USDOT Guidance Summary for Connected Vehicle Deployments

System Requirements and the CVRIA/SET-IT Tool

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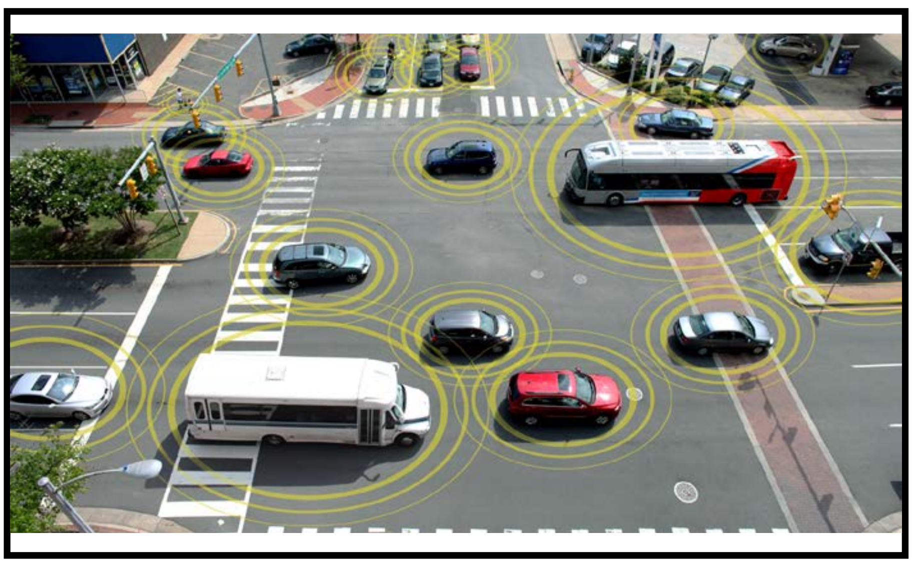

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16. Abstract
This document provides guidance material in regards to System Requirements for the CV Pilots Deployment Concept Development Phase. Methods for system engineering are discussed with definitions for the successful management of each aspect. Important references are given in terms of Laws and Regulations, in-text footnotes, and additional guidance documents. How system engineering ties into the Concept Development Phase deliverables is discussed with a focus on the Tasks 2 and 6. Major challenges are identified and how they can be overcome. The document concludes with a summary of available CV systems engineering training.

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1 Introduction

1.1 Purpose of the Report

This report provides guidance material for the CV Pilots Deployment Concept Development Phase. It focuses on Task 6 and describes the systems engineering principles which should be used to produce deliverables for this task, specifically in relation to System Requirements.

This document does not replace or alter the Broad Agency Announcement (Statement of Work), it only provides technical assistance to the sites in completing tasks that were previously described in the statement of work.

1.2 Organization of the Report

This report contains four additional sections and a references appendix. Section 2 presents a general discussion on the goals and processes for the systems engineering approach. Section 3 provides an introduction to the Connected Vehicle Reference Implementation Architecture (CVRIA) and the Systems Engineering Tool for Intelligent Transportation (SET-IT). Section 4 describes the relevant Task 2 and 6 deliverables and offers guidance on how these tools and processes can be used for those deliverables. Section 5 provides a summary of available requirements development training.

2 Background

2.1 Systems Engineering

Systems engineering is a discipline for designing, developing, deploying and maintaining complex systems. Large systems may fail for a variety of reasons. The designers may not have fully understood the problem from the beginning, or they may not have been aware of critical aspects of the environment surrounding the system. System users may not have understood what they were getting until it was too late, or system owners may not have understood the full risk and cost associated with the system. The systems engineering process mitigates these risks with a structured and holistic discovery process which identifies needs, concerns, issues and impacts for all stakeholders as early in the process as possible. Once the problem area and all of its ramifications are well understood it is decomposed in a stepwise fashion into more manageable components. The analysis done during the decomposition phase is used to verify the system as it is constructed. The process is typically depicted via the “V Diagram”.

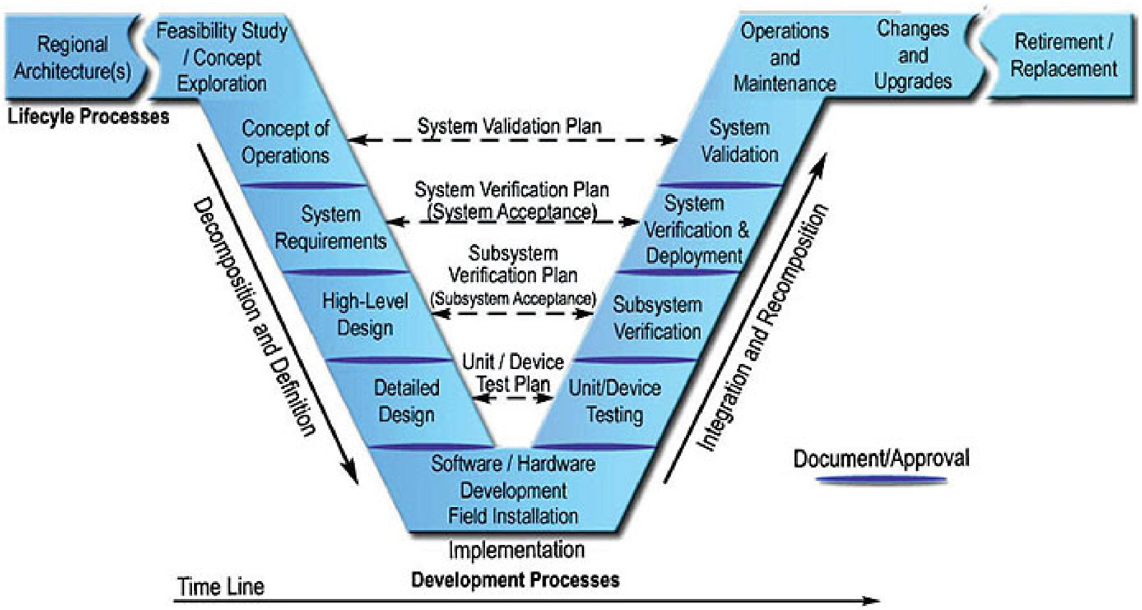

Figure 2-1: System's Engineering V Diagram (Source: USDOT)

Tasks 2 and 6 cover the Concept of Operations and System Requirements. These are the first two steps in the decomposition process and appear in the upper left section of the V diagram. During these early stages the most important task is to clearly **identify and describe the problem that will be solved**. All stakeholders must be considered, and all potential impacts analyzed. The pilot program is not an isolated research project which will be abandoned when the project ends. The systems installed will have lasting impacts on the community so all potential consequences must be studied.

The traditional SE process is not iterative, and this differs from many current software development practices. The Concept Development Phase is only concerned with the Concept of Operations (ConOps) and the System Requirements (SyRS). The artifacts produced at that level do not conflict with an agile approach to software development. The user needs produced in a ConOps correspond strongly with the initial Product Backlog Items (PBI) in an agile environment. The Functional, Interface and Performance requirements correspond to the acceptance criteria for the PBI.

2.1.1 System Requirements

The next step in the systems engineering process is system requirements (SyRS). This is a structured description of what a system will do and how it will behave. It should describe what a system does, not how it does it. However, it is often necessary to identity major subcomponents of the system to accurately describe what the system as a whole does. As such, a high level system architecture showing connections between components can be helpful. The initial draft of the CVRIA functional and communication views can be included here. The IEEE 1233 [2] standard defines the structure and format of a SyRS document.

The Contractor shall develop a System Requirements Specification (SyRS) Document based on the COR-approved ConOps, following the guidance in IEEE Standard 1233-1998 [2]. At a minimum, the following requirements shall be included:

- *Functional requirements*
  Including communications, security, and safety requirements
- *Interface requirements*
  Including identification of relevant standards (where appropriate)
- *Performance requirements*
  Including system performance targets and performance requirements
- *Data requirements*
  Including data-sharing requirements

Requirements shall meet the test of being “well-formed requirements” based on forthcoming USDOT guidance, e.g.: *Tangible, Atomic, Necessary, Consistent, Accurate, Complete and Testable*. The Pilot Deployer shall provide a Needs-To-Requirements Matrix, tracing requirements back to needs defined in the ConOps.

2.1.2 Tangible

Quality:	Tangible
Description:	The requirement should describe something that is real and concrete. Subjective terms should be avoided.
Bad Example:	The red light warning system should notify users of potential violations in time for the users to respond.
Good Example:	The red light warning system should notify users of potential violations two seconds before their vehicle enters the intersection.

2.1.3 Atomic

Quality:	Atomic
Description:	The requirement should describe a single aspect of the system which cannot be further broken down.

Bad Example:	Spot weather warnings will be broadcast from infrastructure to vehicles, and then forwarded to other vehicles.
Good Example:	• Spot weather warnings will be broadcast from infrastructure to vehicles. • Spot weather warnings received by one vehicle will be forwarded to other vehicles.

2.1.4 Necessary

Quality:	Necessary
Description:	The requirement should meet a business need. If system and performance goals can be met without the requirement then it should not be included.

2.1.5 Consistent

Quality:	Consistent
Description:	Two requirements should not contradict each other.
Bad Example:	• The signal preemption system shall grant the highest priority to emergency vehicles. • The signal preemption system shall grant the highest priority to transit vehicles.
Good Example:	• The signal preemption system shall grant the highest priority to emergency vehicles. • The signal preemption system shall grant the second highest priority to transit vehicles.

2.1.6 Accurate

Quality:	Accurate
Description:	Any facts or assumptions included or implicit in a requirement should be accurate.
Bad Example:	DSRC messages will be received by all vehicles within 200 miles of the roadside unit.
Good Example:	DSRC messages will be received by all vehicles within 500 meters of the roadside unit.

2.1.7 Complete

Quality:	Complete
Description:	The requirements should cover all cases and circumstances relevant to the system.
Bad Example:	• DSRC messages will be received by 100% of vehicles within 500 meters of the roadside unit. • DSRC messages will be received by 80% of vehicles between 750 and 1000 meters.
Good Example:	• DSRC messages will be received by 100% of vehicles within 500 meters of the roadside unit. • DSRC messages will be received by 90% of vehicles between 500 and 750 meters.

	• DSRC messages will be received by 80% of vehicles between 750 and 1000 meters.

2.1.8 Testable

Quality:	Testable
Description:	The requirement should have clear pass/fail criteria.
Bad Example:	Queue warning messages broadcasted by a vehicle should be received by most vehicles in the vicinity.
Good Example:	Queue warning messages broadcasted by a vehicle should be received by 90% of vehicles within 500 meters of the broadcasting vehicle.

At a minimum the requirements shall be included:

- **Functional Requirements:** Communications, security, safety requirements
- **Interface requirements:** Identification of relevant standards
- **Performance Requirements:** System Performance targets and performance requirements
- **Data Requirements:** data-sharing requirements

The requirements shall identify what the Pilot Deployment must accomplish; identify the subsystems; and define the functional and interface requirements among the subsystems.

Each performance measure and target identified in the ConOps in Task 2 should have a corresponding performance requirement. The role of each subsystem in supporting system-level performance requirements shall be identified, including associated subsystem functional, interface, data, and performance requirements. Further, the SyRS must be consistent with and support all essential elements of the Performance Measurement Plan (Task 5).

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. Below is a breakdown of how pilot deployers may wihs to operate when deriving a System Requirements.

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

2.2 Regional Architecture: CVRIA and SET-IT

One goal of the system engineering process is to clearly define all components and interfaces within the system. To facilitate this process USDOT has developed the Connected Vehicle Reference Implementation Architecture (CVRIA). CVRIA is a graphical language for describing ITS systems and applications. It defines multiple viewpoints, each of which captures a particular perspective which helps to define the system as a whole.

- Enterprise View: defines the relationships and roles of organizations involved in the system
- Functional View: defines the processes and data flows within the system, and the interactions between the processes
- Physical View: defines the physical objects and devices which are part of the system, and the interaction between the objects
- Communications View: defines the communications protocols used in the system

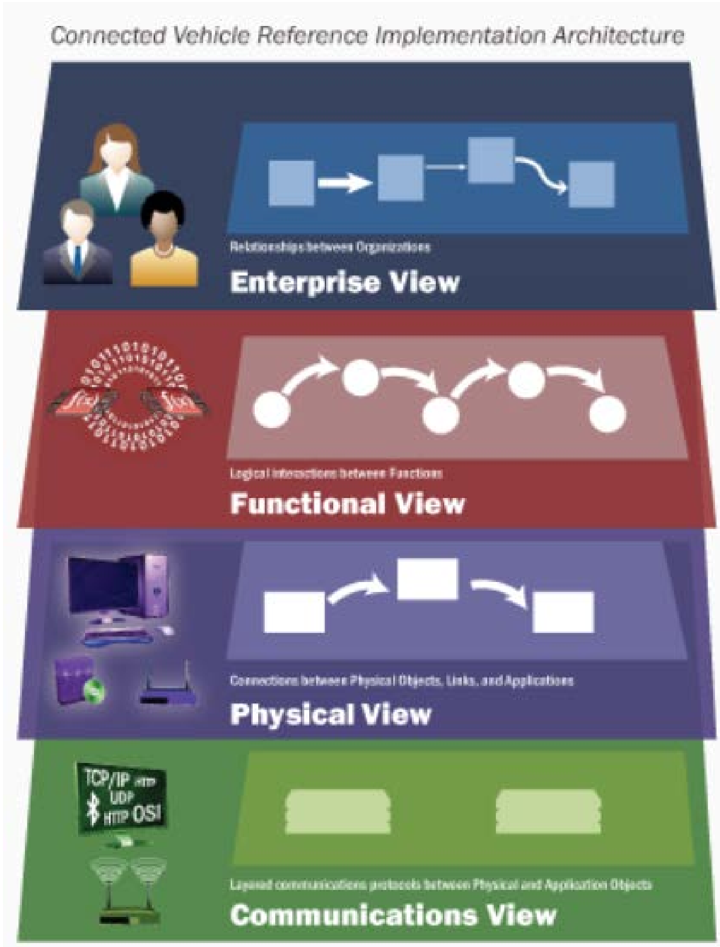

Figure 2-2: Connected Vehicle Reference Implementation Architecture (Source: Iteris)

Once an object, process or data flow is defined using CVRIA, then that definition can easily be reused in other system descriptions. This approach serves the needs of pilot projects in a couple of ways. Reusing existing component definitions makes the system design process more efficient, and encourages uniformity across applications. An important goal of the pilots is to take interoperability to the next level. True interoperability depends on more than formal standards. It depends on common usages, interpretations and patterns. CVRIA promotes this by supporting reuse during design and definition.

USDOT has also developed a tool to help prepare architecture descriptions within the CVRIA framework. The System Engineering Tool for Intelligent Transportation (SET-IT) is a software tool for authoring system definitions. It provides a graphical interface and access to a library of pre-defined applications. SET-IT simplifies the task of preparing standard documents, and promotes reuse of application definitions with its library. The tool can be downloaded from the SET-IT download page [4]. All system diagrams should be prepared with SET-IT.

Why is CVRIA important for the CV Pilots Concept Development Phase?

- CVRIA makes for more efficiency. It facilitates information sharing and libraries of components and subsystems can be reused.
- CVRIA views support the SE approach of holistic discovery
- **An important goal of the pilots is to take interoperability to the next level**. True interoperability depends on more than formal standards. It depends on common usages, interpretations and patterns. CVRIA promotes this by supporting reuse during design and definition

What is SET-IT and why is it important?

- It is a productivity tool for CVRIA.
- It simplifies creation, use and sharing of CVRIA artifacts.
- **It will help you prepare your deliverables.**

2.3 Key References

- *IEEE Guide for Developing System Requirements Specifications*, IEEE Standard 1233, 1998
- *IEEE Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document*, IEEE Standard 1362, 1998
- FHWA's Systems Engineering for Intelligent Transportation Systems http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf
- CVRIA website, http://www.iteris.com/cvria/, accessed 8/29/15
- *SET-IT Download Page, http://www.iteris.com/cvria/html/resources/tools.html, accessed 8/29/15*

3 Deliverables

This section describes each individual deliverable by task as explained in the CV Pilots Broad Agency Announcement. While the main deliverables dealing with systems engineering are included in Tasks 2 and 6, elements of system engineering may need to be developed for many other deliverables in a number of other tasks. Below are each of the tasks which could include privacy concerns. While the examples are not comprehensive, they should give a baseline for what may be considered privacy sensitive.

3.1 Deliverables

The following set of tables describes in sequence all deliverables for Task 6. The tables also show dependencies among deliverables. Formal deliverables are shown in bold with the task number prepended (e.g. **Task 6: Stakeholder Requirements**), and intermediate tasks or processes are shown without bold (e.g. Structured Stakeholder Interaction)

3.1.1 Task 6: Stakeholder System Requirements Review Panel Roster (Draft and Final)

Title:	**Task 6: Stakeholder System Requirements Review Panel Roster (Draft and Final)**
Depends On:	**Task 1: Stakeholder Registry**
Input To:	System Requirements Walkthrough
Description:	Identifies a subset of all stakeholders intended to participate in the System Requirements Walkthrough

3.1.2 Task 6: System Requirements Specification Document (Draft and Final)

Title:	**Task 6: System Requirements Specifications Document (Draft and Final)**
Depends On:	**Task 2: Concept of Operations (Final)** **Task 5: Performance Measurement Plan**
Input To:	System Requirements Walkthrough
Description:	The requirements shall identify what the Pilot Deployment must accomplish; identify the subsystems; and define the functional and interface requirements among the subsystems. Each performance measure and target identified in the ConOps in Task 2 should have a corresponding performance requirement. The role of each subsystem in supporting system-level performance requirements shall be identified, including associated subsystem functional, interface, data, and performance requirements.

3.1.3 Task 6: System Requirements Walkthrough Workbook

Title:	**Task 6: System Requirements Walkthrough Workbook**
Depends On:	**Task 2: Concept of Operations (Final)** **Task 5: Performance Measurement Plan** **Task 6: System Requirements Specification Document**
Input To:	Walkthrough Comment Resolution Report
Description:	The Contractor shall deliver a draft SyRS Report for COR review. The Contractor shall revise the draft report based on comments from COR. After revision based on COR comments, the Contractor shall schedule and conduct a SyRS Walkthrough ("walkthrough"– see IEEE Standard 1028) of the revised report. This SyRS Walkthrough will be conducted as an in-person meeting in Washington, DC in a USDOT-designated facility that supports a webinar function. The SyRS Review Panel members may participate in-person or via webinar, however, key Contractor team members associated with the SyRS must attend in person.

3.1.4 Task 6: Walkthrough Comment Resolution Report

Title:	**Task 6: Walkthrough Comment Resolution Report**
Depends On:	**Task 2: Concept of Operations (Final)** **Task 5: Performance Measurement Plan** **Task 6: System Requirements Specification Document**
Input To:	
Description:	The Contractor shall also provide a walkthrough comment resolution report containing a description of the resolution of all comments received. The Contractor shall revise the report based on comments received at the walkthrough, and provide a final version. The COR must accept and approve all comment resolutions before the revised report is considered final.

4 Key Challenges

There are many key challenges to the Systems Engineering and System Requirements documentation deliverables. This section will give some examples of general key challenges that are foreseen in the process.

4.1 Stakeholder Input

It is important to find a representative sample of the stakeholders that will eventually use the system that is being designed. By doing this, the Concept of Operations can build on the problem statements and needs that are being derived for the system as a whole, and not just a subset of the transportation system. Start the stakeholder involvement as early as possible and use their feedback to build the System Requirements. Ask the question: what do stakeholders truly want the system to do?

4.2 Measurement

It can be difficult to measure the System Requirements. For instance, how will the System Engineer know when the project is failing or succeeding? The specifications for the requirements of the system need to be built with specific goals in sight. It is best to have expertise in system engineering on the deployment team get involved early in the process. By writing the measurement requirements into the System requirements, it is easier to get feedback on the deployment progress/success.

4.3 System Interfaces

How will different systems communicate with one another? By using the CVRIA and SET-IT tools, a graphical representation of the interaction between subsytems can be made.

4.4 Testing

Testing of the system should be incorporated into plans as early on as possible. This way any problems can be rectified before they become major. Build in a testing schedule with specific times and systems to stay on track.

5 Technical Support Summary

The USDOT held a week-long CVRIA and SET-IT bootcamp in October 2015.

Additionally, a web-based training course that provides an introduction to the CVRIA can be found at http://www.iteris.com/cvria/html/resources/cvriatraining.html. The purpose of this training is to acquaint public and private sector professionals with the background, structure, website, and use of the CVRIA. The course includes narration from the National ITS Architecture team.

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Appendix: List of Acronyms

Table A-1: List of Acronyms

Acronym	Meaning
CV	Connected Vehicles
CVRIA	Connected Vehicle Reference Implementation Architecture
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transportation Systems
PBI	Product Backlog Item
SE	Systems Engineering
SET-IT	Systems Engineering Tool for Intelligent Transportation

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