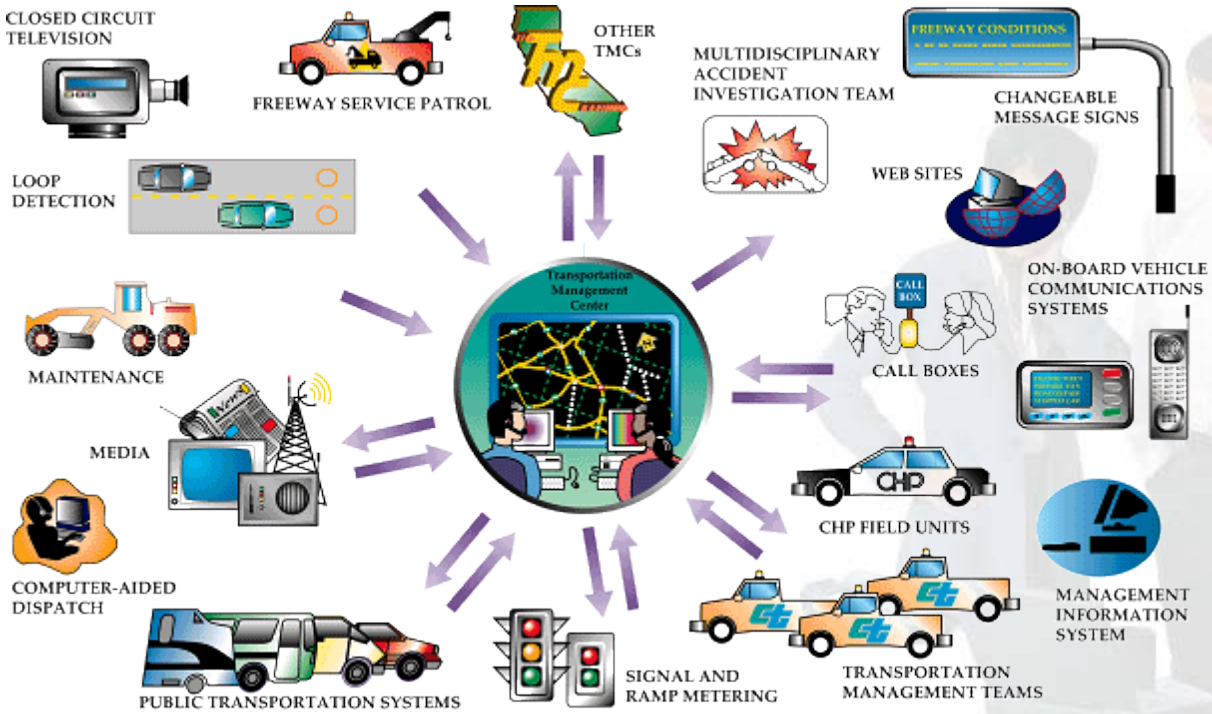
ITS Infrastructure Expansion: Low-Risk Projects

Processes and approved manuals ALSO in place for field installation of many ITS technologies



BUT This Traditional Process Does NOT Work for Complex ITS Projects

Planning	Program/ Budgets	Project Initiation	Prelimin y Engnr	PS	Co truction	Project Closeout	Ops & Maintain	Change & Upgrade	Retire/ Replace



What is Different about Designing Complex Systems?

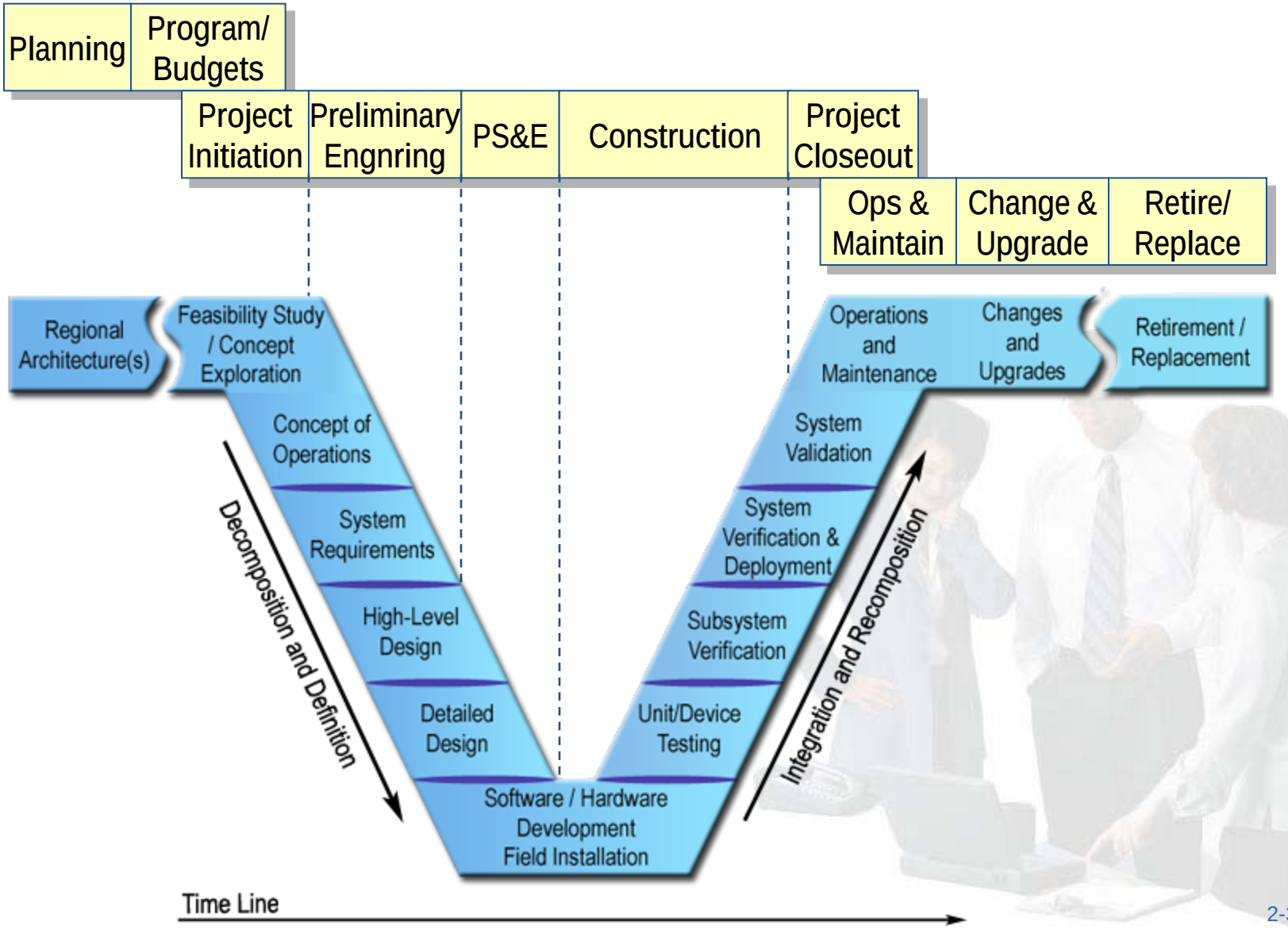
Software and computer technology are involved!

So, just how *do* you manage systems development when software or integration to other systems is involved?

Systems Engineering “V” Process

- FHWA representation of SE methods
- Representation of systems development process
- Addresses project life cycle
- Aligns with traditional project development process

SE "V" and the Traditional Project Development Process

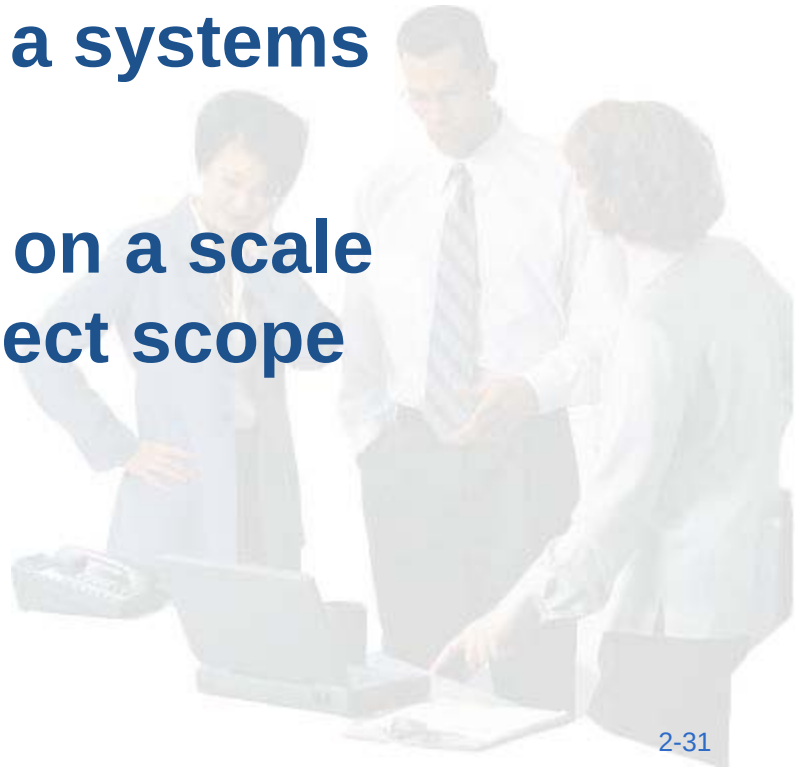


Federal Regulations Require Systems Engineering

23 CFR 940.11 Project Implementation requires:

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 project scope



23 CFR 940.11(c) defines "systems engineering analysis"

1. Identification of portions of the regional ITS architecture being implemented
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
7. Procedures and resources necessary for operations and management of the system

SE "V" covers all 7 requirements

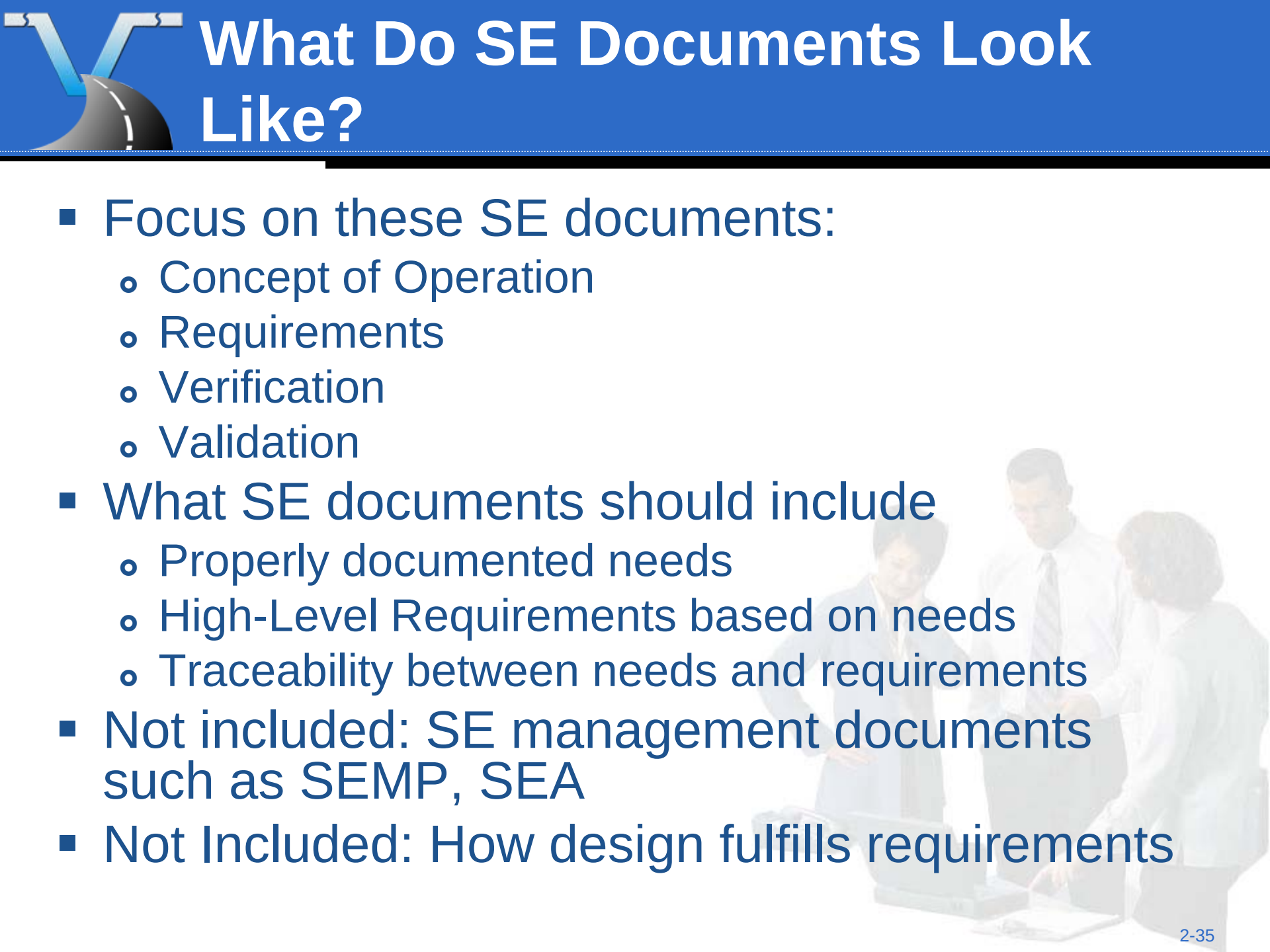
23 CFR 940.13: Project Administration

- Prior to authorization of highway trust funds for construction or implementation of ITS projects, compliance with §940.11 shall be demonstrated
- Compliance will be monitored under Federal-aid oversight procedures
  - Each FHWA Division Office works with State/Local Partners to establish these procedures

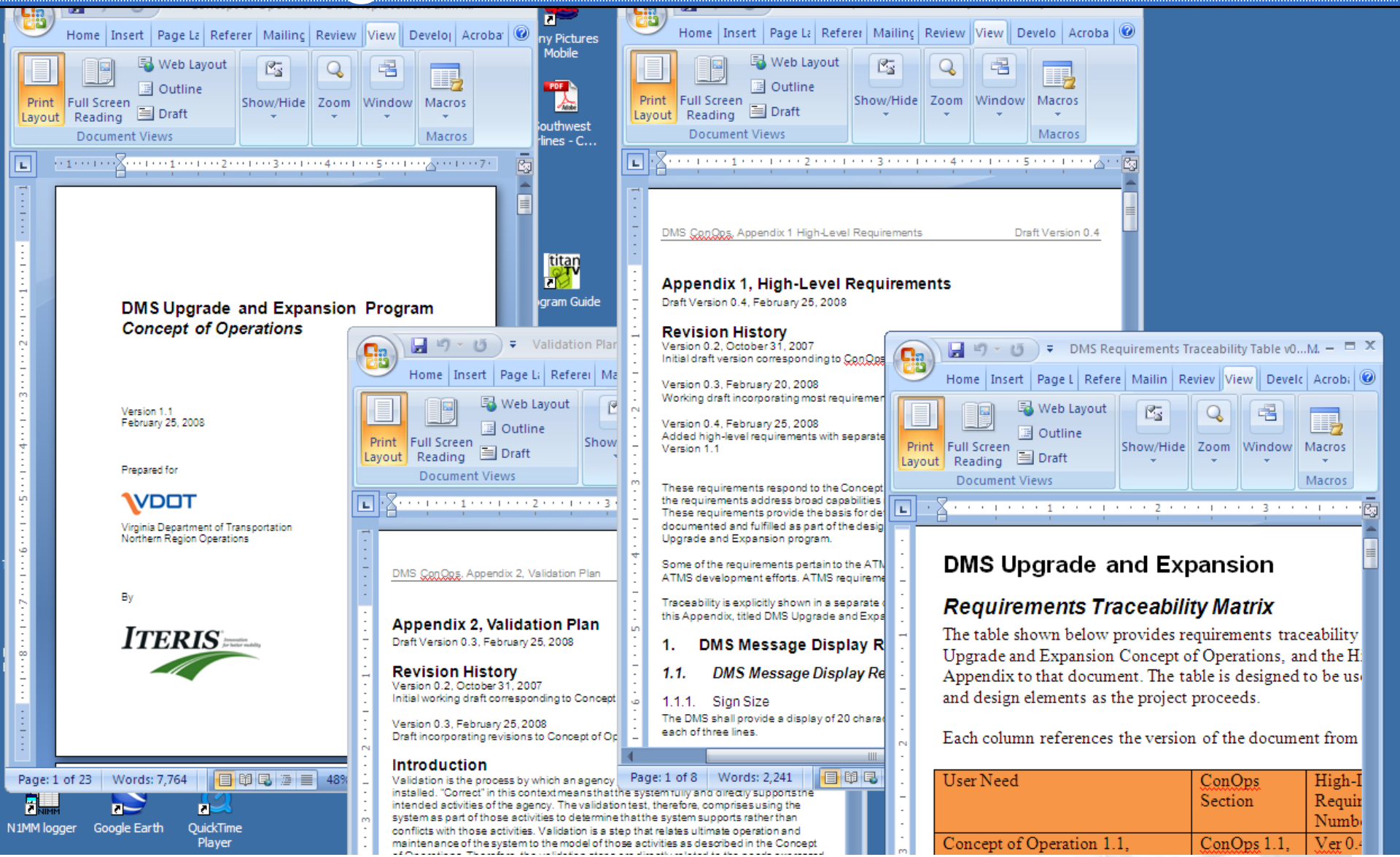
What Do SE Documents Look Like?

What Do SE Documents Look Like?

- Focus on these SE documents:
  - Concept of Operation
  - Requirements
  - Verification
  - Validation
- What SE documents should include
  - Properly documented needs
  - High-Level Requirements based on needs
  - Traceability between needs and requirements
- Not included: SE management documents such as SEMP, SEA
- Not Included: How design fulfills requirements



Example: DMS Replacement Program



Concept of Operations DMS Replacement and Upgrade v1.1.doc [Compatibility Mode] - Microsoft Word

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Zoom | 100% | One Page | Two Pages | Page Width — Zoom
New Window | Arrange All | Split | Switch Windows — Window
Macros — Macros

DMS Upgrade and Expansion Program
Concept of Operations

Version 1.1
February 25, 2008

Prepared for

VDOT

Virginia Department of Transportation
Northern Region Operations

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Revision History

Version 0.3, October 31, 2007
Initial working draft without stakeholder input

Version 0.4, January 25, 2008
First completed draft, including stakeholder input, for VDOT review.

Version 1.0, February 19, 2008
Added sections on project architecture, revised name of TMC, and editorial revisions.

VDOT technicians perform board-level repair of DMS hardware rather than electronic component-level repair. When an electronic component on a circuit board fails, VDOT technicians troubleshoot to determine which board failed, and then return the faulty board to the manufacturer for repair. VDOT's mechanism for paying for these repairs is limited, and the use of extended warranties is preferred.

The expected field-serviceable lifespan of the signs is 10 years.

4.2.5. Maintenance Diagnostics

Technicians need to be able to diagnose sign faults as completely as possible from their shop location, or in consultation with ATMS operators.

4.2.6. Sign Location for Maintenance

Field technicians need to be able to effect maintenance and repair on the sign in all weather conditions without closing any lanes of the facility to traffic. Technicians need to be able to park maintenance vehicles safely with reasonable access to the sign, ground control cabinet, and all pull boxes for maintenance, without closing lanes and without deploying extensive work zone traffic management. Maintenance vehicles do not include buckets or lifts, and therefore need to access signs using secure access from the ground for technicians in accordance with state and federal worker safety requirements.

4. Maintainability Requirements

4.1. DMS Location for Field Accessibility

The DMS shall be located such that field technicians are able to effect a repair on the sign, ground cabinet, and pull boxes in all weather conditions without closing any part of the facility to traffic.

4.2. DMS Design for Field Accessibility

The DMS shall be physically designed to protect the field technician from inclement weather, so that the field technician can effect a board-level repair in all weather conditions without closing the facility to traffic and without exposing sign components to damage from inclement weather.

4.3. DMS Overhead Accessibility

The DMS shall be accessible by field technicians without requiring the use of bucket trucks or other personnel lifting devices.

4.4. DMS Access Safety

The DMS shall be designed such that technician access conforms to all state and federal worker safety requirements.

Sign Location for Maintenance	4.2.6			
Reparable in all weather conditions while protecting technician and sign components	4.2.6	4.2 DMS Design for Field Accessibility	The DMS shall be physically designed to protect the field technician from inclement weather, so that the field technician can effect a board-level repair in all weather conditions without closing the facility to traffic and without exposing sign components to damage from inclement weather	
Sign location provides maintenance vehicle parking area without blocking traffic	4.2.6	4.1 DMS Location for Field Accessibility	The DMS shall be located such that field technicians are able to effect a repair on the sign, ground cabinet, and pull boxes in all weather conditions without closing any part of the facility to traffic	
Sign components accessible from parking area, including sign, ground control cabinet, and all pull boxes	4.2.6	4.1 DMS Location for Field Accessibility	The DMS shall be located such that field technicians are able to effect a repair on the sign, ground cabinet, and pull boxes in all weather conditions without closing any part of the facility to traffic	
Signs serviceable without the use of bucket trucks or personnel lifting devices	4.2.6	4.3 DMS Overhead Accessibility	The DMS shall be accessible by field technicians without requiring the use of bucket trucks or other personnel lifting devices	
Sign access conforms to state and federal worker safety requirements	4.2.6	4.4 DMS Access Safety	The DMS shall be designed such that technician access conforms to all state and federal worker safety requirements	

User Need	ConOps Section	High-Level Requirement Number and Title	High-Level Requirement	Functi Requir Numbe
Concept of Operation 1.1, 2/25/08	ConOps 1.1, 2/25/08	Ver 0.4, 2/25/08	Ver 0.4, 2/25/08	

2.3. Field Accessibility

Are signs located to allow field technician access in all weather conditions without closing lanes? Are signs located to minimize knockdowns? Can technicians safely perform all work on the sign without requiring a bucket truck?

2.4. Reliability

Do signs operate properly in all ambient conditions? Do the signs maintain at least 99.9% reliability? Is the sign designed for 100,000-hour MBTF (10,000 hours for routine maintenance items)?

2.5. Reparability

Are technicians able to effect repairs without special tools or manipulation of software? Can those repairs be made within 20 minutes of diagnosis?

2.6. Maintenance Diagnostics

Are technicians able to request and receive relevant diagnostic information from the sign?

2.7. Sign Location for Maintenance

Review…

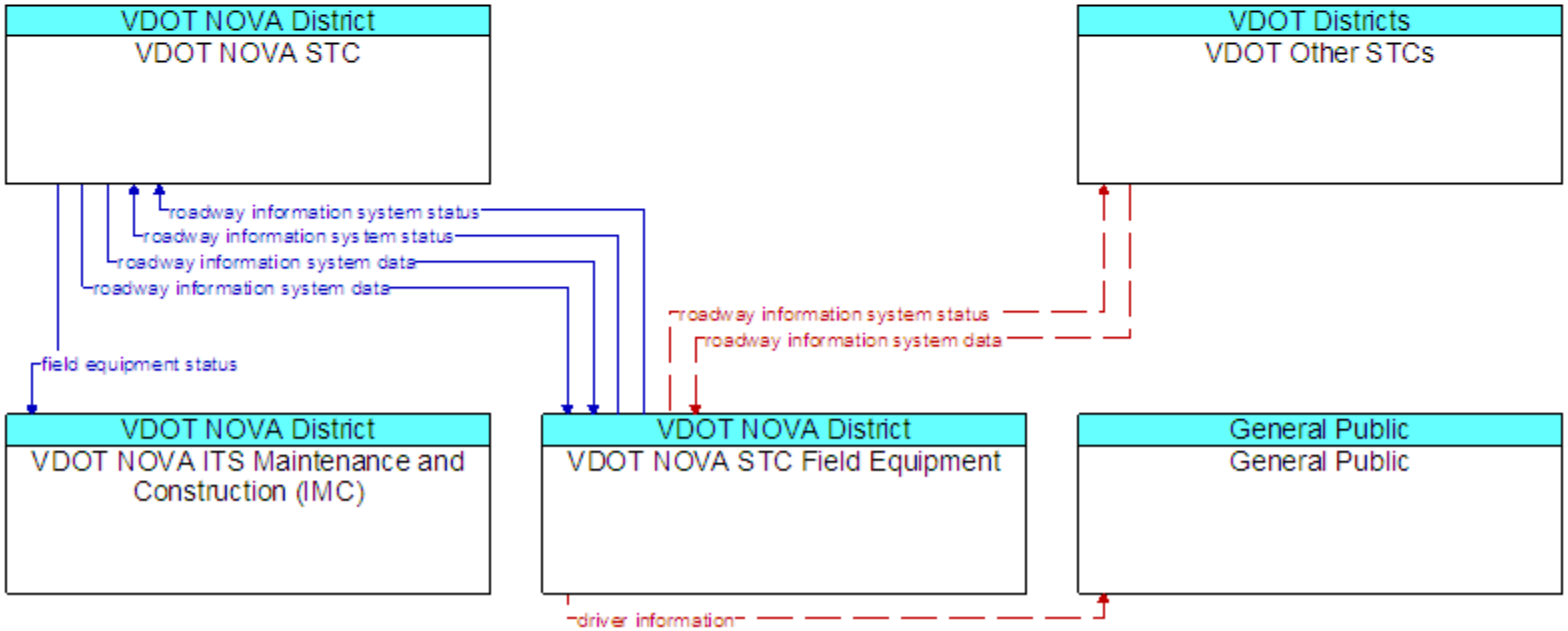
- Needs describe *what the agency will **do** with the system*
- Requirements describe *what the system must do to support those activities*
- Traceability demonstrates
  - All needs are served by requirements
  - All requirements are driven by needs
- Validation means the system supports agency activities as described in the ConOps

One Final Point…

- The SE process should show how the project conforms to the regional ITS architecture

5.1.1.4. *System Architecture, High Level Requirements, and ITS Standards*

The diagram below shows the architecture flows, elements, and stakeholders associated with the DMS Upgrade and Expansion program. These were derived from the current VDOT NOVA District Regional Architecture, Version 2.1, dated December 20, 2005. Flows are shown that affect the interface of the signs to the system, not that affect the information gathered that will be displayed on the signs.



Learning Outcomes

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- List benefits of using SE
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- Describe general contents of key SE Docs