VEHICLE INFRASTRUCTURE INTEGRATION (VII)

SIGNAL TIMING OPTIMIZATION POC APPLICATION REQUIREMENTS

Research and Innovative Technology Administration

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VERSION 1.2

Booz | Allen | Hamilton

REVISION HISTORY

Date	Version	Description
March 1, 2007	1.0	Draft for Review
March 26, 2007	1.1	Revised per Comments and SRR
April 11, 2007	1.2	Revised per additional comments

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1 Introduction

Traffic engineers modify signal timings to provide the highest possible level of service on arterial and surface streets. Modifications rely on extensive collection of traffic data to characterize signal performance. VII offers the possibility of expanding the breadth of data collected, and reducing the difficulty and cost in obtaining information.

The Signal Timing Optimization application is geared toward proving the viability of using VII to support enhanced signal timing applications in the future. The POC efforts concentrate on determining what traffic measures with potential applicability to signal timing can reliably be determined from VII probe data.

2 Requirements Guide

2.1 Precedence and Criticality of Requirements

The following terms are used to qualify the requirements (shall), expectations (should) and assumptions (will) contained in this document and are based on RFC 2119.

WORD	MEANING
SHALL	This word means that the definition is an absolute requirement of the application.
SHOULD	This word means that valid reasons may exist for not meeting the specific expectation, but the full implications of this must be understood carefully.
WILL	This word indicates functionality that the operational environment surrounding the application is to provide.

2.2 Requirements Identification

All articles in this document will be categorized as follows:

- Assumption – assumption about the operation of entities external to the application.
- Constraint – constraint specifies behaviors or characteristics levied on the application by external entities.
- Functional Requirements – functional requirements specify actionable behaviors of the application.
- Performance Requirements – performance requirements specify quantifiable characteristics of application operations.
- Security Requirements – security requirements specify mechanisms to prevent the application from compromising connected resources.
- Performance Expectations – end-to-end performance expected for each application.
- External Interface Requirements– external interface requirements define application interfaces with VII and non-VII Systems.

All articles in this document are identified by a tag of the form: **ST-Category-Number.** The definitions for the tags are listed below:

"S" stands for **Scope**, single character in the 1st position with the following value list

"A" for Application
"V" for VII System
"X" for External Entity

"T" stands for **Type**, a single character in the 2nd position with the following value list

"A"	for "Assumptions"
"C"	for "Constraint"
"F"	for "Functional Requirement"
"S"	for "Security Requirement"
"P"	for "Performance Requirement"
"X"	for "External" Application Interface
"N"	for "End-to-End Performance Expectation"

Category is a variable length text string, usually a defined VII acronym, which will identify a group of requirements.

"TI"	for Traveler Information
"WI"	for Weather Information
"CMLB"	for Corridor Management Load Balancing
"CMPA"	for Corridor Management Planning Assistance
"STO"	for Signal Timing Optimization
"RM"	for Ramp Metering
"PD"	for Pothole Detection

Number is a two digit numerical value which identifies the specific requirement. Child requirements are numbered using a hierarchical decimal system of numerical values.

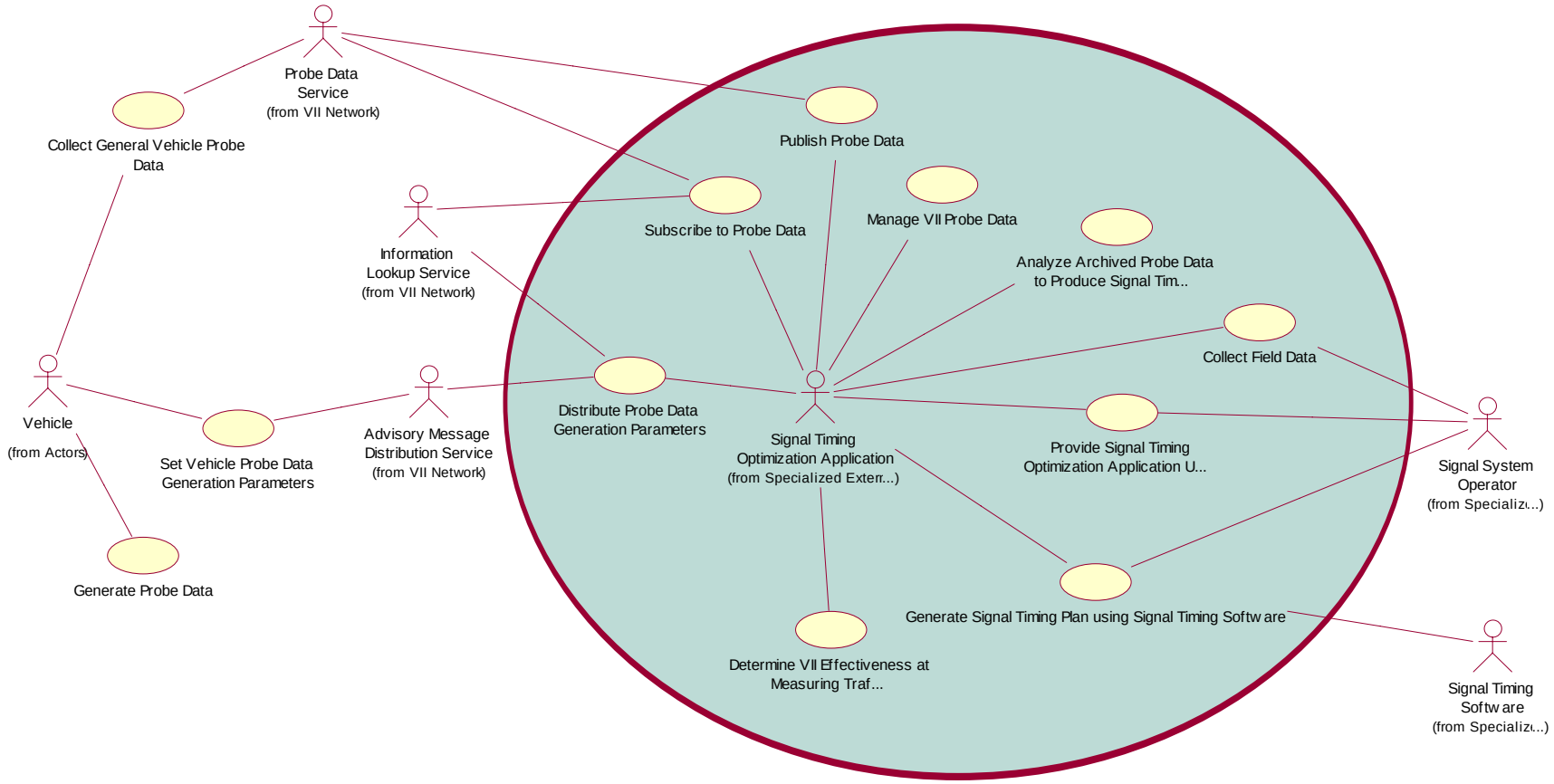
2.3 Requirements Relationship

The requirements have been developed as "parent-child" requirements and should be tested as such. In other words, verification of all "child" requirements automatically implies verification of their "parent" requirement.

3 Application Boundary Definition

The following POC use case diagram identifies the actors and basic functions involved in implementing the Signal Timing Optimization Application. This diagram was taken from the VII POC Applications Concept of Operations document version 1.4[1]. The shaded portion of the diagram represents the boundary of the Signal Timing Optimization Application for POC.

Figure 3.1 – POC Signal Timing Optimization Application Use Case Diagram



[1] This is the most recent version of the Signal Timing Optimization POC Use Case diagram. Version 1.4 of the VII Applications Concept of Operations will eventually be updated with this edition of the diagram. The changes included in this diagram are critical to the writing of the functional requirements for the Signal Timing Optimization application, as they better identify the role of the Signal Systems Operator than the officially published version.

The following table maps the actors in the use case to the VII System Architecture, as defined within the VII National System Requirements v1.2.1.

Table 3.1 – POC Signal Timing Optimization Application Actors

Actor	System Boundary
Vehicle	Vehicle
Probe Data Service	VII System
Information Lookup Service	VII System
Advisory Message Distribution Service	VII System
Signal Timing Optimization Application	Network User
Signal Systems Operator	Network User External Entity
Signal Timing Software	Network User External Entity

As shown in the above table, the Signal Timing Optimization Application "lives" on the Network User side, outside of the VII System. However, in order for the application to function as intended, it requires all the other actors identified in the use case to perform appropriate actions.

The requirements in the following sections are developed around the basic functions identified within the shaded portion of the use case diagram. The actors in the use case diagram are used as "nouns" to describe the requirements. These requirements are levied on the POC implementation only, and may or may not apply to the Day-1 Signal Timing Optimization Application.

4 Assumptions and Constraints

4.1 Assumptions

Identifier	VII System Assumptions
VA-STO-01	The Vehicle will generate probe data snapshots in accordance with SAE J2735 version 15 and the POC Additions and Exceptions to J2735 (APP190-02).
VA-STO-01.1	All probe data snapshots generated by the Vehicle will include latitude and longitude of the vehicle location.
VA-STO-01.2	All probe data snapshots generated by the Vehicle will include elevation of the vehicle location.
VA-STO-01.3	All probe data snapshots generated by the Vehicle will include time (hour, minute and seconds) that the snapshot was generated.
VA-STO-01.4	All probe data snapshots generated by the Vehicle will include date (month, day, year) that the snapshot was generated.
VA-STO-01.5	All probe data snapshots generated by the Vehicle will include vehicle heading.
VA-STO-01.6	All probe data snapshots generated by the Vehicle will include vehicle brake application status.
VA-STO-01.7	All probe data snapshots generated by the Vehicle will include vehicle speed.
VA-STO-01.8	All probe data snapshots generated by the Vehicle will include vehicle wiper status.
VA-STO-01.9	All probe data snapshots generated by the Vehicle will include the probe segment number.
VA-STO-01.10	The Vehicle's probe snapshot generation parameters will be configurable within the vehicle.
VA-STO-02	The Vehicle will buffer probe data snapshots in accordance with SAE J2735 version 15 and the POC Additions and Exceptions to J2735 (APP190-02).
VA-STO-02.1	The Vehicle's probe snapshot buffering parameters will be configurable within the vehicle.
VA-STO-03	The Vehicle will provide probe data snapshots to the Probe Data Service, when available, as part of Probe Data Messages in accordance with the process outlined in SAE J2735 version 15 and the POC Additions and Exceptions to J2735 (APP190-02).
VA-STO-04	The Vehicle will log information related to probe data generation and Probe Data Service interactions.
VA-STO-04.1	The Vehicle will log all probe data snapshots generated within the previous 24-hour period.
VA-STO-04.1.1	For each snapshot logged by the Vehicle, the snapshot type (periodic, start, stop, or event including the event trigger) will be recorded.
VA-STO-04.1.2	For each snapshot logged by the Vehicle, the time and type of buffer state changes will be recorded.

Identifier	VII System Assumptions
VA-STO-04.1.3	For each snapshot logged by the Vehicle, the probe data management scheme at time of each snapshot generation will be recorded.
VA-STO-04.1.4	Each snapshot logged by the Vehicle will be uniquely identifiable.
VA-STO-04.2	The Vehicle will log all of the locations and times at which the probe segment number changes.
VA-STO-04.3	The Vehicle will log the location and times at which the snapshot buffer overflows.
VA-STO-04.4	The Vehicle will log the times at which the vehicle location information is not available.
VA-STO-04.5	The Vehicle will log the location and times at which the vehicle operational data used for probe data generation is not available.
VA-STO-04.6	The Vehicle will log probe messages provided to the Probe Data Service within the previous 24-hour period.
VA-STO-04.6.1	For each message logged, the Vehicle will record information necessary to identify the specific probe snapshots included in each message.
VA-STO-04.6.2	For each message logged, the Vehicle will record the location and time of transmission of the message to the Probe Data Service.
VA-STO-04.6.3	For each message logged, the Vehicle will record information necessary to identify which RSE the message was transmitted to.
VA-STO-04.6.4	For each message logged, the Vehicle will record the probe data management scheme at the time the message was transmitted to the Probe Data Service.
VA-STO-05	The Probe Data Service will accept a subscription from the Signal Timing Optimization Application as specified in Network User to Service Delivery Node (SDN) Subsystem Software Interface Requirements Specification - Version 1.1 (or latest), using the X-031 interface.
VA-STO-06	The Probe Data Service will attempt to deliver all Probe Data Snapshots received from Vehicles to the Signal Timing Optimization Application, if the snapshot parameters meet the Signal Timing Optimization Application's probe data subscription profile.
VA-STO-07	The Advisory Message Distribution Service will accept advisory message delivery requests from the Signal Timing Optimization Application as specified in Network User to Service Delivery Node (SDN) Subsystem Software Interface Requirements Specification - Version 1.1 (or latest), using the X-032 interface.
VA-STO-08	The Advisory Message Distribution Service will forward the Signal Timing Optimization Application-provided advisory messages to vehicles, as specified in SDN to RSE Subsystem Software Interface Requirements Specification - Version 1.1 (or latest) and RSE to OBE Subsystem Software Interface Requirements Specification.
VA-STO-09	The Vehicle will set its probe snapshot generation parameters to the values specified in a Probe Generation Message as defined in the POC Additions and Exceptions to J2735 (APP190-02) upon receipt of a Probe Generation Message.

Identifier	VII System Assumptions
VA-STO-10	The Vehicle shall reset its probe snapshot generation parameters to the values as defined in the POC Additions and Exceptions to J2735 (APP190-02).
VA-STO-11	The Information Lookup Service will respond to a request from the Signal Timing Optimization Application with the information necessary for the Signal Timing Optimization Application to subscribe to probe data within a specified geographic boundary.
VA-STO-12	The Information Lookup Service will respond to a request from the Signal Timing Optimization Application with the information necessary for the Signal Timing Optimization Application to deliver an advisory message within a specified geographic boundary.
VA-STO-13	The Information Lookup Service will respond to a request from the Signal Timing Optimization Application with the information necessary for the Signal Timing Optimization Application to submit advisory messages within a specified geographic boundary.

Identifier	Non-VII External Entity Assumptions
XA-STO-01	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for calculating vehicle volumes using probe data.
XA-STO-02	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for determining vehicle time and position trajectories through an intersection using probe data.
XA-STO-03	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for calculating queue length using probe data.
XA-STO-04	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for the start time of queue overflow events using probe data.
XA-STO-05	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for calculating the duration of queue overflow events using probe data.
XA-STO-06	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for calculating upstream travel time from a signalized intersection using probe data.
XA-STO-07	Noblis, as part of USDOT's "VII Data Characteristics for Traffic Management" study, will provide algorithms for calculating turning movement counts using probe data.

Identifier	Non-VII External Entity Assumptions
XA-STO-08	The Signal System Operator will collect field data on a per-intersection basis within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.1	The Signal System Operator will determine and record average queue length per lane over 5-minute periods within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.2	The Signal System Operator will determine and record number of stops per lane over 5-minute periods within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.3	The Signal System Operator will determine and record average stop delay per lane over 5-minute periods within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.4	The Signal System Operator will determine and record the time of any phase/cycle failures within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.5	The Signal System Operator will determine and record time and position vehicle trajectories (turning movements) of all vehicles passing through the intersections within the geographic extent of the Signal Timing Optimization Application
XA-STO-08.6	The Signal System Operator will determine and record the duration of queue overflow events within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.7	The Signal System Operator will determine and record the start time of queue overflow events within the geographic extent of the Signal Timing Optimization Application
XA-STO-08.8	The Signal System Operator will determine and record upstream travel time within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.9	The Signal System Operator will determine and record turning movements of all vehicles passing through the intersection within the geographic extent of the Signal Timing Optimization Application.
XA-STO-08.10	The Signal System Operator will determine and record the signal timing plan in use during data collection.
XA-STO-08.11	The Signal System Operator will record the labor hours and total cost required to collect field data.
XA-STO-09	The Signal Systems Operator will use the Signal Timing Software to generate a signal timing plan based on the output of the Signal Timing Optimization Application.
XA-STO-10.1	The Signal Systems Operator will provide the Signal Timing Software the inputs generated by the Signal Timing Optimization Application from probe data.
XA-STO-10.2	The Signal Systems Operator will configure the Signal Timing Software to generate a signal timing plan for the intersections within the geographic extent of the Signal Timing Optimization.
XA-STO-10.3	The Signal Timing Software will compute a signal timing plan from the Signal Timing Optimization Application probe data-based signal timing inputs.
XA-STO-11	The Signal Systems Operator will use the Signal Timing Software

Identifier	Non-VII External Entity Assumptions
	to generate a signal timing plan based on field-collected data.
XA-STO-11.1	The Signal Systems Operator will provide the Signal Timing Software the inputs based on field collected data.
XA-STO-11.2	The Signal Systems Operator will configure the Signal Timing Software to generate a signal timing plan for the intersection for which the signal timing inputs were collected.
XA-STO-11.3	The Signal Timing Software will compute a signal timing plan from the field-based signal timing inputs.
XA-STO-12	The Signal System Operator will compare the signal timing plans generated with probe data with the signal timing plans generated with field collected data to determine the relative accuracy.
XA-STO-13	The Signal System Operator will compare the costs of obtaining the measures needed to generate a signal timing plan from field-collected data versus the costs needed to generate a signal timing plan using probe data.
XA-STO-14	The Signal Systems Operator will provide field collected measures of signal system performance to the Signal Timing Optimization Application.
XA-STO-15	The signal systems within the geographic extent of the Signal Timing Optimization Application will operate on a fixed signal timing plan during operation of the Signal Timing Optimization Application.

4.2 Constraints

Identifier	Constraints
AC-STO-01	The geographic extent of the Signal Timing Optimization Application is limited to three (3) signalized intersections within the Detroit VII Development and Test Environment.

5 Functional Requirements

5.1 Subscribe to Probe Data

Identifier	Functional Requirements
AF-STO-01	The Signal Timing Optimization Application shall subscribe to probe data from the Probe Data Service.
AF-STO-01.1	The Signal Timing Optimization Application shall have the ability to obtain information about the availability of Probe Data Service.
AF-STO-01.1.1	The Signal Timing Optimization Application shall send a Probe Data Service availability lookup request to the Information Lookup Service, when directed by the Signal System Operator.
AF-STO-01.1.2	The Signal Timing Optimization Application shall receive information from the Information Lookup Service about the availability of the Probe Data Service.
AF-STO-01.2	The Signal Timing Optimization Application shall include a probe data subscription profile.
AF-STO-01.2.1	The Signal Timing Optimization Application's probe data subscription profile shall include a geographic boundary defined by the Signal System Operator.
AF-STO-01.2.2	The Signal Timing Optimization Application's probe data subscription profile shall include a start time (month, day, year, hour, and minute) of the subscription defined by the Signal System Operator.
AF-STO-01.2.3	The Signal Timing Optimization Application's probe data subscription profile shall include an end time (month, day, year, hour, and minute) of the subscription defined by the Signal System Operator.
AF-STO-01.2.4	The Signal Timing Optimization Application's probe data subscription profile shall include probe data elements defined by the Signal System Operator.
AF-STO-01.3	The Signal Timing Optimization Application shall update the probe data subscription profile when directed by the Signal System Operator.
AF-STO-01.4	The Signal Timing Optimization Application shall send a subscription request based on the subscription profile to the Probe Data Service, when directed by the Signal System Operator.
AF-STO-01.5	The Signal Timing Optimization Application shall cancel a subscription to the Probe Data Service when directed by the Signal System Operator.

5.2 Publish Probe Data

Identifier	Functional Requirements
AF-STO-02	The Signal Timing Optimization Application shall receive probe data snapshots from the Probe Data Service.

5.3 Manage VII Probe Data

Identifier	Functional Requirements
AF-STO-03	The Signal Timing Optimization Application shall manage probe data snapshots received from the Probe Data Service.
AF-STO-03.1	The Signal Timing Optimization Application shall store all probe data snapshots received from the Probe Data Service.
AF-STO-03.1.1	The Signal Timing Optimization Application shall store all probe data snapshots received from the Probe Data Service in received form.
AF-STO-03.1.2	The Signal Timing Optimization Application shall store the time the snapshot was received by the Signal Timing Optimization Application for all probe data snapshots received from the Probe Data Service.
AF-STO-03.1.3	The Signal Timing Optimization Application shall have a mechanism to access stored probe data snapshots based on the value of any parameter included within the snapshots.
AF-STO-03.2	The Signal Timing Optimization Application shall verify the contents of probe data snapshots received from the Probe Data Service .
AF-STO-03.2.1	The Signal Timing Optimization Application shall verify that the contents of probe data snapshots received from the Probe Data Service match with the corresponding subscription requests.
AF-STO-03.2.2	The Signal Timing Optimization Application shall store the result of the verification for all probe data snapshots.

5.4 Analyze Archived Probe Data to Produce Signal Timing Software Inputs

Identifier	Functional Requirements
AF-STO-04	The Signal Timing Optimization Application shall analyze probe data to calculate the inputs to the Signal Timing Software needed to generate a signal timing plan.
AF-STO-04.1	The Signal Timing Optimization Application shall compute volumes per lane.
AF-STO-04.1.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle volumes.
AF-STO-04.1.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each lane.
AF-STO-04.1.3	The Signal Timing Optimization geographic information data shall include information describing boundaries of each stop bar.
AF-STO-04.1.4	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute volumes by lane for each intersection using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study.
AF-STO-04.1.5	The Signal Timing Optimization Application shall store computed

Identifier	Functional Requirements
	lane volumes.
AF-STO-04.1.6	The Signal Timing Optimization Application shall verify that all computed lane volumes are within threshold values defined by the Signal System Operator.
AF-STO-04.1.7	The Signal Timing Optimization Application shall shore the result of the verification for all computed lane volumes.
AF-STO-04.2	The Signal Timing Optimization Application shall compute number of stops per lane.
AF-STO-04.2.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle stops.
AF-STO-04.2.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each lane.
AF-STO-04.2.3	The Signal Timing Optimization geographic information data shall include information describing boundaries of each stop bar.
AF-STO-04.2.4	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute number of stops per lane for each intersection.
AF-STO-04.2.5	The Signal Timing Optimization Application shall store computed vehicle stops.
AF-STO-04.2.6	The Signal Timing Optimization Application shall verify that all computed vehicle stops are within threshold values defined by the Signal System Operator.
AF-STO-04.2.7	The Signal Timing Optimization Application shall shore the result of the verification for all computed number of stops per lane.
AF-STO-04.3	The Signal Timing Optimization Application shall compute average stop delay per lane.
AF-STO-04.3.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle stops.
AF-STO-04.3.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each lane.
AF-STO-04.3.3	The Signal Timing Optimization geographic information data shall include information describing boundaries of each stop bar.
AF-STO-04.3.4	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute the average stop delay per lane for each intersection.
AF-STO-04.3.5	The Signal Timing Optimization Application shall store computed average stop delay per lane.
AF-STO-04.3.6	The Signal Timing Optimization Application shall verify that all computed average vehicle stop delays are within threshold values defined by the Signal System Operator.
AF-STO-04.3.7	The Signal Timing Optimization Application shall shore the result of the verification for all computed average stop delay per lane.
AF-STO-04.4	The Signal Timing Optimization Application shall calculate turning movements per lane.
AF-STO-04.4.1	The Signal Timing Optimization Application shall have up-to-date

Identifier	Functional Requirements
	geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle turning movements.
AF-STO-04.4.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each lane.
AF-STO-04.4.3	The Signal Timing Optimization geographic information data shall include information describing boundaries of each stop bar.
AF-STO-04.4.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-04.4.5	The Signal Timing Optimization Application shall utilize the stored probe data to compute turning movements by lane for each intersection using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study.
AF-STO-04.4.6	The Signal Timing Optimization Application shall store computed turning movements.
AF-STO-04.4.7	The Signal Timing Optimization Application shall verify that all computed turning movements are within threshold values defined by the Signal System Operator.
AF-STO-04.4.8	The Signal Timing Optimization Application shall shore the result of the verification for all computed turning movements.

5.5 Collect Field Data

Identifier	Functional Requirements
AF-STO-05	The Signal Timing Optimization Application shall manage collected field data.
AF-STO-05.1	The Signal Timing Optimization Application shall provide a mechanism for importing field-collected data.
AF-STO-05.1.1	The Signal Timing Optimization Application shall provide a mechanism for importing queue length per lane.
AF-STO-05.1.2	The Signal Timing Optimization Application shall provide a mechanism for importing number of stops per lane.
AF-STO-05.1.3	The Signal Timing Optimization Application shall provide a mechanism for importing average stop delay per lane.
AF-STO-05.1.4	The Signal Timing Optimization Application shall provide a mechanism for importing time of any phase/cycle failures.
AF-STO-05.1.5	The Signal Timing Optimization Application shall provide a mechanism for importing turning movements.
AF-STO-05.1.6	The Signal Timing Optimization Application shall provide a mechanism for importing start time of queue overflow events.
AF-STO-05.1.7	The Signal Timing Optimization Application shall provide a mechanism for importing duration of queue overflow events.
AF-STO-05.1.8	The Signal Timing Optimization Application shall provide a mechanism for importing upstream travel time.
AF-STO-05.2	The Signal Timing Optimization Application shall store imported field data organized by intersection and time of data collection.

5.6 Determine VII Effectiveness at Measuring Traffic Characteristics

Identifier	Functional Requirements
AF-STO-06	The Signal Timing Optimization Application shall analyze probe data to compute measures to determine the effectiveness of probe data at measuring traffic characteristics.
AF-STO-06.1	The Signal Timing Optimization shall determine the variance between field-collected queue length and computed queue length.
AF-STO-06.1.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle queues.
AF-STO-06.1.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each lane.
AF-STO-06.1.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.1.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.1.5	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute average queue length per lane using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study for the same geographic location and time as the field-collected queue length.
AF-STO-06.1.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected queue length and computed average queue length per lane.
AF-STO-06.1.7	The Signal Timing Optimization Application shall store the computed average queue length and variance from field-collected queue length.
AF-STO-06.2	The Signal Timing Optimization shall determine the variance between the number of field-collected stops per lane and the number of computed stops per lane.
AF-STO-06.2.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle stops.
AF-STO-06.2.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.2.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.2.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.

AF-STO-06.2.5	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute the number of stops per lane for the same geographic location and time as the field-collected stops per lane.
AF-STO-06.2.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected stops per lane and computed number of stops per lane.
AF-STO-06.2.7	The Signal Timing Optimization Application store the computed number of stops per lane and variance from field-collected stops per lane.
AF-STO-06.3	The Signal Timing Optimization shall determine the variance between field-collected average stop delay and computed average stop delay.
AF-STO-06.3.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle stops.
AF-STO-06.3.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.3.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.3.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.3.5	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to compute the average stop delay per lane for the same geographic location and time as the field-collected average stop delay.
AF-STO-06.3.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected average stop delay and computed average stop delay.
AF-STO-06.3.7	The Signal Timing Optimization Application shall store the computed average stop delay and variance from field-collected average stop delay.
AF-STO-06.4	The Signal Timing Optimization shall determine the variance between field-collected instances of phase/cycle failures and computed instances of phase/cycle failures.
AF-STO-06.4.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate intersection cycle/phase failures.
AF-STO-06.4.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.4.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.4.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.4.5	When enabled by the Signal System Operator, the Signal Timing Optimization Application shall utilize the stored probe data to

	compute the instances of phase/cycle failures for the same geographic location and time as the field-collected instances of phase/cycle failures.
AF-STO-06.4.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected instances of phase/cycle failures and computed instances of phase/cycle failures.
AF-STO-06.4.7	The Signal Timing Optimization Application shall store the computed instances of phase/cycle failures and variance from field-collected instances of phase/cycle failures.
AF-STO-06.5	The Signal Timing Optimization shall determine the variance between the number of field-collected turning movements and total number of computed turning movements.
AF-STO-06.5.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate turning movements.
AF-STO-06.5.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.5.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.5.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.5.5	The Signal Timing Optimization Application shall utilize the stored probe data to compute the total number of turning movements (time and position trajectories) using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study for the same geographic location and time as the field-record turning movements.
AF-STO-06.5.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected turning movements and computed turning movements.
AF-STO-06.5.7	The Signal Timing Optimization Application shall store the computed number of turning movements and variance from field-collected number of turning movements
AF-STO-06.6	The Signal Timing Optimization shall determine the variance between the field-collected start time of queue overflow events and the computed start time of queue overflow events.
AF-STO-06.6.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle queues.
AF-STO-06.6.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.6.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.6.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.6.5	The Signal Timing Optimization Application shall utilize the stored

	probe data to compute the start time of queue overflow events using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study for the same geographic location and time as the field-collected queue overflow events.
AF-STO-06.6.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected start time of queue overflow events and computed start time of queue overflow events.
AF-STO-06.6.7	The Signal Timing Optimization Application shall store the computed start time of queue overflow events and variance from field-collected start time of queue overflow events.
AF-STO-06.7	The Signal Timing Optimization shall determine the variance between the field-collected duration of queue overflow events and the computed duration of queue overflow events.
AF-STO-06.7.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle queues.
AF-STO-06.7.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.7.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.7.4	The Signal Timing Optimization geographic information data shall include information describing allowed turning movements from each lane.
AF-STO-06.7.5	The Signal Timing Optimization Application shall utilize the stored probe data to compute the duration of queue overflow events using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study for the same geographic location and time as the field-collected queue overflow events.
AF-STO-06.7.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected duration of queue overflow events and computed duration of queue overflow events.
AF-STO-06.7.7	The Signal Timing Optimization Application shall store the computed duration of queue overflow events and variance from field-collected duration of queue overflow events.
AF-STO-06.8	The Signal Timing Optimization shall determine the variance between the field-collected upstream link travel time from a signalized intersection and the computed upstream link travel time from a signalized intersection.
AF-STO-06.8.1	The Signal Timing Optimization Application shall have up-to-date geographic information data covering the geographic extent of the Signal Timing Optimization Application, to geo-locate vehicle travel times.
AF-STO-06.8.2	The Signal Timing Optimization geographic information data shall include information describing boundaries of each approach lane.
AF-STO-06.8.3	The Signal Timing Optimization geographic information data shall include information describing location of each stop bar.
AF-STO-06.8.4	The Signal Timing Optimization geographic information data shall

	include information describing the upstream link start points using arterial intersections.
AF-STO-06.8.5	The Signal Timing Optimization Application shall utilize the stored probe data to compute the upstream link travel using algorithms developed by Noblis as part of USDOT's "VII Data Characteristics for Traffic Management" study for the same geographic location and time as the field-collected upstream travel time.
AF-STO-06.8.6	The Signal Timing Optimization shall calculate the variance between the stored field-collected upstream link travel time and computed upstream link travel time.
AF-STO-06.8.7	The Signal Timing Optimization Application shall store the computed upstream link travel time and variance from field-collected upstream link travel time.

5.7 Distribute Probe Data Generation Parameters

Identifier	Functional Requirements
AF-STO-07	The Signal Timing Optimization Application shall send a Probe Management Message, as defined in the POC Additions and Exceptions to J2735 (APP190-02), to the Advisory Message Distribution Service when directed by the Signal System Operator.

5.8 Provide Signal Timing Optimization Application User Interface

Identifier	Functional Requirements
AF-STO-08	The Signal Timing Optimization Application shall provide a User Interface (UI) for the Signal System Operator to manage the Signal Timing Optimization Application.
AF-STO-08.1	The Signal Timing Optimization Application shall provide a User Interface (UI) for the Signal System Operator to manage the probe data subscription.
AF-STO-08.1.1	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to add and modify the probe data elements of the probe data subscription profile.
AF-STO-08.1.2	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to add and modify the geographic boundary of the probe data subscription profile.
AF-STO-08.1.3	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to add and modify the start and end times of the probe data subscription profile.
AF-STO-08.1.4	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to send a probe data subscription request
AF-STO-08.1.5	The Signal Timing Optimization Application UI shall provide the

Identifier	Functional Requirements
	Signal System Operator the ability to cancel a probe data subscription request
AF-STO-08.2	The Signal Timing Optimization Application shall provide a UI to allow the Signal System Operator to manage probe data.
AF-STO-08.2.1	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view, in a tabular form, probe data stored by the Signal Timing Optimization Application.
AF-STO-08.2.2	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to select a subset of stored probe data for viewing, based on the value of any parameter of the probe data snapshot.
AF-STO-08.2.3	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to select a subset of stored probe data for viewing, based on the time the probe data snapshot was received from the Probe Data Service.
AF-STO-08.2.4	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view the most recently received probe data snapshots.
AF-STO-08.2.5	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view any probe data verification errors generated by the Signal Timing Optimization Application.
AF-STO-08.3	The Signal Timing Optimization Application shall provide a UI to allow the Signal System Operator the ability to set parameters for the algorithms used to compute volumes per lane, stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.
AF-STO-08.4	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to specify the geographic boundaries of the intersections within the geographic extent of the Signal Timing Optimization Application.
AF-STO-08.5	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view computed volumes per lane, stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.
AF-STO-08.6	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view the variances between computed and field-collected stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.
AF-STO-08.7	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to define the parameters of a Probe Management Message as defined in the POC Additions

Identifier	Functional Requirements
	and Exceptions to J2735 (APP190-02).
AF-STO-08.8	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to choose to broadcast a Probe Management Message as an advisory message delivery request to the Advisory Message Delivery Service.
AF-STO-08.9	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view advisory message delivery requests.
AF-STO-08.9.1	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view the active, scheduled, and expired advisory message delivery requests in a tabular format, using one row for each delivery request.
AF-STO-08.9.2	The Signal Timing Optimization Application UI shall update the view with the latest advisory message delivery requests generated by the Signal Timing Optimization Application.
AF-STO-08.9.3	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view any delivery request related errors reported by the Advisory Message Distribution Service.
AF-STO-08.10	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to cancel an advisory message delivery request.
AF-STO-08.11	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to create lookup requests to the Information Lookup Service about VII System managed entities (i.e., RSEs, Probe Data Service Availability, and Advisory Message Distribution Service availability).
AF-STO-08.12	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to view information about VII System managed entities (i.e., RSEs, Probe Data Service Availability, and Advisory Message Distribution Service availability).
AF-STO-08.13	The Signal Timing Optimization Application UI shall provide the Signal System Operator the ability to enable or disable, either separately or together, the analysis of probe data for computing volumes per lane, stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.

6 Security Requirements

Identifier	Security Requirements
AS-STO-01	The Signal Timing Optimization Application shall be coded to ensure that adequate security measures are in place to prevent it from compromising connected system resources both within the host computing and VII infrastructure environments.
AS-STO-02	The Signal Timing Optimization Application shall be subject to a code security assessment to ensure it complies with safe coding practices.
AS-STO-03	The Signal Timing Optimization Application shall validate all user input to prevent maliciously entered data from being accepted.
AS-STO-04	The Signal Timing Optimization Application shall enforce access policies associated with specific user roles.
AS-STO-05	Upon detection of any security event, the Signal Timing Optimization Application shall isolate the compromised component in order to render it harmless to the rest of the network.
AS-STO-06	The Signal Timing Optimization Application shall prevent known message-based attacks from inbound XML formatted data.
AS-STO-07	The Signal Timing Optimization Application shall only use FIPS 140-2 compliant crypto algorithms wherever encryption is needed.
AS-STO-08	The Signal Timing Optimization Application shall encrypt a user's ID and password while performing authentication.
AS-STO-09	The Signal Timing Optimization Application shall encrypt it's own user ID and password used to establish connectivity to the DBMS.
AS-STO-10	The Signal Timing Optimization Application shall store all user ID's and password's in the DBMS in either encrypted or hashed format.
AS-STO-11	The Signal Timing Optimization Application shall be designed with user roles which employ the concept of least privileges.
AS-STO-12	The Signal Timing Optimization Application shall be designed to connect to the DBMS with an account that is consistent with the concept of least privileges.
AS-STO-13	The Signal Timing Optimization application shall only communicate with the VII CA Subsystem via a private, or virtual private communications link.
AS-STO-14	The Signal Timing Optimization application shall only communicate with Managed Entities via a private, or virtual private communications link.

7 External Interface Requirements

Identifier	External Interface Requirements
AX-STO-01	The Signal Timing Optimization Application shall utilize the X-034 interface, as defined in the Network User to Service Delivery Node (SDN) Subsystem Software Interface Requirements Specification - Version 1.1 (or latest), when communicating with the Information Lookup Service .
AX-STO-02	The Signal Timing Optimization Application shall utilize the X-031 interface, as defined in the Network User to Service Delivery Node (SDN) Subsystem Software Interface Requirements Specification - Version 1.1 (or latest), when communicating with the Probe Data Service .
AX-STO-03	The Signal Timing Optimization Application shall utilize the X-032 interface, as defined in the Network User to Service Delivery Node (SDN) Subsystem Software Interface Requirements Specification - Version 1.1 (or latest), when communicating with the Advisory Message Distribution Service.
AX-STO-04	The Signal Timing Optimization Application shall provide signal timing software inputs to the Signal Systems Operator in a format usable by the Signal Timing Software.

8 Performance Requirements

Identifier	Requirement
AP-STO-01	The Signal Timing Optimization Application shall take no longer than ten (10) seconds to retrieve all stored probe data snapshots over a fifteen (15) minute period, for a given intersection.
AP-STO-02	The Signal Timing Optimization application shall take no longer than one (1) minute to compute volumes per lane, stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.
AP-STO-03	The Signal Timing Optimization application shall take no longer than one (1) minute to determine the variances between computed and field-collected stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times.

9 End-to-End Performance Expectations

Identifier	Expectations
AN-STO-01	Variances between computed and field-collected volumes per lane, stops per lane, average stop delay per lane, vehicle time and position trajectories, queue length, phase/cycle failures, start time of queue overflow events, duration of queue overflow events, and upstream link travel times should be within ten percent (10%).
VN-STO-01	Vehicle snapshots provided to the Signal Timing Optimization application should be of sufficient frequency and accuracy to allow the determination of vehicle time and position trajectory through an intersection with lane resolution
VN-STO-02	Latitude and longitude included in Probe Data Snapshots should be sufficiently accurate to determine a vehicle's horizontal position within one (1) meter.
VN-STO-03	Elevation included in Probe Data Snapshots should be sufficiently accurate to determine a vehicle's vertical position within three (3) meters.
VN-STO-04	Time associated with vehicle position included in Probe Data Snapshots should be accurate to within one (1) second.
VN-STO-05	Speed associated with a vehicle position included in Probe Data Snapshots should be accurate to within two (2) kph.
VN-STO-06	Vehicle snapshots should be provided to the Signal Timing Optimization application within fifteen (15) minutes of their generation by the Vehicle.
VN-STO-07	Signal Timing Optimization application's subscription to probe data should commence distribution of probe data snapshots within one (1) minute of subscription.
VN-STO-08	The Advisory Message Distribution Service should commence distribution of Probe Data Management Message within one (1) minute of the advisory message broadcast start time for all advisory message delivery requests received from the Signal Timing Optimization Application.
VN-STO-09	Vehicles should set their probe generation parameters in accordance with a Probe Management Message within one (1) second of receipt of a Probe Management Message.
VN-STO-10	Probe Management Messages should be distributed to Vehicles at least five hundred (500) feet before the Vehicle enters the center of the intersection under test.
VN-STO-11	Vehicles should reset their probe generation parameters to those values in place prior to receipt of a Probe Management Message within one (1) second after the Vehicle has determined that the Probe Management Message no longer applies, as defined in the POC Additions and Exceptions to J2735 (APP190-02).

Appendix A. List of Acronyms

AAM	Alliance of Automobile Manufacturers
AASHTO	American Association of State and Highway Transportation Officials
ABS	Antilock Braking System
AMDS	Advisory Message Distribution Service
AMI-C	Automotive Multimedia Interface Collaboration
ASTM	American Society for Testing and Materials
CA	Certification Authority
CAMP	Crash Collision Avoidance Metrics Partnership
CICAS	Cooperative Intersection Collision Avoidance Systems
CSP	Content Service Provider
DIC	DSRC Industry Consortium
DiD	Defense In Depth
DOT	Departments of Transportation
DSRC	Dedicated Short Range Communications
DTE	Development and Test Environment
EDMap	Enhanced Digital Map
ENOC	Enterprise Network Operations Center
ENS	Event Notification System
ESS	Environmental Sensor Stations
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
GHz	Gigahertz
GPS	Global Positioning System
GSA	General Services Administration
HMI	Human Machine Interface
IdAM	Identity and Access Management
IEEE	Institute of Electrical and Electronic Engineers
ILS	Information Lookup Service
ISTEA	Intermodal Surface Transportation Efficiency Act
IT	Information Technology
ITIL	Information Technology Infrastructure Library
ITS	Intelligent Transportation System
ITSM	Information Technology Service Management
IVHS	Intelligent Vehicle Highway Systems
IVI	Intelligent Vehicle Initiative
LBS	Location Based Services
MDSS	Maintenance Decision Support System
MPO	Metropolitan Planning Organization
NAP	Network Access Point
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NMS	Network Management System

NOC	Network Operations Center
NWS	National Weather Service
O&M	Operations and Maintenance
OBE	On Board Equipment
OBU	On Board Unit
OEM	Original Equipment Manufacturer
OSI	Open Systems Interconnection
PATH	Partners for Advanced Transit and Highways
PDS	Probe Data Service
PSAP	Public Service Answering Point
QoS	Quality of Service
RSE	Road Side Equipment
RSU	Road Side Unit
RWIS	Road Weather Information System
SAE	Society of Automotive Engineers
SDLC	System Development Life Cycle
SDN	Service Delivery Node
SNMP	Simple Network Management Protocol
SOC	Security Operations Center
SSL	Secure Sockets Layer
TEA-21	Transportation Equity Act for the 21st Century
TMC	Traffic Management Center
TOC	Traffic Operations Center
VII	Vehicle Infrastructure Integration
VPN	Virtual Private Network
VSC	Vehicle Safety Communications
U.S. DOT	U.S. Department of Transportation

Appendix B. References

REF #	REFERENCE	VERSION
1	VII POC Applications Concept of Operations	Version 1.4
2	VII National System Requirements	Version 1.2.1
3	Road Side Equipment (RSE) Subsystem Specification	Version 1.0
4	Enterprise Network Operations Center (ENOC) Subsystem Specification	Version 1.1
5	Certificate Authority (CA) Subsystem Specification	Version 1.1
6	ENOC to Administrative User Subsystem Software IRS [X-011]	Version 1.1
7	Network User to SDN Subsystem Software IRS [X-031, X-032, X-033]	Version 1.1
8	ENOC to Managed Entity Subsystem Software IRS	Version 1.1
9	ENOC to Managed Network Element Software IRS	Version 1.1
10	SDN to RSE Subsystem Software IRS [I-06]	Version 1.1
11	ENOC to CA Subsystem Software IRS [I-13]	Version 1.1
12	ENOC to SDN Subsystem Software IRS [I-11]	Version 1.1
13	VII USDOT Day-1 Use Case Descriptions (May 2006)	Version 1.0
14	Network Subsystem Specification	Version 1.0
15	VII Concept of Operations	Draft 1.2
16	VII Systems Security Plan	Version 2.1
17	SDN Subsystem Specification (SSS)	Version 1.1
18	VII Infrastructure Lexicon	Version 1.0
19	Draft SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary	Rev. 15
20	APP190-02 POC Additions & Exceptions to the POC Version of SAE J2735	R00
21	VII x.509 Certificate Authority Certificate Practice Statement (CPS)	TBD