USDOT Guidance Summary for Connected Vehicle Deployments

Concept of Operations and the CVRIA/SET-IT Tool

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16. Abstract

This document provides guidance material in regards to the Concept of Operations for the CV Pilots Deployment Concept Development Phase. Methods for system engineering are discussed in depth 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 Task 2- Pilot Deployment Concept of Operations. Major challenges are identified and how they can be overcome. The document concludes 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 2 and describes the systems engineering principles which should be used to produce deliverables for this task, specifically in relation to Concept of Operation.

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 relevant technical support.

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".

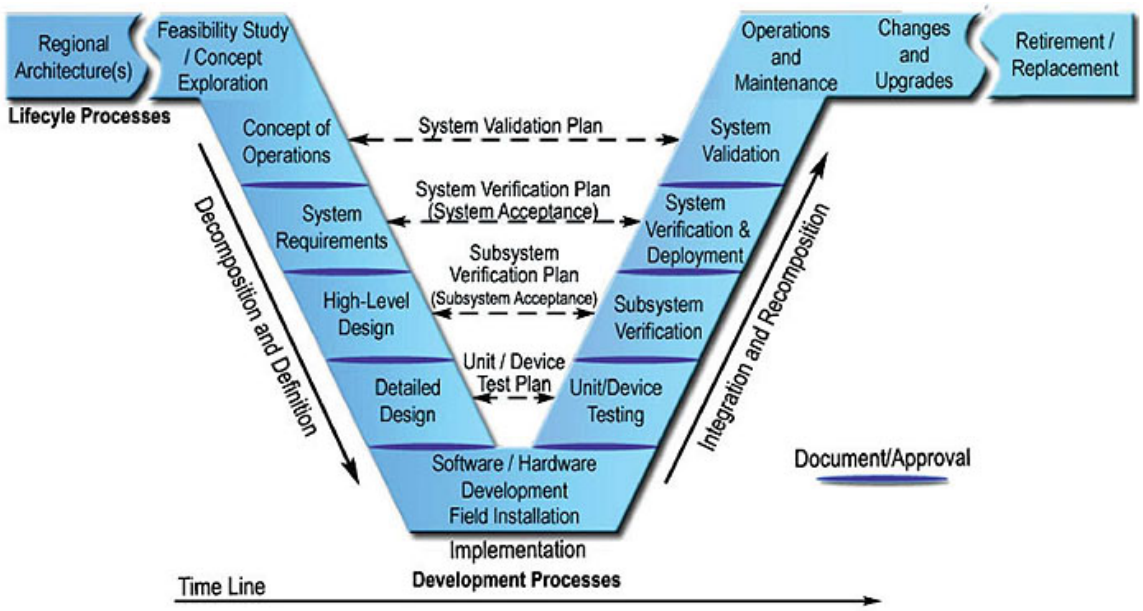

Figure 2-1: System's Engineering V Diagram (Source: USDOT)

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 Operation (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 Feasibility Study / Concept Exploration

A business case is made for the project. Technical, economic, and political feasibility is assessed; benefits and costs are estimated; and key risks are identified. Alternative concepts for meeting the project's purpose and need are explored, and the superior concept is selected and justified using trade study techniques.

OBJECTIVES

- Identify superior, cost-effective concept, and document alternative concepts with rationale for selection
- Verify project feasibility and identify preliminary risks
- Garner management buy-in and necessary approvals for the project

INPUT

Sources of Information

- Project goals and objectives
- Project purpose and need
- Project scope/subset of the regional ITS architecture

PROCESS

Key Activities

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

OUTPUT

Process Results

Feasibility study that identifies alternative concepts and makes the business case for the project and the selected concept

REVIEW

Proceed only if you have:

Received approval on the feasibility study from project management, executive management, and controlling authorities, as required

Reached consensus on the selected alternative.

2.1.2 Concept of Operations

What is a ConOps? It is a user oriented document that describes at a high level what the system will accomplish. It is not a technical document. Any stakeholder should be able to read this document and come away with an understanding of what the system will accomplish.

Why is a ConOps important in general? The ConOps establishes and documents a consensus among all stakeholders regarding the new system. Often the process of creating a ConOps is more important than the document itself. It forces stakeholders to engage with each other, understand each other and reach common understandings.

Why is a ConOps important during the Concept Development Phase of the Pilots?

- These are brand new systems which may perform functions which did not previously exist. People, organizations and systems may have entirely new interactions as a result of the pilot. A thorough process is necessary to discover as much as possible about these impacts.
- The pilots are not pure research. They have to work in the real world beyond the timeframe of the pilot program. Issues of training, maintenance, sustainability etc. need to be addressed
- **The user needs and operational scenarios are critical for capturing what the system will do**. Performance measures for those needs are explicitly required in RFP.

The BAA states that (see Page 8 in [1]):

"Structured Stakeholder Interaction. Using the Stakeholder Registry developed in Task 1, the Contractor shall conduct a structured stakeholder interaction to gain insight on draft needs, performance measures (and targets), and descriptions of altered operational practice. These methods of interaction may include but are not limited to surveys, interviews, webinars, and in-person meetings. A ConOps Stakeholder Review Panel shall be identified, drawing on the Stakeholder Registry developed in Task 1. The Stakeholder Review Panel is a subset of all stakeholders intended to participate in the ConOps Walkthrough (see below). The Contractor shall deliver a draft Stakeholder Review Panel Roster for COR review."

The Pilot sites shall necessarily focus on combinations of applications that result in improved measureable system performance in one, or preferably more, of the following high level categorical areas:

- Safety
- Mobility
- Environment
- Public Agency Efficiency

Context Diagram. The ConOps shall include a schematic context diagram illustrating a high-level physical description of the proposed system. The context diagram shows the set of physical objects expected in the deployed pilot deployment system. The context diagram shows high-level data exchanges expected among system objects. Text supporting the diagram shall detail all assumptions made and catalog any/all uncertainties in these assumptions.

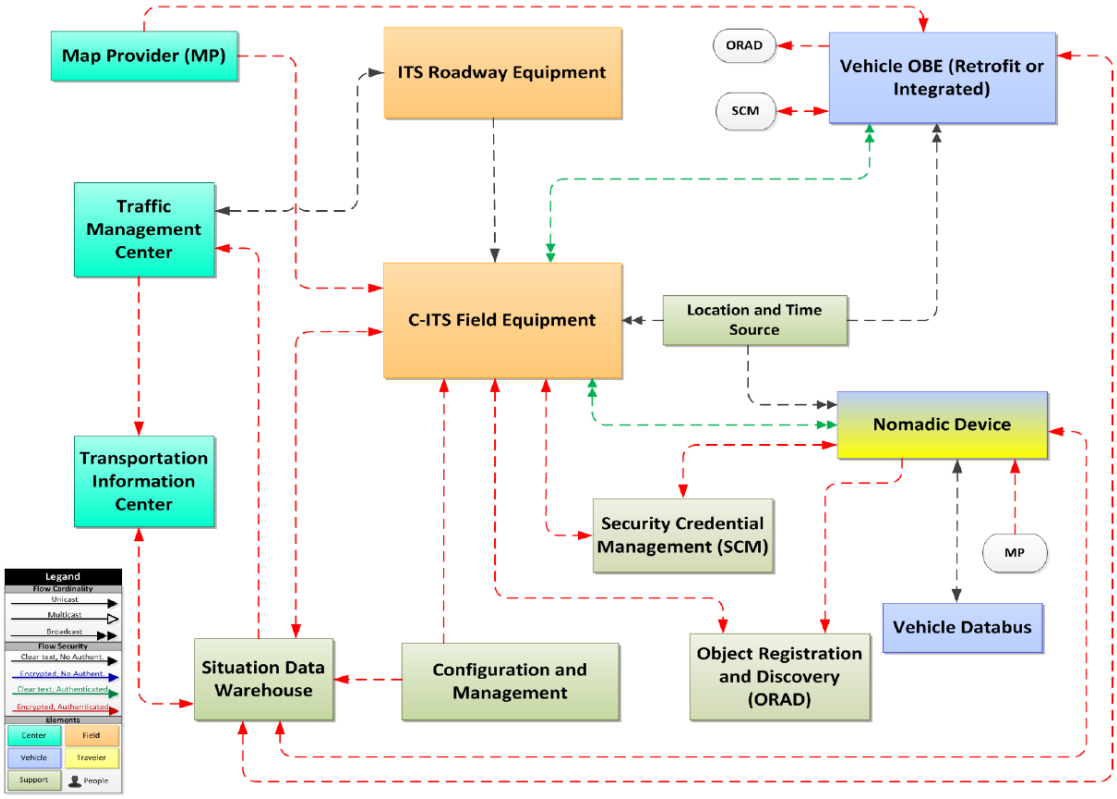

Figure 2-2: Example Context Diagram for ConOps (Source: USDOT)

How might a CV pilot ConOps diverge from a more typical ConOps? The standard devotes a lot of attention to the 'system being replaced'. In most cases, there will not be such a system. The document should focus on what functions are being replaced by the new system. (See Enhancements to Operational Practice in RFP).

Reference: http://www.fhwa.dot.gov/cadiv/segb/views/document/sections/section8/8_4_5.cfm
Concept of operations template.

Enhancements to Operational Practice. The ConOps shall describe proposed operational practice ("with Pilot Deployment") and current operational practices ("no Pilot Deployment") for benchmarking system performance. The ConOps shall identify a set of proposed applications to deploy as a part of a deployed system supporting the proposed enhanced operational practice. The ConOps shall identify and detail the specific use cases relevant to the proposed Pilot Deployment concept, specifically in the use cases where applications associated with the Pilot Deployment are expected to have the most impact in achieving target performance goals. Key factors that could confound performance measurement shall be identified and a high-level mitigation approach outlined for each confounding

factor. The ConOps shall also include a set of quantitative performance targets associated with each performance measure (e.g., within the Operational Impacts portion of the ConOps).

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

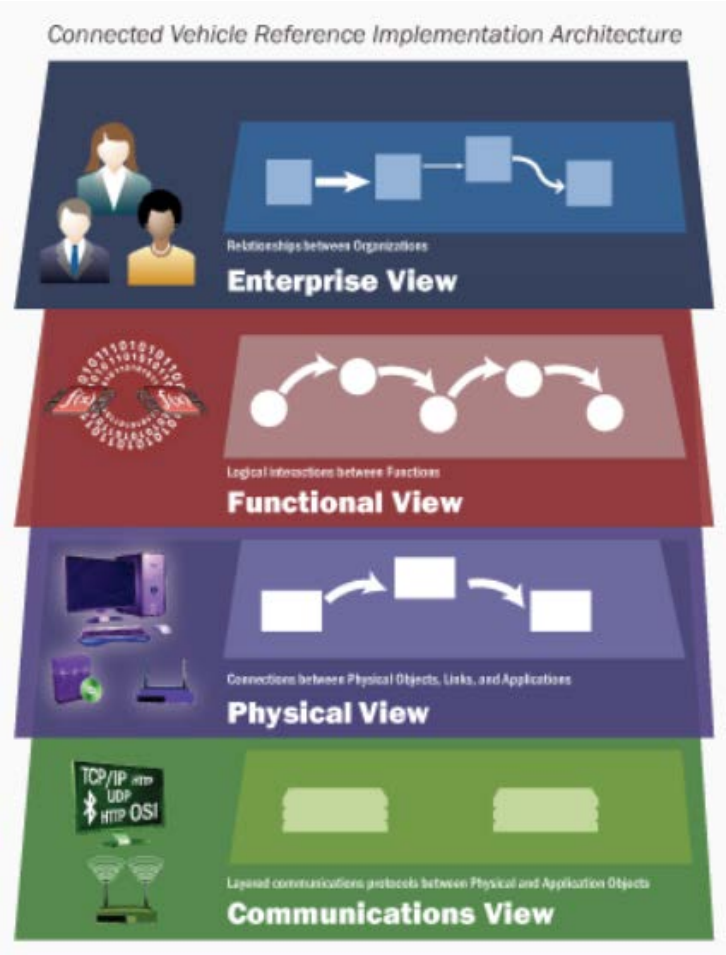

Figure 2-3: Connected Vehicle Reference Implementation Architecture (Source: Iteris)

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 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 the deliverables that are directly related to Concept of Operations and System Requirements.

3.1 Deliverables

The following set of tables describes in sequence all deliverables for Tasks 2 and 6. The tables also show dependencies among deliverables. Formal deliverables are shown in bold with the task number prepended (e.g. Task 2: Needs Summary), and intermediate tasks or processes are shown without bold (e.g. Structured Stakeholder Interaction)

3.1.1 Task 2: Stakeholder ConOps Review Panel Roster (Draft and Final)

Title:	Stakeholder ConOps Review Panel Roster
Depends On:	**Task 1: Stakeholder Registry**
Input To:	Structured Stakeholder Interaction
Description:	The stakeholder review panel is a subset of the stakeholder registry developed in Task 1. It will be used to develop the plan for structured stakeholder interaction. Thorough stakeholder engagement is crucial for developing a valuable ConOps. Engagement can take many forms including surveys, interviews, webinars and in-person meetings.

3.1.2 Task 2: Structured Stakeholder Interaction

Title:	Structured Stakeholder Interaction
Depends On:	**Task 2: Stakeholder ConOps Review Panel Roster (Final)**
Input To:	**Task 2: Needs Summary**
Description:	Stakeholder interaction is the primary way to discover user needs and impacts. This is the most vital input to the entire ConOps process. If all stakeholders are not engaged early in the process then the results cannot cover their needs. Engagement can happen in many ways including: surveys, interviews (remote or onsite), meetings, etc. Engagement is a two way process. The ConOps authors need to learn stakeholder needs, but also need to communicate the vision for the system back to stakeholders as it evolves. All stakeholders should be included in the engagement process in some way.

3.1.3 Task 2: Needs Summary

Title:	Task 2: Needs Summary
Depends On:	**Structured Stakeholder Interaction**
Input To:	**Task 2: Concept of Operations (Draft)**
Description:	A clear statement of stakeholder needs is one of the most important outcomes of the ConOps process. Reviewing the needs summary independently provides an extra opportunity to verify this critical part of the ConOps. A needs summary is not as formal as requirements, but it should have some of the characteristics of good requirements: • Tangible – needs should be expressed in terms of real information, actions, events and processes relevant to the user • Necessary – needs may have varying levels of importance, but all should be indispensable relative to some user task or function • Consistent – there should not be any contradictions between two or more user needs. If there is an inherent tradeoff between two conflicting user needs then the summary should describe how those conflicting needs are balanced. • Accurate – the summary should correctly describe user needs • Complete – the summary should cover all user needs which will be addressed or impacted by the system The COR will also provide input on any expected additional needs supporting a broader independent evaluation effort that will run concurrently with the Design/Deploy/Test Phase and the Maintain/Operate Phase of the Pilot Deployment. The Contractor shall finalize the needs summary based on the COR's comments.

3.1.4 Task 2: Concept of Operations (Draft)

Title:	Task 2: Concept of Operations (Draft)
Depends On:	• Structured Stakeholder Interaction • **Task 2: Needs Summary**
Input To:	• **Task 2: Concept of Operations Walkthrough Briefing Deck** • **Task 2: Concept of Operations Comment Resolution Report (Draft)**
Description:	See section 4.1 of the ConOps IEE Guide [4] for a general description of a ConOps. The ConOps standard (IEEE1362-1998) refers to a new system and an old system that is being replaced. In most cases the pilot projects will not be a direct replacement of an existing system. In those cases the ConOps should focus on the functions that are being replaced by the new system. In addition to the usual sections described in the standard (IEEE 1362-1998), the ConOps should include the following: • The "Justification for and nature of changes" section (section 4.1 in 1362-1998) should include a quantitative description of performance improvements achieved by the new system. • The sections describing the old system (section 3.3 in 1362-1998) and the new system (section 5.3 in 1362-1998) should both address operational practices and how they differ between the new and old system. • The ConOps should include the Physical and Enterprise schematics for the new system as generated by the SET-IT system. • The contents of the needs summary should be further refined and included in the ConOps.

3.1.5 Task 2: Concept of Operations Comment Resolution Report (Draft)

Title:	Task 2: Concept of Operations Comment Resolution Report (Draft)
Depends On:	• **Task 2: Concept of Operations (Draft)** • COR review of ConOps draft
Input To:	**Task 2: Concept of Operations Comment Resolution Report (Final)**
Description:	The draft comment resolution report is based on COR review of the initial draft. Each entry in the report should contain information on the comment, its context, source and resolution.

3.1.6 Task 2: Concept of Operations Walkthrough Briefing Deck

Title:	Task 2: Concept of Operations Walkthrough Briefing Deck
Depends On:	• **Task 2: Concept of Operations (Draft)** • COR review of ConOps draft
Input To:	Concept of Operations Walkthrough
Description:	This presentation will be used to organize a ConOps walkthrough for COR and key stakeholders.

3.1.7 Task 2: Concept of Operations Walkthrough

Title:	Concept of Operations Walkthrough
Depends On:	• **Task 2: Concept of Operations (Draft)** • COR review of ConOps draft • T**ask 2: Concept of Operations Walkthrough Briefing Deck**
Input To:	• **Task 2: Concept of Operations (Final)** • **Task 2: Concept of Operations Comment Resolution Report (Final)**
Description:	Further review comments will be collected from COR and key stakeholders during the walkthrough.

3.1.8 Task 2: Concept of Operations Comment Resolution Report (Final)

Title:	Task 2: Concept of Operations Comment Resolution Report (Final)
Depends On:	• **Task 2: Concept of Operations (Draft)** • COR review of ConOps draft • T**ask 2: Concept of Operations Walkthrough**
Input To:	• **Task 2: Concept of Operations (Final)**
Description:	This is the complete report of all comments from any stage in the process and their resolution.

3.1.9 Task 2: Concept of Operations (Final)

Title:	Task 2: Concept of Operations (Final)
Depends On:	• **Task 2: Concept of Operations (Draft)** • COR review of ConOps draft • T**ask 2: Concept of Operations Walkthrough**
Input To:	• **Task 2: ConOps Webinar** • **Task 6: System Requirements Specification (SysRS) Document (Draft)**
Description:	This is the final Concept of Operations document.

3.1.10 Task 2: ConOps Webinar

Title:	Task 2: ConOps Webinar
Depends On:	**Task 2: Concept of Operations (Final)**
Input To:	-
Description:	This presentation for selected stakeholders completes the ConOps process, and continues the overall stakeholder engagement process by communicating the refined vision of the system.

4 Key Challenges

There are many Key challenges to the Systems Engineering and Concepts of Operations documentation deliverables. Many of these key challenges are directly related to the individual Connected Vehicle Pilots deployment that are being planned. 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.

4.2 System Engineer

Having a system engineer on board early in the process can bring much expertise to the project and can build on the needs of stakeholders to truly drive effective operations. While this is not a prerequisite for a successful deployment, it will help ensure that the true value of systems engineering will be reached.

4.3 What does the system do?

Ask the question: what do stakeholders truly want the system to do? This is the most important part of the Concept of Operations. By asking this question, you can take the stakeholders needs and build a system for accommodating those needs with actions. By building your ConOps in this process, it becomes easier to understand what the end performance of the system can accomplish.

5 Technical Support Summary

Each Connected Vehicle Pilot Deployment will include different technologies and strategies with their own challenges regarding systems engineering deliverables. This section gives guidance on the opportunities to get continued technical support along the process of delivering Concept Development Phase materials.

5.1 Technical Support Opportunities

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.

References

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2. *IEEE Guide for Developing System Requirements Specifications*, IEEE Standard 1233, 1998, 10.1109/IEEESTD.1998.88826

3. *IEEE Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document*, IEEE Standard 1362, 1998, 10.1109/IEEESTD.1998.89424

4. North Dakota Department of Transportation Overview of Systems Engineering Process. http://www.dot.nd.gov/divisions/maintenance/docs/OverviewOfSEA.pdf

5. FHWA's Systems Engineering for Intelligent Transportation Systems http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf

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7. CVRIA website, http://www.iteris.com/cvria/, accessed 8/29/15

Appendix: List of Acronyms

Table A-1: List of Acronyms

Acronym	Meaning
BAA	Broad Agency Annoucement
ConOps	Concept of Operations
CV	Connected Vehicles
CVRIA	Connected Vehicle Reference Implementation Architecture
ITS	Intelligent Transportation Systems
PBI	Product Backlog Item
SE	Systems Engineering
SET-IT	Systems Engineering Tool for Intelligent Transportation

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