System Requirements for Rural Deployment

Anchorage, AK
September 4, 2008
1. Understand the systems engineering fundamentals
2. Be able to recognize good and bad requirements
3. Explain the importance of traceability
4. Name the required elements for ITS Projects based on the FHWA Rule and FTA Policy
System Requirements for Rural Deployment

Understanding the system engineering fundamentals
An *inter-disciplinary approach* and means to enable the realization of successful systems.\(^1\)
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
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
Traditional Project Development Process Has Led to This Success

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<tr>
<td>Ops &amp; Maintain</td>
<td>Change &amp; Upgrade</td>
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Low Risk of Unsuccessful Implementation!

- ✓ Performance of products and materials well understood
- ✓ Requirements well defined and understood
- ✓ Proven, well-known technology
- ✓ Documented, proven designs
Small ITS Projects: Low-Risk Projects

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

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- 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 Regression

**Time Line**
Rural Projects

- Characteristics
  - Localized
  - Isolated
  - Minimal (if any) full-time communication
  - Not usually complex

- Examples
  - Animal Crossing Warning System
  - Road Weather Information System
  - Oversize Vehicle Identification System
Key activities:

- Identify relevant regional ITS architecture(s)
- Identify portions of regional ITS architecture that the project will implement
- Verify project is consistent with regional ITS architecture
- Identify any necessary changes to regional ITS architecture
Regional Architecture Use in Project Development

- Step by Step
Assess economic, political, and technical feasibility

Evaluate alternative concepts

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

Makes the business case
The ConOps defines

- **Who**: Stakeholder roles and responsibilities
- **What**: System elements and high-level capabilities
- **Where**: Geographic and physical extent
- **When**: Sequence of activities performed
- **How**: Development, operation, and maintenance of system
Benefits of Developing a Concept of Operations

- Early stakeholder agreement on:
  - System capabilities
  - 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 for Rural Deployment

Be able to recognize good and bad 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”
Key activities

- Elicit Requirements
- Analyze Requirements
- Document Requirements
- Validate Requirements
- Manage Requirements
- Use “shall” rather than “will” or “should”
- One requirement per sentence
- Avoid use of pronouns
- Avoid vague references such as “good workmanship” and “proven technology”
Quality Requirements Are

- Necessary
- Unambiguous
- Complete
- Measurable
- Consistent
- Achievable
- Testable
- Technology-independent
Characteristics of Poor Requirements

- Unnecessary
- Ambiguous
- Incomplete
- Not measurable
- Inconsistent
- Not achievable
- Not testable
- Technology-specific
Examples of Poor Requirements

- “The system shall use radar detectors for traffic monitoring.”
- “State-of-the-art computers shall be used.”
- “The system shall manage incidents.”
- “All work shall be performed to the satisfaction of the Engineer.”
- “Industry standard designs and components shall be used.”
Requirements Examples (good or bad?):

- “The retrieval of any single status from any field device shall not exceed 2 seconds from the initiation of the request.”
- “Congestion shall be reduced.”
- “The system user shall be able to verify reversible lane gate status of up, down, locked, and 15° status.”
- “People shall feel safer about riding the bus.”
System Requirements

- Usually defined in a hierarchy – for example:

Parent Requirement

1. The system shall read tag data

Child Requirement

1.1 The system shall read tag ID
1.2 The system shall read vehicle type

Increasing Detail and Specificity
Tips for Eliciting Requirements

- Start with the high-level view by function
- Decompose each function into subfunctions (and subrequirements)
- Review
- Set the level of detail to the experience of the designers, developers and testers
- Review
Rural Project Requirements Example

- Deploy an Environmental Sensor Station (ESS) as a part of an RWIS (Road Weather Information System)
Focused application for this exercise is to provide weather data to
- Information Service Providers
- Weather Service Providers
Requirements Exercise

- Take 20 minutes to develop a set of requirements specifying what type of data you are collecting and transmitting with your ESS

- Hint: Use the RWIS ESS Siting Guidelines Document and the excerpt of the NTCIP 1204 standard in the back of the workbook
Benefits of System Requirements

- 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.
System Design

- The bridge between requirements and implementation
- Two distinct levels
  - High-Level Design – Overall structure of the system (subsystems, components, and interfaces)
  - Detailed Design – Complete specification of hardware, software, and communications components
Benefits of System Design

- A good system design:
  - Relates requirements to the system specifications
  - Defines open interfaces that supports different vendor solutions and off-the-shelf products
  - Supports efficient hardware and software development
  - Provides a roadmap for system integration and testing
  - Facilitates maintenance and future expansion and upgrade of the system

A superior system design allows new technologies to be cost-effectively incorporated.
Key activities
- Plan software/hardware development
- Establish development environment
- Procure off-the-shelf products
- Develop software and hardware
- Perform unit/device testing

Performed by technical specialists
- Developers & Testers should be independent, particularly for higher risk efforts

Systems engineering plays a monitoring role
Monitoring Software/Hardware Development and Testing

- Check software quality
  - Structure
  - Documentation
  - Standards and conventions

Implement

Test

Walkthroughs

Inspections

Reviews
Integration and Verification

- **Key activities**
  - Add detail to integration and verification plans
  - Establish integration and verification environment
  - Perform integration
  - Perform verification
  - Confirm system meets requirements

- **Verification** – was system built right?
Validation – was the right system built?
Confirm that user needs are met by the installed system

Key activities
- Update Validation Plan as necessary and develop procedures
- Validate system
- Document validation results including any recommendations or corrective actions
In-Process Validation was Clearly Lacking on this Project

How the customer explained it
How the Project Leader understood it
How the Analyst designed it
How the Programmer wrote it
How the Business Consultant described it

How the project was documented
What operations installed
How the customer was billed
How it was supported
What the customer really needed
Operations & Maintenance

- Key activities
  - Conduct Operations and Maintenance Plan Reviews
  - Maintain operations and maintenance procedures
  - Provide user support
  - Collect system operational data
  - Change or upgrade system
    - Another pass through the “V”
  - Maintain configuration control of system
  - Provide maintenance activity support
The end of the system lifecycle

- Stakeholder needs change or are met in an alternative manner
- Cost of operations and maintenance exceeds cost of new system development

Key activities

- Plan system retirement
- Deactivate system
- Remove system
- Dispose of system
System Requirements for Rural Deployment

Explain the importance of traceability
Traceability

- Regional Architecture(s)
- Feasibility Study / Concept Exploration
- Concept of Operations
- System Requirements
- High-Level Design
- Detailed Design
- Software / Hardware Development
- Field Installation
- Unit / Device Testing
- Subsystem Verification
- System Verification & Deployment
- System Verification
- Operations and Maintenance
- Changes and Upgrades
- Retirement / Replacement

It's good to know where things come from.
And where they're going.
It is important to have unique project references to:

- User Needs and Scenarios
- Requirements
- Design elements
- Software and Hardware items
- Test Plans and Procedures

<table>
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<tr>
<td>1.1 The system shall generate …</td>
</tr>
<tr>
<td>1.2 The system shall provide …</td>
</tr>
<tr>
<td>2.1 The system shall collect…</td>
</tr>
<tr>
<td>2.2 The system shall store…</td>
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</table>
Both forward traceability

- Needs and requirements are satisfied by the design and implementation
- Requirements are verified by tests

And backward traceability

- Every design and implementation item has corresponding user needs and requirements
- Each test verifies one or more requirements
Traceability Example

Requirements:
2.0 The system shall have the ability to monitor weather conditions
   2.1 The system shall measure air temperature

Specification:
3.83 System processing of air temperature data shall be performed by obtaining the temperature of each ESS ...

Implementation (software modules):
   17.6.1 Air Temperature data input module
   18.3.4 Air Temperature comparison module
   2.4.5 Air Temperature storage (DBMS interface)

Test:
8.0 Compare air temperature reading with truth temperature
## Traceability Matrix Illustration

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Specifications</th>
<th>Implementations</th>
<th>Verification (Acceptance Tests)</th>
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<tbody>
<tr>
<td>1.1</td>
<td>1.1, 2.6</td>
<td>2.0, 3.4, 5.1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>1.2</td>
<td>1.2</td>
<td>6.8</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>2.1</strong></td>
<td><strong>3.83</strong></td>
<td><strong>17.6.1, 18.3.4, 2.4.5</strong></td>
<td><strong>8.0</strong></td>
</tr>
<tr>
<td>2.2</td>
<td>4.9</td>
<td>12.2, 17.10</td>
<td>2.0</td>
</tr>
<tr>
<td>2.3</td>
<td>3.5</td>
<td>6.6</td>
<td>9.0</td>
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System Requirements for Rural Deployment

Name the required elements for ITS Projects based on the FHWA Rule and FTA Policy
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

Fact: FTA Policy uses the same language as the FHWA Rule
23 CFR 940.11(c) defines “systems engineering analysis”

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
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.
Indicators of Small 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
Roadmap for Project Implementation

Small ITS Projects

Start

Assess Risk

Low Risk

SEA

Low Risk

Confirm Risk Assessment and document conformance to Final Rule

Determine Type of Project - Preliminary Assessment -
Open-book quiz…

1. What are the steps of the SE “V” process?
2. What are some benefits of using the SE process?
3. Give examples of some poorly worded requirements.
4. Explain why documenting traceability is a good idea.
5. What are the items in SE Analysis?
Thank You!

Questions?
Comments?

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