# The System Engineering Approach for SMART Grant Recipients

November 14, 2024

SMART

# Topics for Today

- Overview of Systems Engineers – Defining our terms
- Purpose & Goal
- Benefits
- Steps and Products
- Alternative Approaches
- Available Resources

  https://ops.fhwa.dot.gov/seits/

# Introduce Speakers

- Madeline Zhu, Office of the Secretary of Transportation, SMART Grants Program
- Sudhakar Nallamothu, US DOT ITS Joint Program Office
- Kingsley Azubike, FHWA Office of Operations
- David Binkley & Cliff Heise, Iteris

# Poll Question #1

- Background of Audience
  - State DOTs
  - Transit Agencies
  - Municipal transportation
  - MPOs
  - Private Sector
  - Academic

# Poll Question #2

- Experience with Systems Engineering
  - Never heard of it before today
  - Do it when we have to
  - Have done some steps on a couple of projects
  - Do systems engineering on all our projects

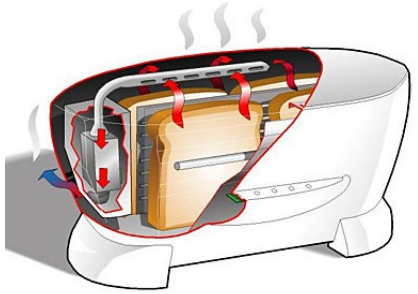
# What Is a System?

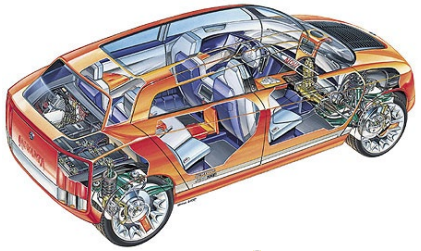
"A combination of interacting elements organized to achieve one or more stated purposes."

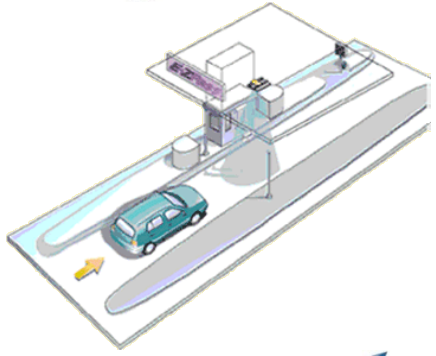
International Council of Systems Engineering

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

Electronics Industry Association EIA-632

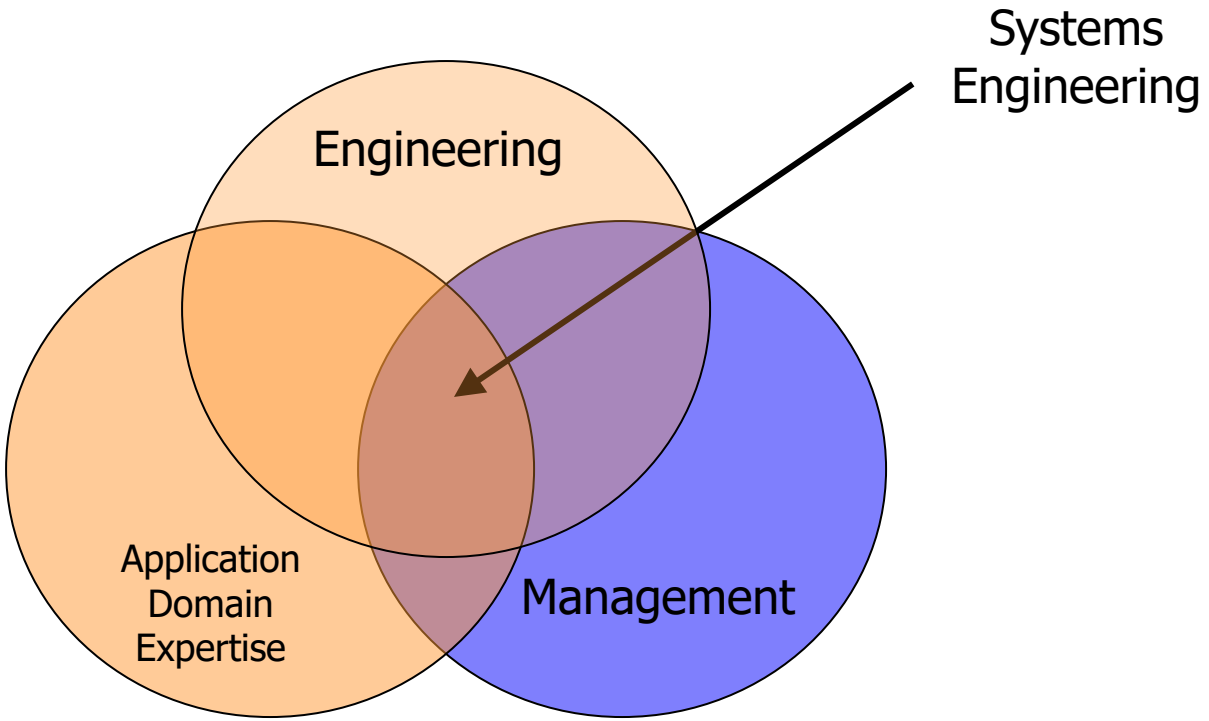






# What is Systems Engineering?

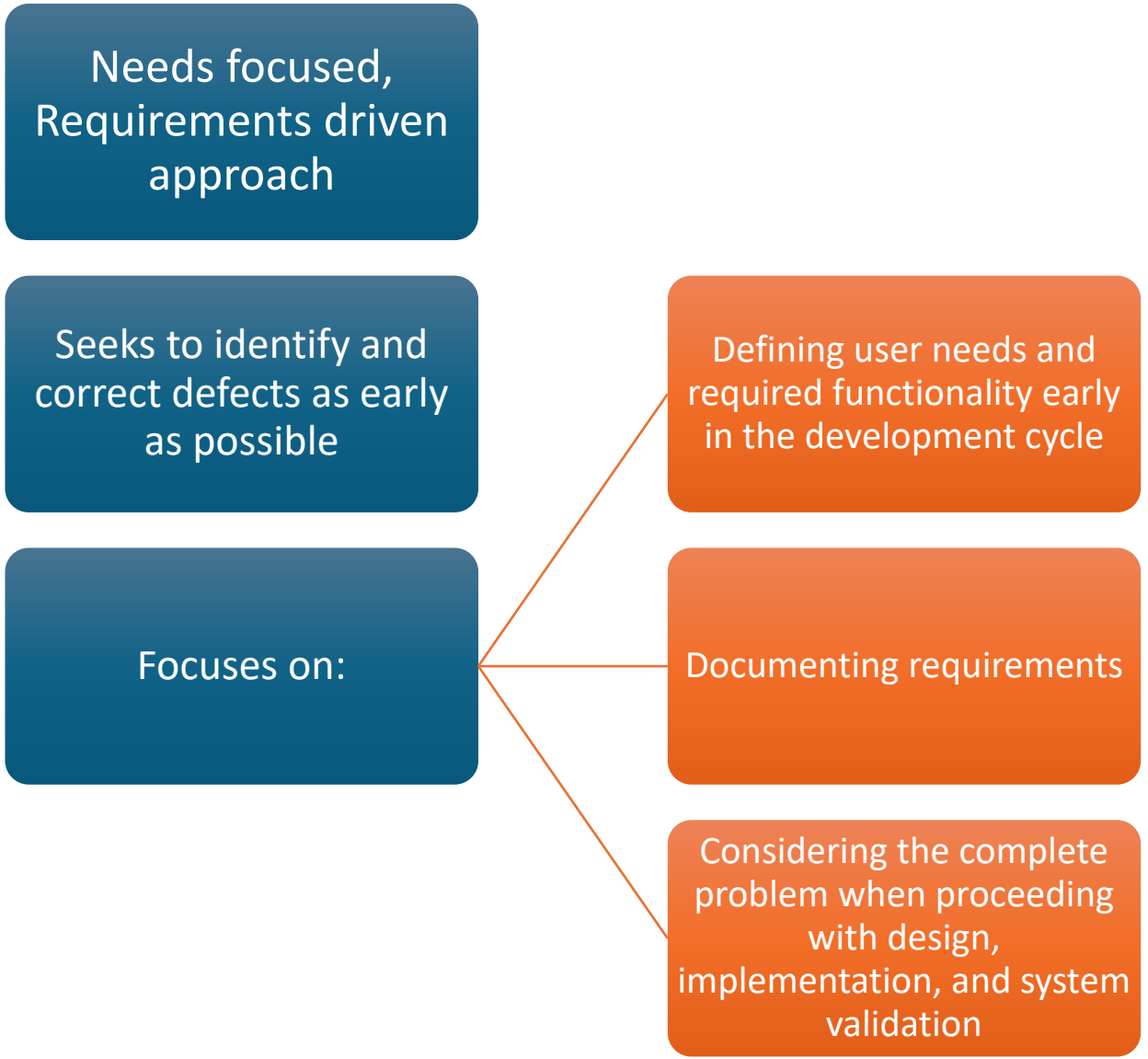
- An ***inter-disciplinary approach*** and means to enable the realization of successful systems.[1]






1. EIA-731 Annex B (Glossary)

# Systems Engineering (cont.)



# Systems Engineering Principles

- Start with Your Eye on the Finish Line

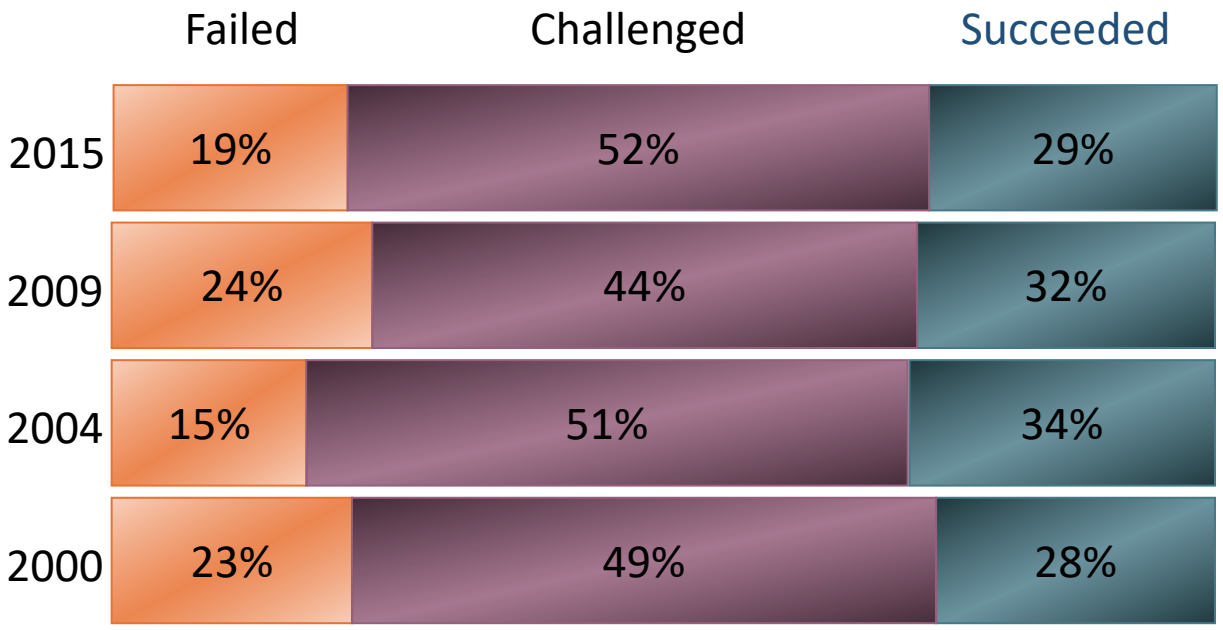
- Stakeholder Involvement is Key

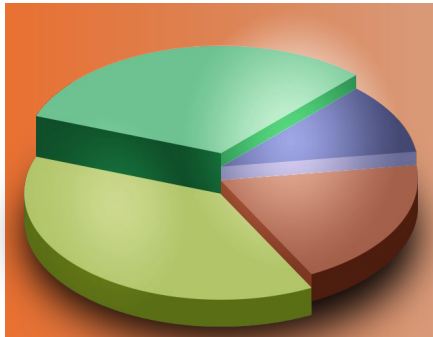
- Define the Problem before Implementing the Solution

- Delay Technology Choices

# Why? Perhaps because project success is rare

- Source: The Standish Group International, *Extreme Chaos, The Standish Group International, Inc., 2015*



Average cost overrun: 45%

Time overrun: 63%

Functionality delivered on average: 67%

Standish Group

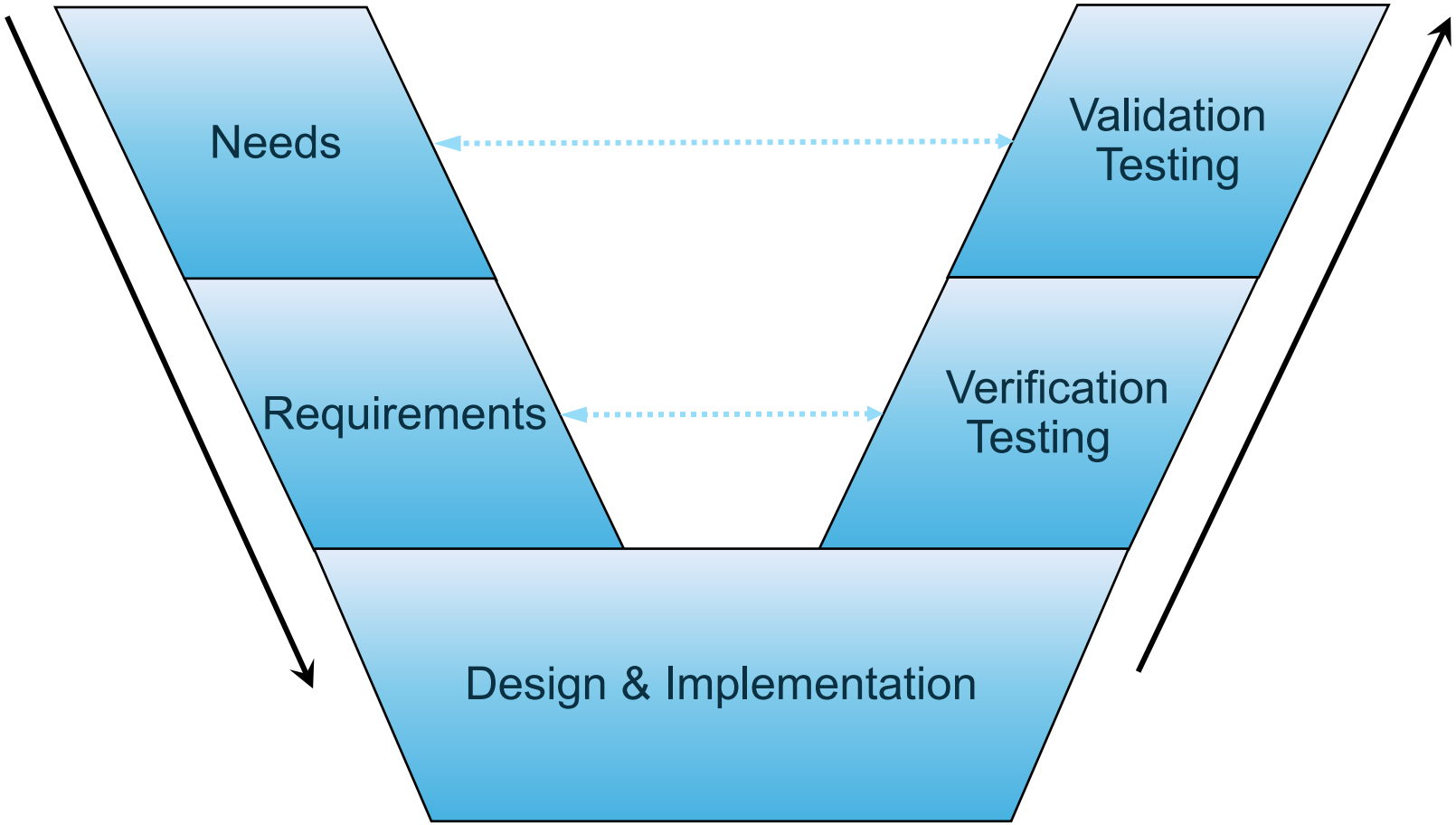
# Benefits of Using SE

- 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

# Approaches to Systems Engineering

- Working backward…
  - Requirements flow from needs
  - Needs flow from operations activities
- Are we sure we know our activities?
- If yes, then consider *sequential* systems engineering
- If no, then consider *iterative* approaches

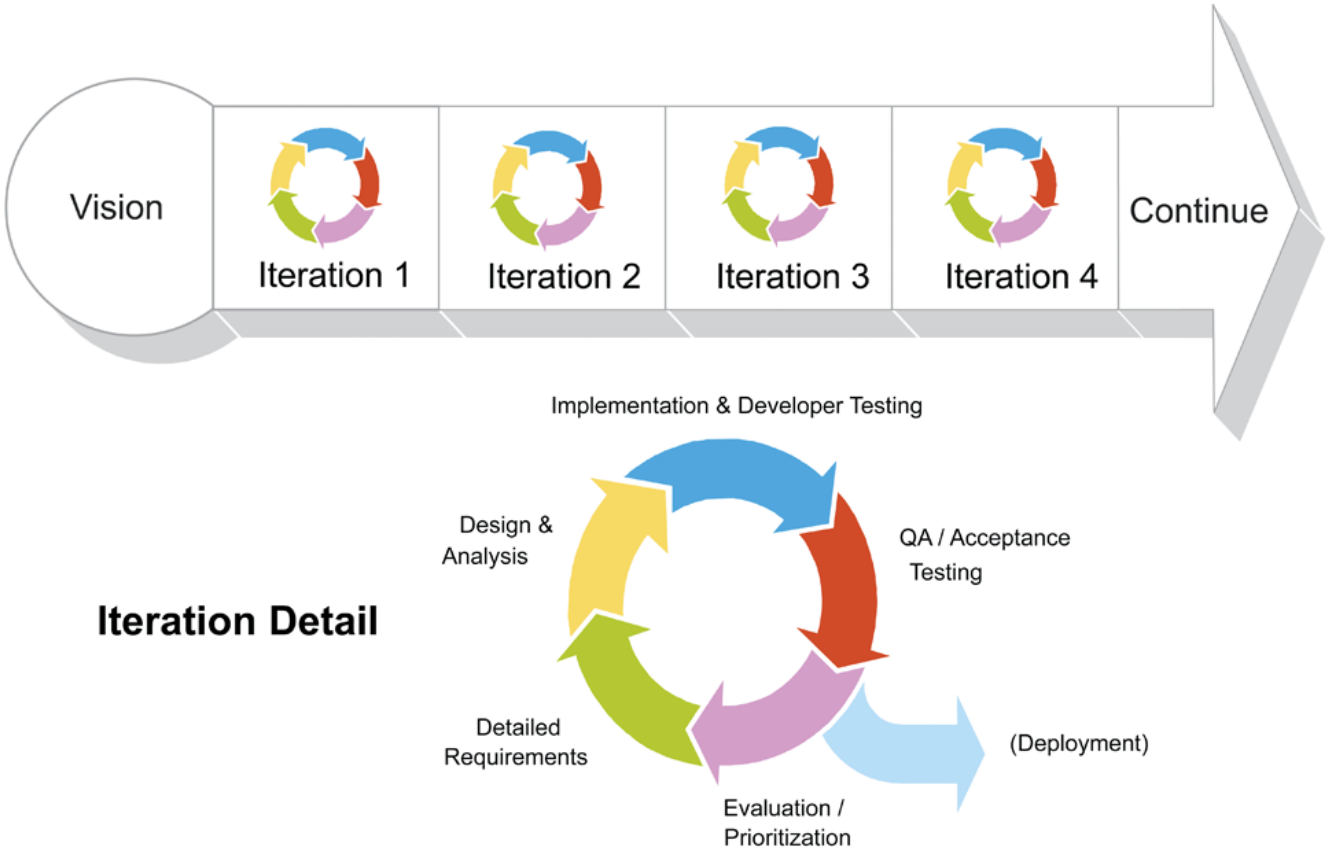
# A Sequential Approach



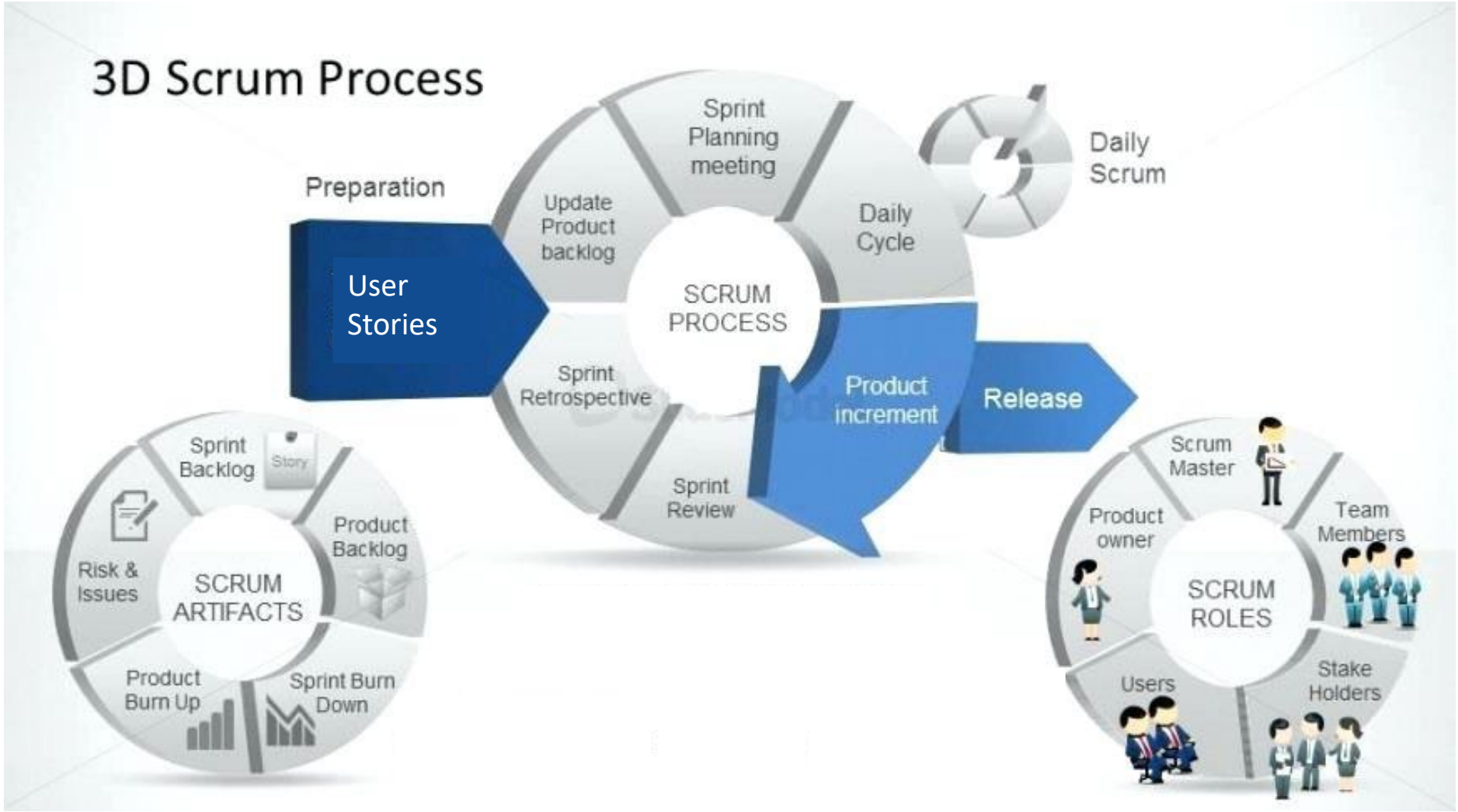
# Sequential Works When…

- We can clearly define the activities
- We can clearly articulate the needs
- We can write reliable, complete, and correct requirements before implementation

# How about an iterative approach?



# Iterative Example: Scrum/Agile



# How about Hybrid?

- Vee vs Agile – is one better than another?
  - They both have uses, depends on the project
  - See https://hbr.org/2023/10/its-time-to-end-the-battle-between-waterfall-and-agile from Harvard Business Review on hybrid approaches
- Indicators of a hybrid approach:
  - Diverse stakeholder needs
  - Varied project phases
  - Uncertain requirements
  - Risk
  - Complex project structures

# Speaking of Risk – how do we define it?

This Photo by Unknown Author is licensed under CC BY-SA

- RISK = UNCERTAINTY or things that could happen to cause your project to:
  - Not meet budget
  - Not meet schedule
  - Not meet expectations and needs
    - Operational strategies are new and insufficiently understood
    - Technology is new and insufficiently understood

# Assessing Risk – Questions to Ponder

- ✓Jurisdictional and modal clarity? (more jurisdictions/modes = more risk)
- ✓Proposed software already verified (i.e., fulfills requirements)?
- ✓Proposed technology already verified?
- ✓Interfaces already defined and verified?
- ✓Requirements documented? Complete? Correct?
- ✓Operating procedures documented?
- ✓Proposed technology is not at end of life?

# Low-Risk Processes

- Categorical SE
  - Projects all of same type
    - Same stakeholder
    - Same software
    - Same hardware
  - Documentation applies to whole category
  - Use standard, *verified* specifications
  - Example: closed-loop signal systems within one county
- Reuse SE documentation from similar project
- Model SE documents
  - Small projects
  - Conventional technologies

# Processes for Higher Risk Projects

- Sequential: For infrastructure-dominant projects
  - Example: Vee diagram
- Iterative: For software-dominant projects
  - Example: Scrum (“Agile”)

- Approach & level of effort should match the scale – size, complexity – of the project

# Systems Engineering

Steps & Products

# Typical SE Steps for Transportation Projects

- ✓Link a project to regional vision, operational plans
- ✓Capture user needs and the concept of operations
- ✓Define the requirements
- ✓Design to efficiently allocate requirements to the solution
- ✓Implement, Test, Verify, Accept
- ✓Validate, then Operate & Maintain

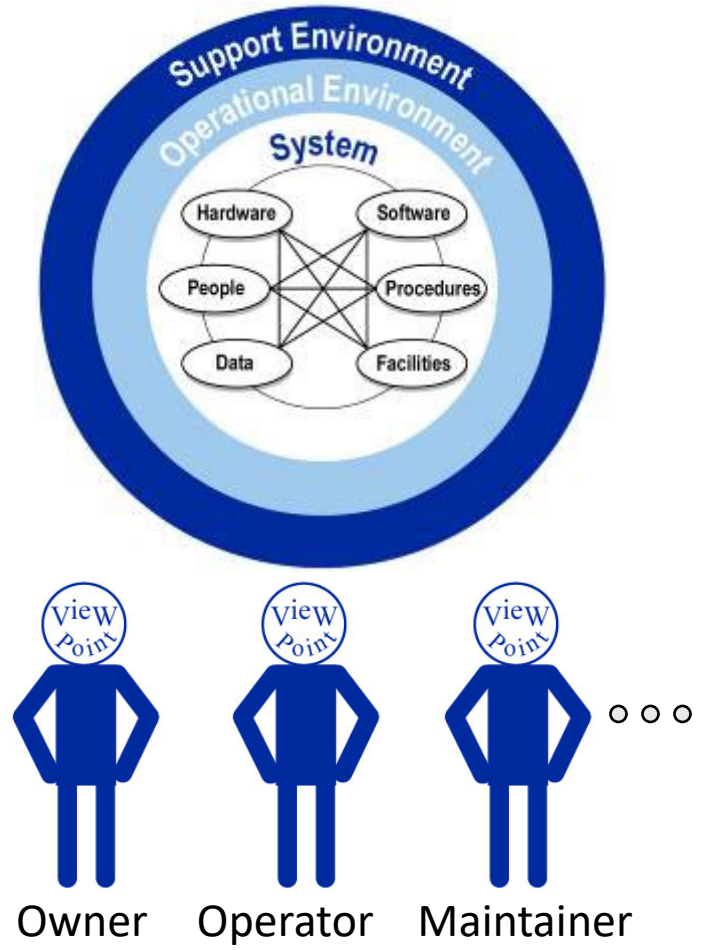
- Talk about 2 today
  - Concept of Operations
  - Requirements
    - (tied to good outcomes for those successful IT projects)

# Concept of Operations

- The ConOps defines
  - **Who**: Stakeholder/user roles and responsibilities
  - **What**: User needs, system elements and high-level capabilities
  - **Where**: Geographic and physical extent
  - **When**: Sequence of activities performed
  - **How**: Development, operation, and maintenance of system

# Concept of Operations (cont'd)

- Written in the users' language
- Shows agreement on:
  - Goals, objectives, and expectations
  - Project scope
  - Stakeholder responsibilities
  - Operational needs
  - How the system will operate
  - Operational and support environment




Adapted from ANSI/AIAA G-048-1992

# Suggested industry standard outlines

**ANSI/AIAA-G-043 Outline**

1. Scope
2. Referenced Documents
3. User-Oriented Operational Description
4. Operational Needs
5. System Overview
6. Operational Environment
7. Support Environment
8. Operational Scenarios

Supports New Systems Developments

**ISO/IEC/IEEE 29148 Outline**

1. Scope
2. Referenced Documents
3. The Current System or Situation
4. Justification for and Nature of Changes
5. Concepts for the Proposed System
6. Operational Scenarios
7. Summary of Impacts
8. Analysis of the Proposed System

Supports System Upgrades

Tailor the outline & content to your project's needs and your user's needs

# Benefits of Developing a ConOps

- Early stakeholder agreement on:
  - System capabilities
  - Users' Needs
  - Roles and responsibilities
  - Key performance measures and a basic plan for system validation
- Manage stakeholder expectations

Start with Your Eye on the Finish Line

A ConOps helps the project team visualize the final system at the beginning of the project.

# System Requirements

"Something that governs *what*, *how well*, and *under what conditions* a product will achieve a given purpose"

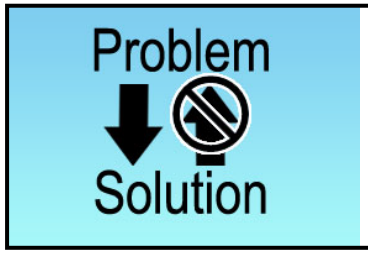
-- EIA-632, Electronics Industry Association Standard "Processes for Engineering a System"

# Quality Requirements Are…

- Necessary
- Unambiguous
- Complete
- Measurable
- Consistent
- Achievable
- Testable
- Technology-independent

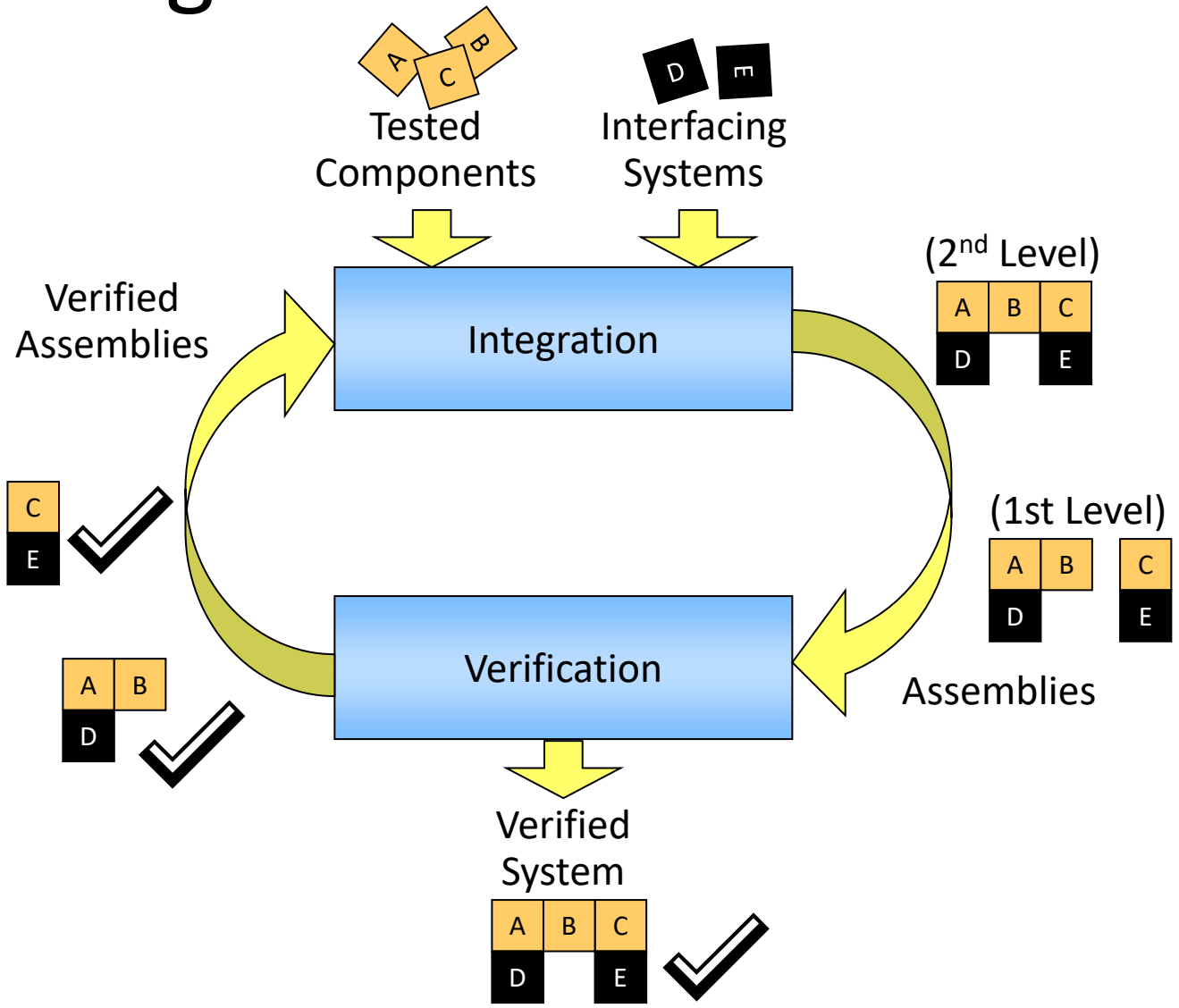
# A clear statement of requirements provides:

- A shared understanding of the problem to be solved by customer and developer
- A firm basis for managing project scope
- The connection between user needs and system design
- The foundation for system verification/testing



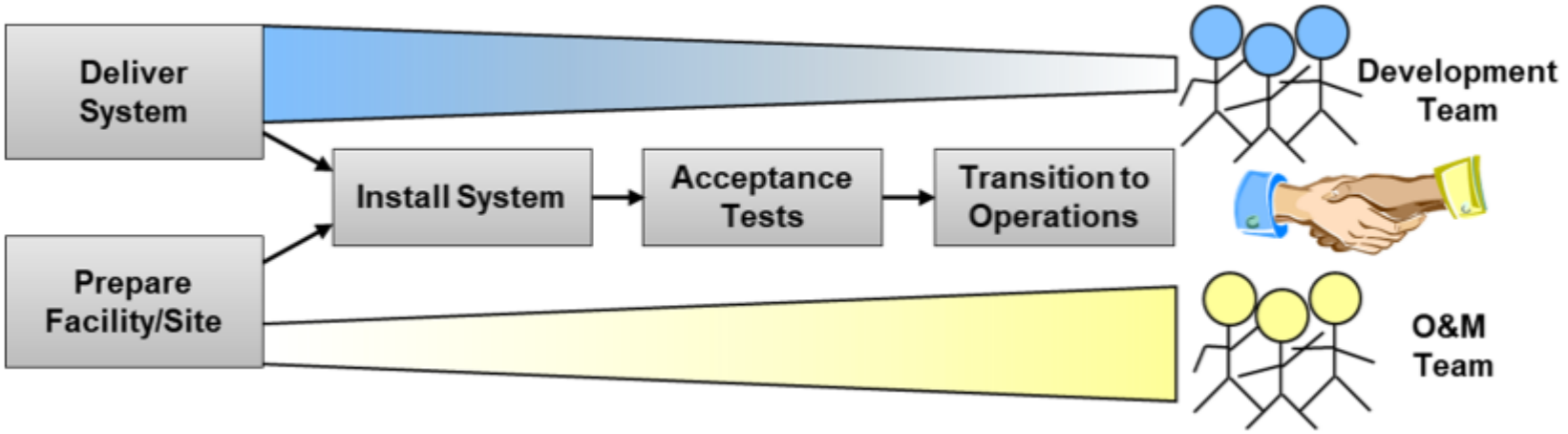

A clear statement of requirements is frequently identified as a key factor in successful IT projects.

# Iterative Integration and Verification



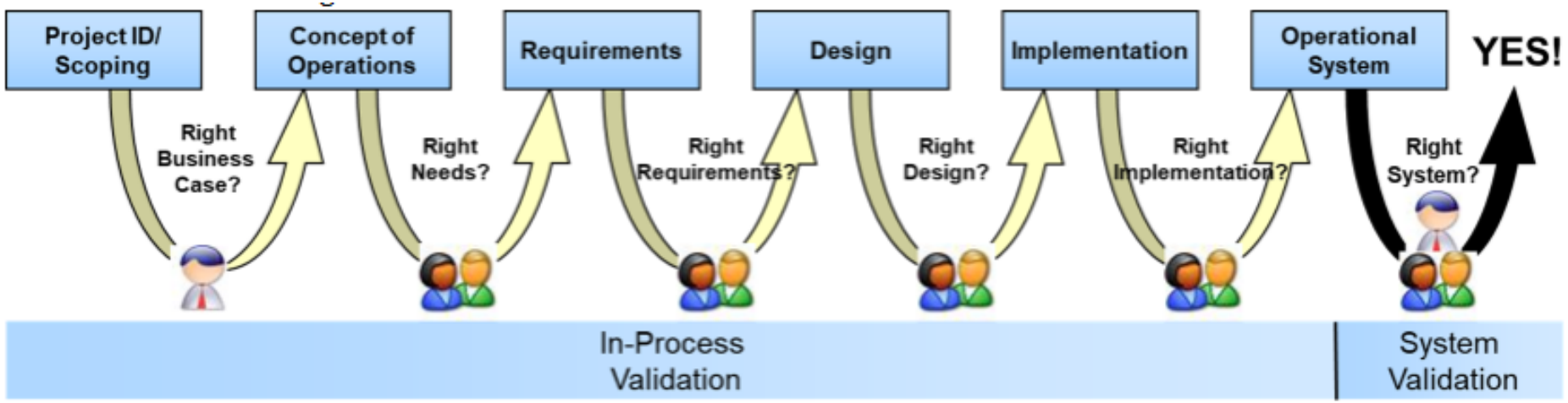
# Initial Deployment/Implementation

- Plan/Prepare for system installation and transition
- Deliver/Install the system
- Perform acceptance tests
- Review/accept documentation
- Train & Transition to operation



# System Validation

- Validation takes place throughout the Systems Engineering process



# Review so far…

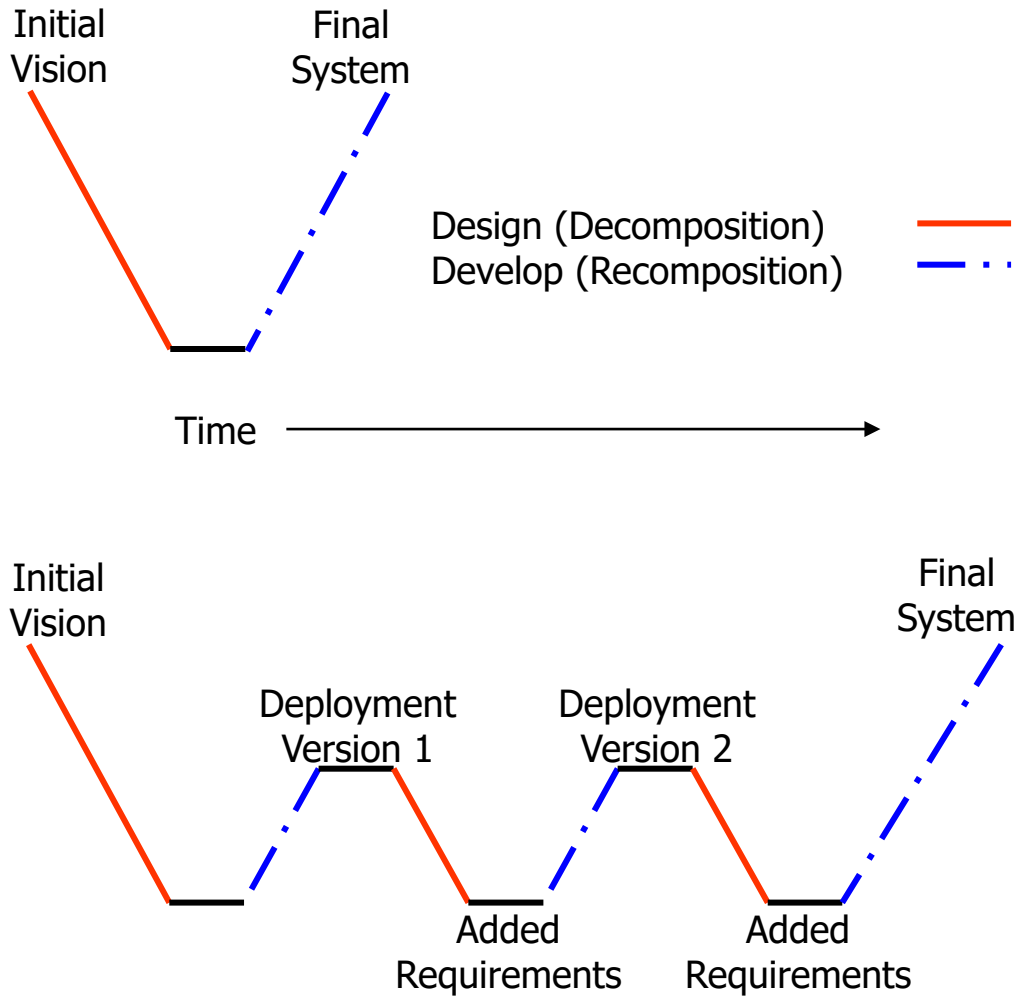
- Needs describe *what the agency will **do** with the system*
- Requirements describe *what the system must do to fulfill those needs*
- Traceability demonstrates
  - All needs are served by requirements
  - All requirements are driven by needs
- Validation means the system supports agency activities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

# Systems Engineering

Approaches

# Alternative Development Strategies

- Once-Through
  - Efficient if requirements are well understood and stable
- Incremental, Phased, or Evolutionary
  - Several passes through “Vee” to implement a little, learn, repeat
  - Good approach for very high-risk projects
    - Lots of unknowns to sort through
    - Prototype, Pilot, then scale the implementation
    - Requirements changes can be deferred for the next iteration



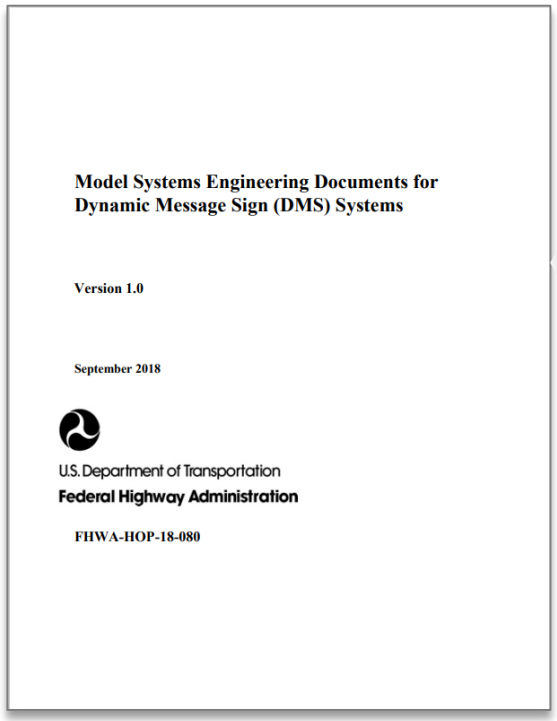
# Systems Engineering

Resources

# Systems Engineering for ITS Website

https://ops.fhwa.dot.gov/seits/

# Model SE Docs

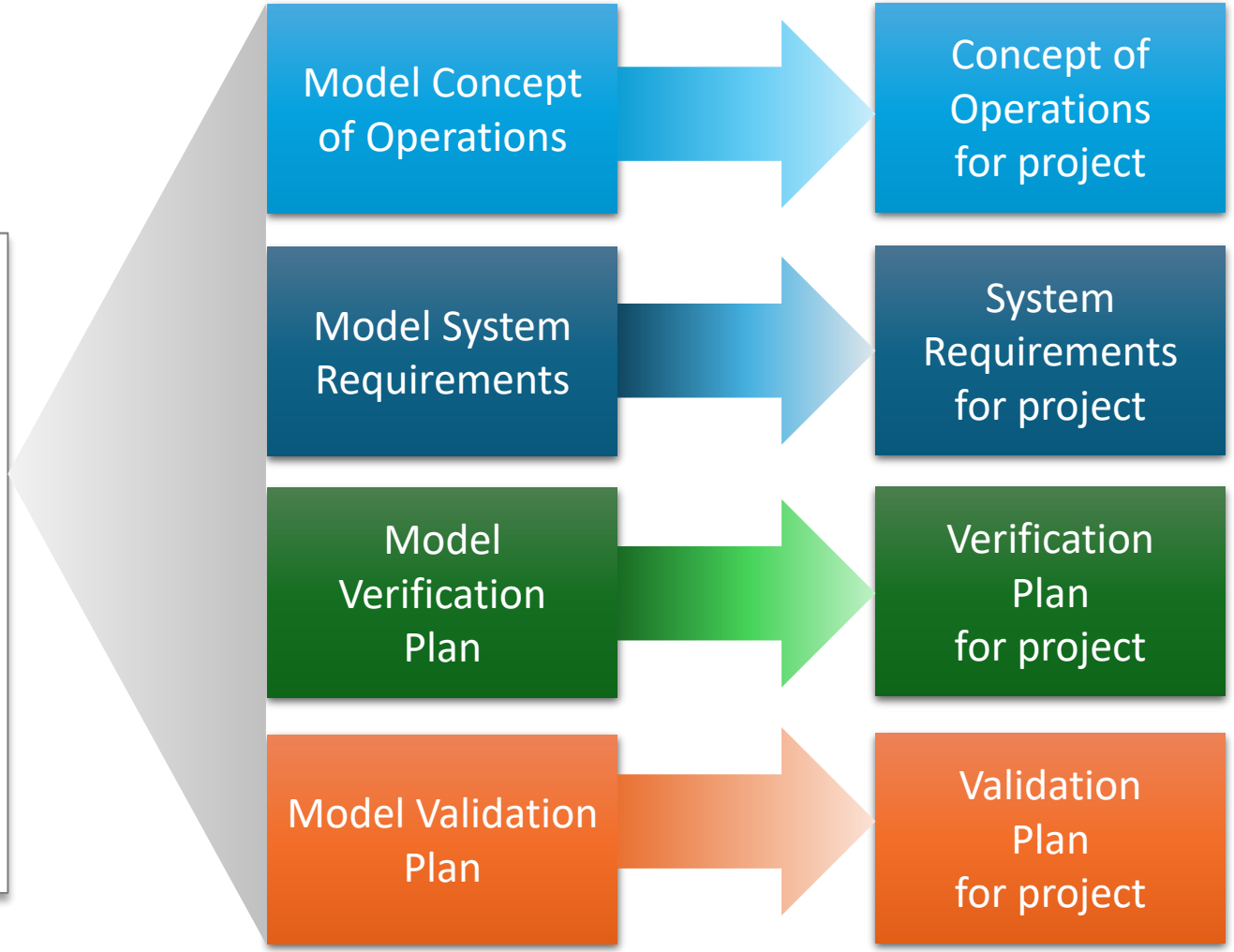

Model Systems Engineering Documents for
Dynamic Message Sign (DMS) Systems

Version 1.0

September 2018

U.S. Department of Transportation
Federal Highway Administration

FHWA-HOP-18-080



# Where to Find the Model Documents

| | |
|---|---|
| FHWA Model Systems Engineering Documents for Central Traffic Signal Systems | https://ops.fhwa.dot.gov/publications/fhwahop19019/index.htm |
| FHWA Model Systems Engineering Documents for Closed Circuit Television (CCTV) Systems | https://ops.fhwa.dot.gov/publications/fhwahop18060/index.htm |
| FHWA Model Systems Engineering Documents for Dynamic Message Sign (DMS) Systems | https://ops.fhwa.dot.gov/publications/fhwahop18080/index.htm |
| FHWA Model Systems Engineering Documents for Transportation Sensor and Detection Systems (TSDS) | (coming soon) |

Also, see the Publications section of the FHWA Operations Facilitating Integrated ITS Deployment Program site at https://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm and https://ops.fhwa.dot.gov/seits/examples.html (search for 'Complete documents')

# Your Regional ITS Architecture

- Illustrates and documents regional integration
- Provides a framework that identifies:
  - Organizations
  - Systems operated
  - Functions performed, services provided
  - Communications required
  - Information exchanged
- WITHOUT picking specific technologies

# Smart Community Resource Center

https://its.dot.gov/scrc/index.html#/

# Poll Question #3

- Now that you've seen some information about Systems Engineering,
  - I didn't mind the presentation but probably won't do anything with it
  - I still have some questions about why I need this
  - I learned some new things and will share with my coworkers
  - I will reach out for help so I can try some of this
  - I am ready to apply this today

# Systems Engineering for ITS & SMART Grants

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