Session 5: Applying SE to a Project

These materials developed under the RITA National ITS Architecture Program
Learning Outcomes

- Define the types of projects for which the SE “V” process is needed
- Explain in general terms the federal requirements for a System Engineering Analysis (SEA)
- Explain how to use the SE “V” process
- Identify the benefits and challenges of using SE
- Explain how SE relates to 23CFR635
Risk Factors for ITS Projects

- Custom Software Development
- New Technology Applications
- Multi-Agency Implementation
- New Interfaces (external or legacy)
Recall:
Two Processes for ITS Projects

Planning

Program/Budgets

Project Initiation
Preliminary Engineering
PS&E
Construction
Project Closeout

Ops & Maintain
Change & Upgrade
Retire/Replace

Regional Architecture(s)

Feasibility Study/Concept Exploration

Concept of Operations
System Requirements
High-Level Design
Detailed Design
Software/Hardware Development Field Installation

System Validation
System Verification & Deployment
Subsystem Verification
Unit/Device Testing

Integration and Recomposition

Time Line
Once-Through
- Implement complete system in one pass through the “V”
- Efficient if requirements are well understood and stable

Evolutionary
- Several passes through “V”. Implement a little, learn a little, and repeat
- Good approach for highest-risk projects
Low-Risk ITS Projects

- Requirements Defined
- Product Performance Solid
- Technology Proven
- Designs Documented
- Agency has years of experience
SE “V” Process Needed for Higher-Risk Projects
Evolutionary Development Strategy
Best for the Highest Risk Projects

- Initial Vision
- Deployment Version 1
  - Added Requirements
- Deployment Version 2
  - Added Requirements
- Final System

Time

Design (Decomposition)
Develop (Recomposition)
Indicators of Low-Risk ITS Projects

1. Single jurisdiction and/or stand-alone system
2. No software creation (COTS or proven software OK)
3. Proven COTS hardware and communications
4. No new interfaces
5. System requirements well defined and documented
6. Operating procedures well documented
7. Agency has previous experience
Let’s Analyze a Specific Example …

“Add 4 CCTV cameras to surveillance system with 10 existing cameras”

Low Risk Indicators that apply:

- Single jurisdiction and/or single mode
- No software creation (COTS or proven software OK)
- Proven COTS hardware and communications
- No external interfaces; duplication of existing
- System requirements well defined, documented
- Agency has previous experience procuring/operating/maintaining existing system
Indicators of Higher-Risk ITS Projects

- Multi-jurisdictional and/or multimodal
- New software creation
- New hardware integration
- New technology applications
- New interfaces -- especially if to external systems
- System requirements not well understood
- Likely technology changes
Let’s Analyze a Higher-Risk Example

“Share control of existing CCTV cameras between State DOT and adjoining city”

Risk factors that apply -

✓ Multi-jurisdictional and/or multimodal
✓ New software creation; new hardware integration
  ▪ New technology applications
✓ New interfaces - especially if to external systems
  ▪ ✓ System requirements fairly well understood?
  ▪ Need to account for technology evolution
An Even Higher-Risk Example

“Implement a statewide 5-1-1 system”

Risk factors that apply -

✔✔ Multi-jurisdictional and/or multimodal
✔✔ New software creation; new hardware integration
✔ New technology applications
✔✔ New interfaces - especially if to external systems
✔✔ System requirements not well understood
✔ Need to account for technology evolution
How to Choose the Best Process Based on ITS Project Risk

As we complete the Planning/TIP stage …

- Simply from a cursory assessment of the risk factors, we can make an early determination of best process

- Is there an additional resource that should be used for confirmation before we begin project development?

YES:
The Systems Engineering Analysis described in the Final Rule and Policy
Recall the 7 SEA items:

1. How project fits into regional ITS architecture
2. Roles/responsibilities of participating agencies
3. Requirements definition
4. Analysis of alternative systems and technologies
5. Procurement options
6. ITS standards and testing procedures
7. Procedures and resources needed for O&M
**Example 1:**

**SEA for “Adding 4 Cameras” Project**

<table>
<thead>
<tr>
<th>SEA Requirement</th>
<th>Defined?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How project fits into regional architecture…</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Roles/responsibilities of participants</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Requirements definition</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Analysis of alternative systems &amp; tech</td>
<td>Yes</td>
</tr>
<tr>
<td>5. Procurement options</td>
<td>Yes</td>
</tr>
<tr>
<td>6. ITS standards and testing procedures</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Procedures and resources for O&amp;M</td>
<td>Yes</td>
</tr>
</tbody>
</table>

All 7 items can be answered immediately; hence, this is likely a low-risk ITS project, and the Roadway Process and SEA can be used
Roadmap for Project Implementation

Low Risk ITS Projects

1. Start
2. Assess Risk
3. Low Risk
4. SEA
5. Determine Type of Project - Preliminary Assessment -
6. Confirm Risk Assessment and document conformance to Final Rule
Example 2: SEA for “Sharing CCTV Control” Project

**SEA Requirement**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Defined?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How project fits into regional architecture…</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Roles/responsibilities of participants………………………………………</td>
<td>Maybe</td>
</tr>
<tr>
<td>3. Requirements definition……………………………………………………</td>
<td>No</td>
</tr>
<tr>
<td>4. Analysis of alternative systems &amp; tech………..</td>
<td>Maybe</td>
</tr>
<tr>
<td>5. Procurement options …………………………………………………………</td>
<td>Yes</td>
</tr>
<tr>
<td>6. ITS standards and testing procedures ……..</td>
<td>Yes</td>
</tr>
<tr>
<td>7. Procedures and resources for O&amp;M …………</td>
<td>No</td>
</tr>
</tbody>
</table>

Some of the 7 items can **not** be answered immediately; hence, this is probably a higher-risk ITS project and the SE “V” should be used.
Roadmap for Project Implementation

Higher Risk ITS Projects

Start

Assess Risk

High Risk

SE A

Preliminary Assessment

Confirm Risk Assessment

Document Conformance to Final Rule
Example 3: SEA for Statewide “5-1-1” Project

SEA Requirement | Defined?
--- | ---
1. How project fits into regional architecture… | Maybe
2. Roles/responsibilities of participants……….. | No
3. Requirements definition………………………… | No
4. Analysis of alternative systems & tech……….. | No
5. Procurement options ……………………………….. | No
6. ITS standards and testing procedures ……… | No
7. Procedures and resources for O&M ………… | No

None of the 7 items can be answered immediately; hence, this is probably a very-high-risk ITS project and an evolutionary development strategy should be used.
Roadmap for Project Implementation

Very-High-Risk ITS Projects

Assess Risk → Very High Risk → SEA → Very High Risk → Confirm Risk Assessment

Preliminary Assessment

Document Conformance to Final Rule
Summary: Roadmap for Project Implementation

Start

Assess Risk
- Low Risk
- High Risk
- Very High Risk

SEA

Higher Risk

Very High/Large-Project Risk

Low Risk

Deployment Version 1
- Added Requirements

Deployment Version 2
- Added Requirements

Final System

Project Initiation
- Preliminary Engineering
- PS&E
- Construction
- Project Closeout

Program/Budgets
- Planning

Ops & Maintain
- Change & Upgrade
- Retire/Replace

Regional Architecture(s)
- Feasibility Study/Concept Exploration

Lifecyle Processes
- Concept of Operations
- System Validation Plan
- System Verification Plan
- Subsystem Verification Plan
- High-Level Design
- Detailed Design
- Software/Hardware Development
- Field Installation
- Implementation

Development Processes
- Post-Original Design
- Operations and Maintenance
- Changes and Upgrades
- Retirement/Replacement

Time Line

Document/Approval
State DOT Examples of Documented Processes
Summary: Types of ITS Projects
(California Definitions)

1. **Exempt ITS Projects**
   Signal timing, studies, maintenance, and new isolated traffic signals; Use traditional construction design processes

2. **Minor ITS Projects** [Low Risk ITS]
   Expansion/Upgrade to existing systems. Design and installation of ITS field devices; Use roadway project development processes

3. **Major ITS Projects** [High Risk ITS]
   New systems, multi-jurisdictional, multi-modal, or software development; Use/Tailor SE V.
Roadmap to S.E. Compliance (California)

Start

Classify Project

Minor

Major

Exempt

Preliminary decisions made during TIP programming and Concept Exploration

SERF

Minor

Major

Typical Infrastructure Project

Planning → Environment → Design (P&E) → Construction/Installation → Operations & Maintenance

SEMP
Florida SunGuide ITS Checklist

Process Steps

1. Arch Scope & Region
2. Key Agency Providers
3. Agreements
4. ConOps
5. Requirements
6. Interfaces / Info Flows
7. Analyze Alternatives
8. Procurement Options
9. Schedule
10. Standards
11. Maint./Ops. Plan
12. Acceptance Test Plan
13. Config. Mgmt. Plan

Ref FL SEMP Appendix A
Assess completeness of the applicable items of the SEMP

Acknowledge a commitment to address items during early stages of the SE Process

For all ITS projects – obtain FHWA review/approval prior to PE authorization

For all ITS projects – submit SEMP, or equivalent document, to FHWA for review/approval of detailed design

Ref FL SEMP Appendix A
- **User Guide for SE and ITS Architecture**
  - Explains VDOT processes and incorporation of SE and Architecture
  - Checklists guide user through compliance process

![User Guide Example](image-url)
- VDOT Checklist collects information for each step of the systems engineering process, through acknowledgement and references.
How Do We Manage the SE Technical Development?
Systems Engineering Management Plan (SEMP)

- Documents how the technical development will be managed and what needs to be documented
- Details how the process will be tailored and development will be done
- Explains how the process activities will be brought together
- Should be closely synchronized with Project Plan to avoid unnecessary duplication
  - System planning activities (i.e., WBS, training, constraints, decision points)

SEMP Template and Checklist in CA SEGB, Sec. 8.4.2
Project’s unique characteristics will dictate need

Technical Review  SW/HW Development
Interface Control  System Integration
Stakeholders’ Cooperation  Deployment
Resource Management  Operations & Maintenance
Verification  Training
Validation  Security
Configuration Management  Safety
Risk Management  Quality Assurance
Technology
SEMP Development Stages

SEMP milestones formalized between Agency and contractor(s)

SEMP Plans developed, delivered, and approved

SEMP Plans used during project implementation
Recall: Benefits of Using SE “V” Process

**A few highlights…**

**Reg. Arch.** – Nothing/nobody gets overlooked

**ConOps** – Manage expectations, avoid surprises

**Reqmts.** – Avoid disputes during Acceptance

**Design** – Not too much, not too little – just right!

**Verification** – Ensures “you got what you paid for”

**Deployment** – Smooth transition to operations
What are the Challenges of Using SE?
Challenges of Using SE

- **Time and Skills**
  - Assigning Adequate Staff
  - Knowledge of SE Process and SE Management
  - Integrating SE into current project delivery process

- **Contracts & Procurement**
  - Using best form of contracting

- **Selection of Qualified Consultants**
  - Determining contractor qualifications
Good Project Management Takes Lots of Time!

Projects > $1 million/yr. Require > 1 full time person

Staffing range

<table>
<thead>
<tr>
<th>PM/SE FTE</th>
<th>Projects &gt; $1 million/yr. Require &gt; 1 full time person</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Project Size ($million/yr)
Why Is So Much Staff Time Needed?

1. Develop RFP
2. Contract negotiations
3. Conduct risk analysis
4. Requirements walk-thru
5. Internal coordination
6. Document activities
7. Review documentation
8. Inspect work
8. Review deliverables
9. Acceptance tests
10. Lead project meetings
11. Contract management
12. Review invoices
13. Coord. stakeholders
14. Contribute to website
15. … and more …

Which of these is **NOT** necessary?
If Your Agency Can’t Commit the Staff Time …

- Supplementary staff are available:
  - Consultants
  - Universities
  - Not-for-profit organizations
  - USDOT
  - Peers

- Just ask, there’s plenty of willing help out there

- Or do not initiate the project!
  Without adequate staffing, the project will probably not succeed.
Contracting Should Include…

- Contractor participation as early in the development process as possible
- Contractor selection that requires appropriate IT development skills (certification)
- Task order (indefinite quantity) contract to permit use of evolutionary process
- Multiple reimbursement alternatives (FP and T&M) to permit appropriate risk allocation
Choosing the Right Contracting Approach

National Cooperative Highway Research Program (NCHRP)

NCHRP Project 03-77: Guide to Contracting ITS

http://www.citeconsortium.org/Model/index.htm
Contractor Roles Vary Across the Three Phases of the “V” Process

Definition

Integrate & Test

Implementation
<table>
<thead>
<tr>
<th>Role</th>
<th>Action</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner/Agency</td>
<td>Review</td>
<td>Needs, Vision, Constraints, Eval</td>
</tr>
<tr>
<td></td>
<td>Participate</td>
<td>Plan, Agreements, Resources</td>
</tr>
<tr>
<td>System Engineer (SE)</td>
<td>Identify</td>
<td>Vision, Ops Scenarios, Requirements, Test Plans, Interfaces, High-Level</td>
</tr>
<tr>
<td></td>
<td>Prepare</td>
<td>Design</td>
</tr>
<tr>
<td>System Integrator (SI)</td>
<td>Review</td>
<td>(No official role)</td>
</tr>
<tr>
<td></td>
<td>Comment</td>
<td></td>
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## Roles and Responsibilities in the *Implementation* Phase

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<tbody>
<tr>
<td>Owner/Agency</td>
<td>Review, Participate, Approve</td>
<td>Tech Reviews, CM activities, Product Reviews, Detailed Design, SI RFP</td>
</tr>
<tr>
<td>System Integrator (SI)</td>
<td>Identify, Perform, Document, Implement</td>
<td>Tech Plans, CM, Development activities, Unit Test</td>
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## Roles and Responsibilities in the *Integrate & Test* Phase

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<td>Review, Participate, Approve</td>
<td>Integration Plan/Support, Training, Test Plans/Procedures</td>
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<tr>
<td>System Engineer (SE)</td>
<td>Support, Participate, Monitor, Report</td>
<td>Integration reviews, Training, Test procedures, Tests, RM</td>
</tr>
<tr>
<td>System Integrator (SI)</td>
<td>Perform, Document, Implement</td>
<td>Integrate, Test, Resolve Defects, Verification, CM, RM</td>
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</table>
When You Are Hiring Consultants, SE Capabilities Can be Measured

- *Transportation Engineers* have certifications (PE, PTOE) to measure their level of expertise
- *Systems Engineers* have certifications for people (CSEP, PMP), and also for organizations (CMMI), to measure their level of expertise
- SE certifications for individuals and organizations should be evaluation criteria in ITS procurements
  - For CMMI info: [http://www.sei.cmu.edu/cmmi/](http://www.sei.cmu.edu/cmmi/)
  - For CSEP info: [www.incose.org](http://www.incose.org)
  - For PMP info: [www.pmi.org](http://www.pmi.org)
A Last Word: Proprietary Acquisition

- Proprietary Materials (23 CFR 635.411)
  - Certification of no available competitive product
    - Uniquely fulfills the requirements imposed on the product
    - Achieves synchronization with existing systems
  - Public Interest Finding for proprietary purchase despite alternative available competitive products
    - Limited experimental application
- Systems Engineering Analysis can provide justification
Open-book quiz…

1. Give **examples** of some projects for which SE “V” process is needed
2. What are the items in SE Analysis?
3. What are the steps of the SE “V” process?
4. What are some benefits of using SE “V”? 
5. What are challenges in using SE “V”?