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Joint Program Office

Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V)

System Requirements Specification

Final Phase I Release v3.01

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16. Abstract

The Cooperative Intersection Collision Avoidance Systems for Violations (CICAS-V) project aims to develop and field-test a comprehensive system to reduce the number and severity of crashes at intersections due to violations of traffic signals and stop signs.

The document is intended to identify and describe the detailed requirements of CICAS-V roadside and vehicle based modules. Requirements define the specific behavior of a system, that is, they provide a description of what the system is intended to do.

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Table of Contents

List of Figures

List of Tables

1 Introduction

The purpose of this document is to provide a set of requirements for the Cooperative Intersection Collision Avoidance System (CICAS) for Violations (CICAS-V), a system that involves both infrastructure and in-vehicle elements, working together, to reduce the number of crashes at controlled intersections within the United States.

The document is intended to identify and describe the detailed requirements of CICAS-V roadside and vehicle based modules. Requirements define the specific behavior of a system, that is, they provide a description of what the system is intended to do.

Section 2 of the document will provide a general description of the system and scenarios demonstrating the desired functionality of the system under various modes of operation. This section is a re-statement of the information provided in the *Concept of Operations* (ConOps) and the *High-Level System Requirements Specification* (HRS). The material provides context for those reading this document that might not be familiar with the preceding documents.

Section 3 of the document includes the functional decomposition of the CICAS system published in the *System Architecture Description* (SAD). This information will provide the system developers and developers of other interfacing systems with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system. System designers will use this view to design each module so that it performs the required functions. Each of the system requirements will be allocated to one or more of the modules in this decomposition.

Section 4 provides the system requirements for the On-board Equipment (OBE) components of the CICAS-V system. The high-level requirements in this section are generally a direct re-statement of the high-level requirements in the HRS, although additional detailed requirements have been added to expand, clarify, or fill in requirement information where appropriate. Some of the high-level requirements have been split into multiple detailed requirements to allow the requirements to be allocated appropriately.

Section 5 provides the system requirements for the Roadside Equipment (RSE) components of the CICAS-V system. The high-level requirements in this section are generally a direct re-statement of the high-level requirements in the HRS, although additional detailed requirements have been added to expand, clarify, or fill in requirement information where appropriate. Some of the high-level requirements have been split into multiple detailed requirements to allow the requirements to be allocated appropriately.

OBE and RSE requirements have been split into separate sections at this time to allow the design teams responsible for each design effort to focus on the requirements within their respective scopes of work. Some content and requirements may be duplicated in these sections to provide each design team with a complete set of information.

1.1 System Purpose

CICAS-V is intended to reduce intersection crashes due to violations of traffic signals and stops signs. There are about 9,500 fatalities in intersection area crashes in the U.S.

every year with an impact of approximately $97 Billion. Out of those totals, CICAS-V has the potential to address intersection crossing path crashes that entail about 2,700 fatalities with an impact of $19 Billion.[1]

This is done by issuing a warning to the driver while there is still time to stop the vehicle in a controlled manner and prevent the violation. When a vehicle is approaching a controlled intersection in a manner that indicates a high probability that the driver will not stop when the signal is red (or at a stop sign), the vehicle shall issue a warning alerting the driver of the impending violation in sufficient time for the driver to bring the vehicle to a stop before entering into the cross-traffic path.

The operational goal of the system is that by warning inattentive or distracted drivers that they are about to violate an intersection control the system reduces the likelihood and severity of intersection crashes.

The CICAS-V system is being developed under a cooperative agreement program between the Crash Avoidance Metrics Partnership (CAMP) Vehicle Safety Communications 2 Consortium (Mercedes Benz Research and Development North America, Inc., Ford, GM, Honda and Toyota), hereafter referred to as VSC2, along with the Virginia Tech Transportation Institute (VTTI), the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) of the Research and Innovative Technology Administration (RITA), the National Highway Traffic Safety Administration (NHTSA), and the Federal Highway Administration (FHWA). The purpose of implementing CICAS-V is to reduce crashes due to violation of traffic control devices, including both traffic signals and stop signs. When deployed, this system is intended to:

- Reduce fatalities at controlled intersections
- Reduce the number of injuries at controlled intersections
- Reduce the severity of injuries at controlled intersections
- Reduce property damage associated with collisions at controlled intersections
- Create an enabling environment that additional technologies can leverage to extend safety benefits further

An initial analysis of relevant NHTSA crash databases shows that violation crashes have a variety of causal factors. The CICAS-V system is intended to address the causal factors that include driver distraction; obstructed or limited visibility due to weather, intersection geometry or other vehicles; driver inattention; and driver judgment errors. CICAS-V driver warnings may prevent many violation-related crashes by alerting the distracted or inattentive driver in sufficient time to stop the vehicle.

CICAS-V is intended to provide a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by warning the vehicle driver that an intersection violation, at an intersection controlled by a stop sign or by traffic signal, is predicted to occur. The basic concept of CICAS-V is illustrated at a high level in Figure 1 for a signalized intersection.

[1] Chang et al., *CICAS-V Research on Comprehensive Costs.*

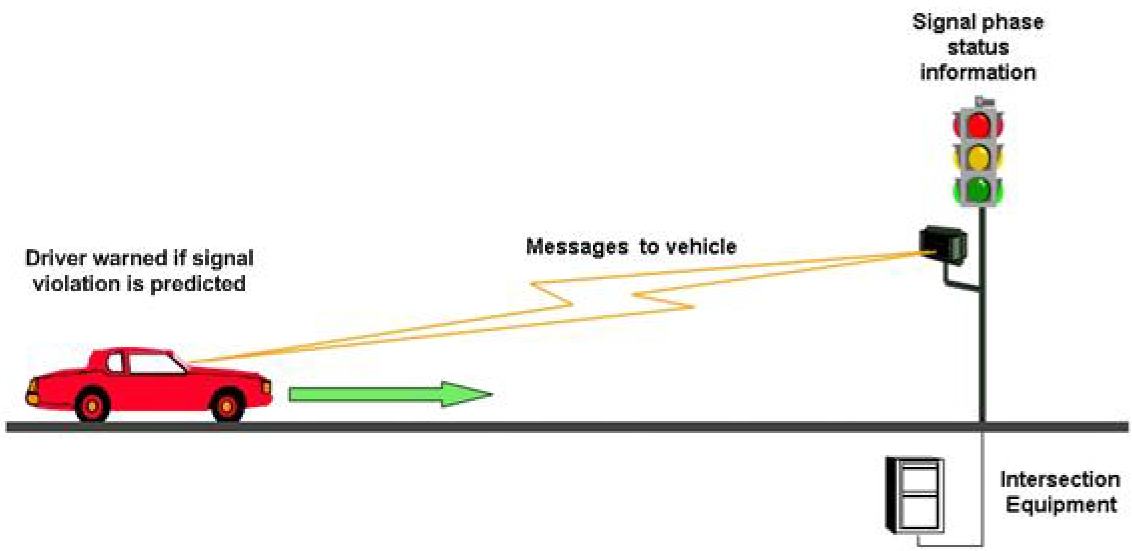

Figure 1 - Basic Concept of the CICAS-V System at a Signalized Intersection

In the figure above, a CICAS-V vehicle approaching a CICAS-V intersection receives messages about the intersection geometry and status of the traffic signal. The driver is issued a warning if the equipment in the vehicle determines that, given current operating conditions, the driver is predicted to violate the signal in a manner which is likely to result in the vehicle entering the intersection. While the system may not prevent all crashes through such warnings, it is expected that, with an effective warning, the number of traffic control device violations will decrease, and result in a decrease in the number and severity of crashes at controlled intersection

1.2 System Scope

The CICAS-V system will include the On-board Equipment (OBE) and Roadside Equipment (RSE)[2] components. In this system, "components" will include system documentation, hardware, software, and firmware components. The OBE will integrate with existing vehicle systems such as the vehicle network, Vehicle Infrastructure Integration (VII) systems, and driver interface systems. The RSE will integrate with existing roadside equipment including traffic signal systems, VII systems, and Department of Transportation (DOT) communication systems.

This project will develop and test CICAS-V intersections and is split into two phases. The first phase is the development and testing of the CICAS-V system for several intersections and vehicles. After the first phase, the system will be evaluated for readiness to continue to the second phase, which is a larger field operational test (FOT).

[2] The term "roadside equipment" or "RSE" is common to many transportation programs and, in particular, is used in Vehicle Infrastructure Integration (VII) programs in a similar context. "RSE" throughout this document will refer to the CICAS-V RSE, and others will be identified with a specific context. The VII RSE, for example, will be explicitly referred to as the "VII RSE".

1.3 Definitions, Acronyms, and Abbreviations

This document may contain terms, acronyms, and abbreviations that are unfamiliar to the reader. A list of acronyms used in this document can be found in Appendix A, and Appendix B contains a glossary of terms.

1.4 References

The following documents contain additional information pertaining to this project or have been referenced within this document. A general description of CICAS-V can be found in its Concept of Operations document. Other papers describe intersection violation research and human factors guidelines for driver-vehicle interfaces.

Advanced Traffic Controller (ATC) Standard Version 5.2b. Washington, DC: American Association of State Highway and Transportation Officials; Washington, DC: Institute of Transportation Engineers; Rosslyn, VA: National Electrical Manufacturers Association, 2006.

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Campbell, J.L., C. Carney, and B.H. Kantowitz. *Human Factors Design Guidelines for Advanced Traveler Information Systems (ATIS) and Commercial Vehicle Operations (CVO)*. McLean, VA: Federal Highway Administration, 1998.

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IEEE 1609.3-2006: Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)-Networking Services. IEEE, 2006.

IEEE 1609: WAVE Short Message Format. IEEE, 2006.

IEEE 802.11p: IEEE Standard for Information Technology – Telecommunications and Information Exchange Between Systems – Local and Metropolitan Area networks – Specific Requirements – Part II: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification. IEEE, 2006.

Lyons, R.D., N. Lerner, and B. Kotwal. *Preliminary Human Factors Guidelines for Crash Avoidance Warning Devices*. Washington, DC: National Highway Traffic Safety Administration, 1996.

Neale, V.L., M.A. Perez, Z.R. Doerzaph, S.E. Lee, S. Stone, and T.A. Dingus. *Intersection Decision Support: Evaluation of a Violation Warning System to Mitigate Straight Crossing Path Collisions*. Charlottesville, VA: Virginia Transportation Research Council, 2006.

NTCIP 1202 v02: NTCIP Object Definitions for ASC. National Transportation Communications for ITS Protocol, 2007.

NTCIP 1210: NTCIP Objects for Signal System Masters. National Transportation Communications for ITS Protocol, 2006.

1.5 System Overview

Figure 2 shows a functional decomposition schematic of the system in Normal Operating Mode.

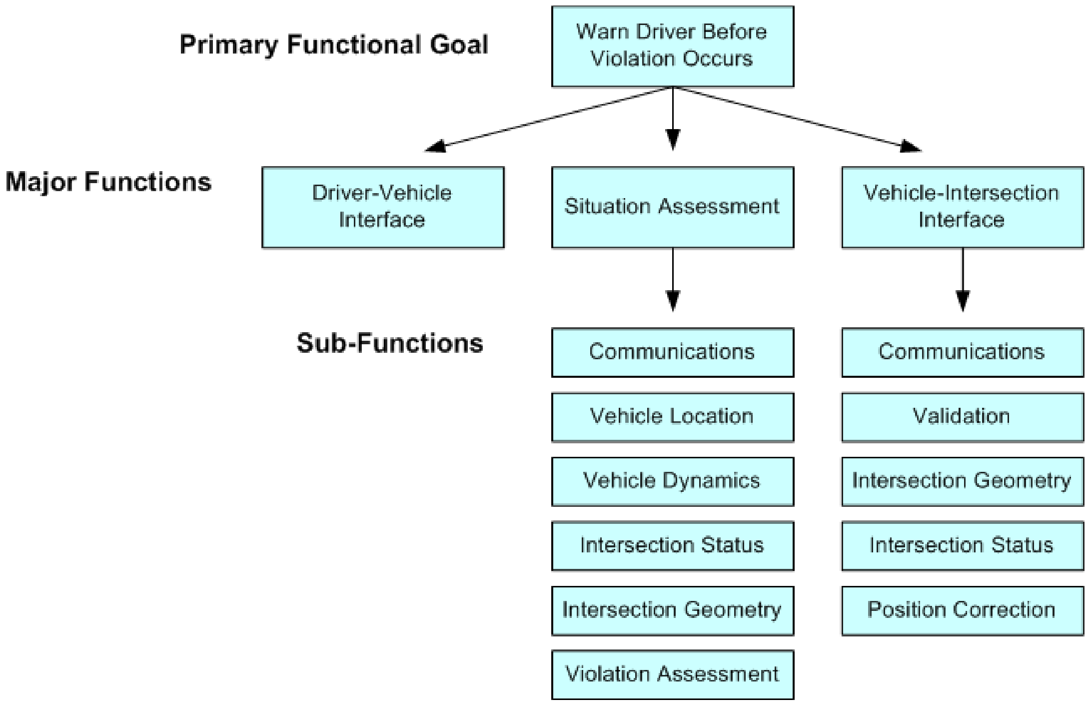

Figure 2 - CICAS-V Functional Schematic (Normal Operating Mode)

The top block, "Warn Driver Before Violation Occurs," is a condensed version of the primary functional goal quoted above. The three blocks below the primary functional goal identify major functions needed to support the goal, and include: "Driver-Vehicle Interface"; "Situation Assessment"; and "Vehicle to Intersection Interface." The remaining blocks represent supporting sub-functions to perform the major functions.

2 General System Description

2.1 System Context

CICAS-V is intended to help a driver of a CICAS-V equipped vehicle approaching a CICAS-V equipped intersection to avoid a crossing path crash by warning the driver of an impending red-light violation or stop sign violation. To achieve benefits, it takes only a single equipped vehicle approaching a single equipped intersection at the proper time to activate the system. This "single vehicle" approach maximizes the probability of value being provided to drivers and DOTs, while simplifying deployment issues and logistics. The benefit to society increases with growing numbers of CICAS-V equipped intersections and vehicles. Because of its relative simplicity, CICAS-V is seen as a step toward the deployment of initial vehicle safety communications as well as reliable positioning and geospatial mapping techniques. Once these technologies are available and installed in vehicles, they will enable many other safety applications, including both vehicle-to-infrastructure and vehicle-to-vehicle applications.

Figure 3 below addresses logical system boundaries for CICAS-V. Items inside the dashed "CICAS-V Boundaries" are the subject of this specification and items outside the boundaries are outside the scope of this document.

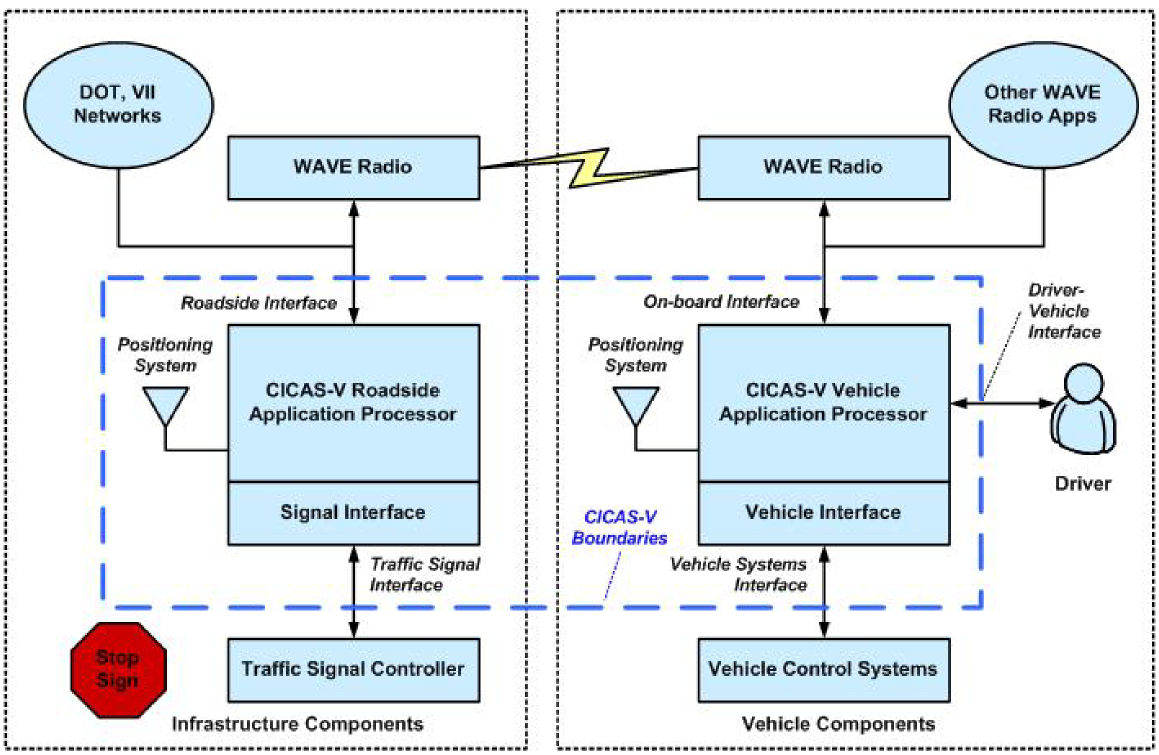

Figure 3 - CICAS-V Logical System Boundaries

Although this figure shows the Positioning System component as one of the CICAS-V components, the Positioning System may, in fact, be external to the CICAS-V system in some implementations. The Positioning System will be shown as a part of the CICAS-V requirements and architecture for completeness.

One additional boundary exists within the CICAS-V system which is based on the location of the components. Infrastructure components located on the roadside are designated as RSE components and components located on the vehicles are designated as OBE components. Documentation components can be OBE components, RSE components, or CICAS-V System components, depending on the scope and purpose of the documentation.

Requirements applying to the whole system will be phrased: “The CICAS-V System shall…” Requirements applying to CICAS-V infrastructure or vehicle components will be phrased: “The RSE components shall…” or “The OBE components shall…”

2.2 System Modes and States

The CICAS-V system can exist in several modes and states. Modes are particular functioning conditions or arrangements. The modes identified for CICAS-V include the following:

- Startup/Validation
- Normal Operation
- System Failure
- Maintenance

The above modes are common to both the RSE components and OBE components. Scenarios for these modes are provided in Section 2.8.

States represent the controlling attributes that define the system behavior. The combination of modes and states will determine how a system behaves. Since the primary behavior of the on-board portion of the system is to issue a warning to a driver if the vehicle should stop and does not appear to be stopping, there are several mode/state combinations that must be evaluated by the system to arrive at the desired behavior. Figure 4 shows the relationship between the modes of operation, the states relevant to driver notifications and warnings, and the desired behavior of the system.

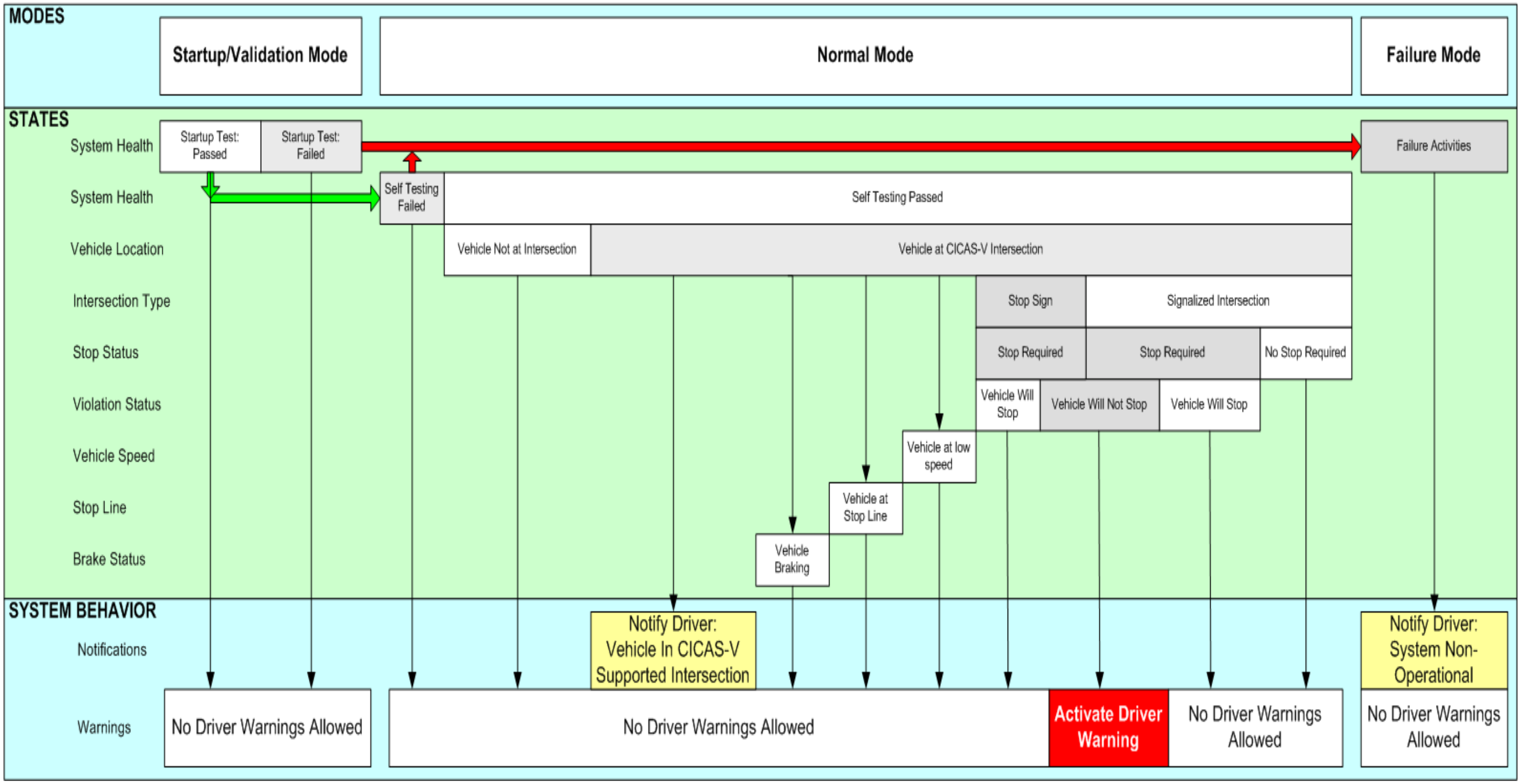

Figure 4 - CICAS-V Mode-State-Behavior Diagram

2.3 Major System Capabilities

CICAS-V capabilities are dependent on *co*-operation of infrastructure (roadway intersection) and vehicle components. Although the system can be architecturally viewed and concisely described in terms of the physical distribution of the components, it is important to reiterate that both the infrastructure and vehicle components are necessary for CICAS-V to achieve its operational objectives.

2.3.1 Infrastructure Component Capabilities

CICAS-V needs to work at both signalized and stop sign controlled intersections. Because of the signal system interface, a signalized CICAS-V intersection will always have CICAS-V intersection components, while a stop sign controlled CICAS-V intersection may or may not have CICAS-V infrastructure. The sections below discuss what capabilities are present when CICAS-V components are deployed at an intersection, and the additional capabilities that are needed when that CICAS-V intersection is also a signalized intersection. For CICAS-V intersections where there is no equipment deployed, all CICAS-V functions are performed within the vehicle.

2.3.1.1 General Infrastructure Component Capabilities

For each CICAS-V intersection with an infrastructure component, the CICAS-V roadside application processor broadcasts WAVE messages that include, but are not limited to, the following:

1. A CICAS-V service announcement (i.e., an announcement that the intersection has information for the vehicle)[3]
2. A positioning correction message
3. Geospatial information messages
4. Road surface information and other weather-related data if available

The content for these messages has not been finalized. The following briefly describes the conceptual contents of each of these messages. The final message sets may include additional or different information.

Service Announcement: The service announcement provides vehicles with the intersection's identification (ID) code number and indicates whether the intersection's CICAS-V capability is operational. It also states whether GID or area-wide geospatial information is available, the version number of the currently available geospatial information (both GIDs and area-wide), and the channel on which the geospatial information is broadcast.

Positioning Correction Message*:* This message contains the positioning correction information that the vehicle uses to improve its positioning accuracy.

Geospatial Information Messages*:* There are two types of geospatial information that may be broadcast.

[3]This is equivalent to the WAVE Service Announcement (WSA) used in other VII contexts.

The first type is the *intersection* GID, consisting of the following:

- GID version
- Intersection ID
- Road/lane geometry for all approach roads
- Location of the intersection stop lines
- A lane numbering scheme that corresponds to the numbering of traffic signals and the geometry of any obstacles, dividers, etc. in the intersection box

The second type of geospatial information that may be broadcast is the CICAS-V *area* geospatial information consisting of the following:

- Geospatial information version ID
- Intersection IDs for all CICAS-V intersections within a specified area
- Intersection type IDs (e.g., signalized intersection, stop sign controlled intersection) for all CICAS-V intersections within the specified area
- Intersection GID detail for all CICAS-V controlled intersections in the specified area

The vehicle uses the GID version ID to determine if it needs to download a new version of the GID; it only does so if the GID version ID indicates that this GID is more up-to-date than the one currently stored in the vehicle's data store. The vehicle uses the intersection ID to match itself to the correct intersection in case it receives simultaneous messages from multiple intersections. The vehicle needs the road/lane geometry to match itself to the approach road and the specific lane[4] on the approach road, if such accuracy is needed. The vehicle uses the location of the intersection stop lines, which could be different for different lanes, to determine the distance from the stopping location. This distance is an important parameter for the warning calculation. The lane numbering scheme has to correspond to the traffic signal phase and timing (SPaT) scheme so that the vehicle can determine which signal information is pertinent.

An intersection's CICAS-V equipment must be placed at a point along the travel path to the intersection where it can complete transmission of GID updates in time for basic safety assessment algorithms to decode the information and calculate the likelihood of a traffic control violation. It must also be placed such that it can complete the download of the area CICAS-V geospatial information before the vehicle leaves the equipment's transmission range.

Road Surface Information and Other Weather-Related Data: CICAS-V equipment might transmit information to the vehicle about the road surface coefficient of friction at the intersection and weather related data such as dew point, temperature, visibility, rain, etc. that might help the in-vehicle CICAS-V system adjust the warning timing to take reduced friction into account.

[4] Examples of different lane types that need to be identified are: dedicated left/right turn lanes and bicycle lanes that can be used as turn lanes. Other types exist.

2.3.1.2 Infrastructure Component Capabilities Specific to Signalized Intersections

At signalized intersections, the CICAS-V infrastructure-side equipment broadcasts an additional message containing traffic signal phase and timing data. The signal phase and timing message contains information and current status on the phase and timing of all the signals for each approach in the intersection. This message, together with the intersection GID, will enable the vehicle to determine which signal indication applies to it and use this information for determining whether a warning is warranted.

2.3.2 Vehicle Component Operation

When a CICAS-V equipped vehicle approaches a CICAS-V equipped intersection, the actions that the vehicle performs depend on whether the intersection is signalized or has a stop sign and on whether the intersection has CICAS-V infrastructure components. The scenarios in Section 2.8 and Table 1 summarize what occurs in the vehicle as it approaches a CICAS-V equipped intersection. In all cases, the assumption is that the vehicle has previously received a download of GID information that identifies the CICAS-V intersection. If it has not received that download, the actions described in the column for “Stop Sign Controlled Intersections without Equipment” cannot be performed.

If the intersection has CICAS-V equipment, the vehicle also has to determine whether it has detected any problems with that equipment. If, for example, the vehicle does not receive a service announcement at an intersection that its internal geospatial information memory identifies as a CICAS-V equipped intersection, the vehicle should store the information about a malfunctioning CICAS-V intersection and broadcast this information to the next functional CICAS-V roadside equipment that it encounters. Not receiving expected messages constitutes an error condition that the vehicle should report at the next functional CICAS-V intersection equipment it encounters.

Table 1 - Summary of Action Sequences at CICAS-V Intersections

Step No.	CICAS-V Signalized Intersection	CICAS-V Stop Sign Intersection with Equipment	CICAS-V Stop Sign Intersection without Equipment
1	Vehicle approaches a CICAS-V equipped intersection	Vehicle approaches a CICAS-V equipped intersection	Vehicle approaches a CICAS-V intersection
2	When in range of the RSE, vehicle receives a CICAS-V service announcement on the control channel indicating the availability of the intersection's GID, area geospatial information, the status of the intersection, and positioning corrections if needed	When in range of the RSE, vehicle receives a CICAS-V service announcement on the control channel indicating the availability of the intersection's GID, area geospatial information, and positioning corrections if needed	N/A (This may occur at a different location, where a CICAS-V RSE exists.)
3	Vehicle decides if it needs either the GID or the area geospatial information broadcast, or both	Vehicle decides if it needs either the GID or the area geospatial information broadcast, or both	N/A (This may occur at a different location, where a CICAS-V RSE exists.)
4	If necessary, the vehicle switches to the service channel to receive the intersection's GID and/or the area geospatial information	If necessary, the vehicle switches to the service channel to receive the intersection's GID and/or the area geospatial information	N/A (This may occur at a different location, where a CICAS-V RSE exists.)
5	Vehicle receives the intersection's GID and/or the geospatial information	Vehicle receives the intersection's GID and/or the geospatial information	N/A (This has occurred previously at a different location, where a CICAS-V RSE exists.)
6	Vehicle stores the new GID and/or geospatial information in its data store, replacing older versions	Vehicle stores the new GID and/or geospatial information in its data store, replacing older versions	N/A (This may occur at a different location, where a CICAS-V RSE exists.)

Step No.	CICAS-V Signalized Intersection	CICAS-V Stop Sign Intersection with Equipment	CICAS-V Stop Sign Intersection without Equipment
7	Vehicle decodes the intersection GID and performs geospatial matching to locate itself relative to the intersection at the road or lane level, whichever is appropriate	Vehicle decodes the intersection GID and performs geospatial matching to locate itself relative to the intersection at the road or lane level, whichever is appropriate	Vehicle decodes the intersection GID and performs geospatial matching to locate itself relative to the intersection at the road level
8	Vehicle informs the driver that it is approaching a CICAS-V intersection	Vehicle informs the driver that it is approaching a CICAS-V intersection	Vehicle informs the driver that it is approaching a CICAS-V intersection
9	Vehicle determines from available parameters (e.g., GID, position, speed, driver behavior, signal phase and timing) if a violation is likely to occur	Vehicle determines from available parameters (e.g., GID, position, speed, driver behavior) if a violation is likely to occur	Vehicle determines from available parameters (e.g., GID, position, speed, driver behavior) if a violation is likely to occur
10	If a violation is likely to occur, as determined by the warning parameters in the vehicle's safety assessment algorithm, vehicle issues a warning to the driver through the Driver-Vehicle Interface (DVI)	If a violation is likely to occur, as determined by the warning parameters in the vehicle's safety assessment algorithm, vehicle issues a warning to the driver through DVI	If a violation is likely to occur, as determined by the warning parameters in the vehicle's safety assessment algorithm, vehicle issues a warning to the driver through DVI
11	Driver reacts to the warning and takes appropriate action	Driver reacts to the warning and takes appropriate action	Driver reacts to the warning and takes appropriate action
12	Vehicle may broadcast that a warning has been issued to the driver (optional)	N/A	N/A
13	Vehicle may broadcast CICAS-V diagnostic messages	Vehicle may broadcast CICAS-V diagnostic messages	N/A

2.4 Major System Conditions

This section discusses the conditions under which the system must work and meet its **performance** goals.

OBE Environment – The OBE hardware components must meet the temperature, humidity, vibration, and shock standards established by applicable automotive standards.

OBE Reliability – The OBE hardware components should be reliable. OBE hardware components must meet the reliability standards established by applicable automotive standards.

OBE Power – The OBE hardware components must function normally on 12 VDC +/- 1 VDC power.

RSE Environment – The RSE hardware components should meet the same temperature, humidity, vibration, and shock standards as those set for other ITS roadside equipment by AASHTO/ITE/NEMA standards. (-34 C to +74 C, 9-95% Relative Humidity non-condensing, Shock per MIL-STD-810E Method 516.4, Vibration per MIL-STD-810E Method 514.4 equipment class G)

RSE Reliability – The RSE hardware components should be reliable. Typical roadside ITS equipment specifications require a component Mean-Time-Between-Failure (MTBF) of 100,000 operating hours or better.

RSE Power – Components shall properly operate within the following limits unless otherwise noted. For primary power:

- Line voltage – 89 to 135 VAC
- Frequency – 60 (+/- 3.0) Hertz

Other operating constraints may apply for backup power.

RSE Mounting – RSE hardware may be installed in existing cabinets which require pole-mount, rack-mount, or shelf-mount configurations. The RSE must be configurable for these mounting configurations.

2.5 Major System Constraints

The CICAS-V system design is based on the foundation infrastructure provided by the VII deployment. As such, there are some VII constraints which apply to CICAS-V:

- Radios will use the Wireless Access in Vehicular Environment (WAVE) standards, based on the Dedicated Short Range Communications (DSRC) standard approved by the Federal Communications Commission (FCC) for use by automotive safety systems.
- The WAVE radios will transmit at a frequency of 5.9 GHz and have a range limited to about 1000 meters. Their range radius may be reduced in urban environments where radio communications are affected by buildings, trees, or other signal-blocking structures.

2.6 User Characteristics

This section was developed based on input from CICAS-V stakeholders who include members of the United States Department of Transportation (USDOT), vehicle manufacturers, and state and local DOTs. The concepts represented here are subject to change as the CICAS-V operating model is determined.

Users of CICAS-V include the organizations, agencies, and individuals that are necessary for installing, maintaining, operating, and interacting with a functioning CICAS-V system. The primary users of CICAS-V are:

- Automobile Original Equipment Manufacturers (OEMs) – responsible for original equipment, and for vehicle-related equipment and software actions necessary to establish and maintain the in-vehicle CICAS-V system.
- State and local governments and their DOTs – responsible for all infrastructure-related actions except those handled by the VII Network Operating Entity, necessary to establish and maintain CICAS-V systems.
- USDOT – responsible for developing high level guidance to state and local agencies in the deployment and operation of CICAS-V systems.
- Vehicle drivers – responsible for the decisions made when approaching and entering an intersection. Drivers are also responsible for the following:
  - Familiarizing themselves with the vehicle safety features
  - Maintaining the vehicle, including the CICAS-V components
  - Assessing the traffic situation when an alert is issued and making a decision
- Traffic control equipment manufacturers – responsible for the development and maintenance of infrastructure equipment and software that can interface with CICAS-V (and other related safety systems, as they are fielded).
- VII Network Operating Entity – responsible for the network that will supply the communications supporting CICAS-V.
- Organization responsible for CICAS-V guidelines and standards – responsible for rules and procedures necessary for CICAS-V systems and components to become operational.

2.6.1 Automobile OEMs

Automobile OEMs may incorporate their role into existing organizational structures. There are additional roles that they will assume to help ensure that CICAS-V remains in operation over the long-term. These roles include:

- Developing standards and certification procedures
- Training personnel in CICAS-V systems
- Installing CICAS-V hardware and software in new vehicles

2.6.2 State and Local DOTs

Since state and local DOTs currently have the responsibility for intersection safety. Therefore, they are viewed as having the primary role for the installation and maintenance of CICAS-V equipment at intersections.

State and local DOTs may incorporate the operation and maintenance of CICAS-V infrastructure-side applications and equipment into their existing transportation management organizations. Additional roles that they may assume include the following:

- Planning, identifying, and selecting CICAS-V intersections
- In conjunction with other states and local DOTs and traffic control equipment manufacturers, maintenance of test beds for testing enhancements and changes to CICAS-V infrastructure-side software and equipment
- Developing maintenance plans for CICAS-V equipment at intersections
- Installing CICAS-V equipment at selected intersections
- Installing and maintaining connectivity between the CICAS-V equipment at intersections and the traffic signal controller assembly
- Validating and maintaining CICAS-V operation at equipped intersections
- Providing backend connectivity from roadside equipment to Traffic Control Centers, if needed or desired
- Generating, maintaining, and updating GID and other geospatial information. Note that responsibility for this item is to be determined, and the state and local DOTs may choose to delegate this role to another entity.
- Participating in standards development activities
- Training personnel in CICAS-V systems
- Implementing and maintaining connectivity from the VII backbone network to state and local DOT centers

2.6.3 USDOT

The USDOT may incorporate its role into its existing organizational structures. There are additional roles it may assume to enable the success of a nationwide deployment of CICAS-V. These roles include:

- Development of guidelines to assist state and local agencies in the installation, operation, and maintenance of CICAS-V systems;
- Development of training materials and training courses related to CICAS-V system installation, operation, and maintenance;
- Development of automated tools that can be used to assist in the deployment design of CICAS-V component deployments at specific intersections and in the performance monitoring of CICAS-V systems;
- Participation in joint working groups and standards activities to continually assess stakeholder needs with respect to CICAS-V and VII.

2.6.4 Vehicle Drivers

The primary user for the system is a light vehicle driver. The CICAS-V is intended to alert a driver to an impending intersection violation so that the driver can stop the vehicle in an appropriate manner and avoid crashes.

The contributing factors for intersection violations include the following:

- Obscured or obstructed vision
- Driver distraction
- Judgment errors

- Speeding
- Impairment including alcohol

CICAS-V is intended to address these factors, and it is important to note that the operation of CICAS-V does not depend in any way on these contributing factors. The DVI alert will be presented to the driver if needed, regardless of why the driver is not stopping. The driver response may vary depending on driver behavior and condition, so the overall effectiveness of CICAS-V may also vary based on the nature of the contributing factors.

2.6.5 Traffic Control Equipment Manufacturers

Traffic control equipment manufacturers may enhance and modify their organizations to incorporate CICAS-V into their product lines. This role includes ensuring that CICAS-V (and other related safety systems) remains in operation over the long term. Specifically, the manufacturer's role will include:

- Developing and producing new traffic control equipment that includes the hardware and software required for CICAS-V capabilities
- Retrofitting existing traffic control equipment to accommodate CICAS-V functionality
- Participating in standards activities
- Developing test and installation procedures for CICAS-V infrastructure-side equipment in conjunction with state and local DOTs
- Training personnel in CICAS-V systems
- Training state and local DOT personnel in the operation and maintenance of CICAS-V infrastructure-side equipment
- Maintaining application software for CICAS-V infrastructure-side equipment

The roles of manufacturers' trade support and standards organizations are represented in Section 2.6.7 below.

2.6.6 VII Network Operating Entity

The VII program is in the process of defining the role of a VII Network Operating Entity. This entity will be tasked with the implementation and management of all aspects of the VII network that include the wireless communication between a CICAS-V equipped vehicle and the VII RSE, communications across the backbone network, connectivity to VII Network end users, central processing systems required for network and applications support, and nationwide operation centers. The elements of the VII Network Operating Entity's role that are important to CICAS-V include the following:

- Implementing and maintaining the VII backbone network to include transmission equipment, computing systems, and operations centers that may be necessary to sustain the nationwide network
- Establishing and managing standards activities that are related to WAVE communications
- Establishing, managing, and enforcing policies related to the use of and access to systems that are part of the network; as well as data transmitted using the VII network

- Establishing, implementing, and managing a security program that addresses both physical and logical threats to the system
- Certifying software for compliance with the Federal Information Security Management Act (FISMA) and other applicable regulations

2.6.7 Organization Responsible for CICAS-V Guidelines and Standards

The organization that will be responsible for CICAS-V guidelines and standards has not yet been identified. The guidelines and standards organization will define the rules and procedures used to determine that CICAS-V equipped intersections are ready for operational use. At a minimum, when the CICAS-V system is ready for operational use at an intersection, the CICAS-V infrastructure-side equipment, the interfaces between CICAS-V and the traffic signal controller assembly, and all other related equipment must be performing to specified system-level parameters. The guidelines and standards organization will specify the system-level performance parameters, the guidelines for certification, and the guidelines for any diagnostic procedures. These roles are part of a set of issues that need to be resolved as part of the VII program.

2.7 Assumptions and Dependencies

The CICAS-V system is initially intended to work with "light vehicles". The term "light vehicles" refers to passenger vehicles sold or operated legally within the U.S., including sedans, light trucks, and vans.

It is assumed that appropriate driver warnings will alert the driver and allow appropriate countermeasures to be taken. That is, CICAS-V warnings should increase the likelihood that the driver will stop the vehicle and avoid a crash.

The driver response may vary depending on driver behavior and driving conditions, so the overall effectiveness of CICAS-V may also vary depending on the contributing factors. It is understood that vehicles traveling significantly over the speed limit may approach an intersection too fast for the CICAS-V systems to provide a warning to the driver in time for the vehicle to stop before entering the intersection.

Based on the current VII architecture, it is assumed that the CICAS-V equipped signalized intersection will have the following equipment:

- A WAVE Radio System
- Roadside equipment (RSE) including memory, interfaces, and an application processor for running the CICAS-V application
- One or more systems for positioning augmentation to aid vehicles in determining their position with sufficient accuracy
- A network connection for remote maintenance access, status reporting, and updates
- A means of determining the current SPaT data for all signal heads in the intersection

Similarly, it is assumed that the CICAS-V equipped vehicles will have the following equipment:

- A WAVE Radio System

- On-board equipment (OBE) including memory, interfaces, and an application processor for running the CICAS-V application
- Positioning system
- Vehicle Systems capable of reporting vehicle speed, deceleration, and braking status

2.8 Operational Scenarios

CICAS-V has four groups of operating scenarios – Startup/Validation, Normal Operation, System Failure, and Maintenance.

- The Startup/Validation Mode scenarios occur after CICAS-V equipment is installed at an intersection and provides a final test before going into normal operation.
- The Normal Operation Mode scenarios occur after the System has been placed in service. In these scenarios, a CICAS-V equipped vehicle is approaching a CICAS-V equipped intersection and all equipment is functioning correctly.
- System Failure Mode scenarios occur when either the intersection or vehicle fails a built-in test.
- Maintenance Mode scenarios cover system communication to backend or local networks.

Table 2 shows the relationship between the four groups of operating scenarios and the supporting data types that define states within the scenarios, and the functional requirements for the operational mode and data states.

Table 2 - CICAS-V Scenarios

<table>
<tr><th colspan="3">Operational Scenario Data Types</th><th>Requirement from CICAS-V ConOps</th></tr>
<tr><td rowspan="4">Startup/ Validation</td><td>Coverage</td><td rowspan="4"></td><td rowspan="4">• Before a CICAS-V intersection is put into operational service, it is put in Validation Mode to complete the testing of the cooperation between vehicles and the intersection.</td></tr>
<tr><td>Positioning</td></tr>
<tr><td>Geospatial Information</td></tr>
<tr><td>Phase and Timing</td></tr>
<tr><td rowspan="16">Normal Operation</td><td rowspan="4">Intersection Types</td><td>Stop Sign</td><td rowspan="16">• Alert potential violators of traffic control devices in time for the driver to take action to prevent a violation.
• Acceptable rate of false alarms and missed alarms when an alarm should have been issued.
• Work with transit signal priority and emergency vehicle signal preemption.
• Coexist with other collision avoidance systems, e.g., rear-end collision avoidance, lane change collision avoidance, roadway departure collision avoidance.
• Alert must be appropriate for most drivers, including inexperienced (e.g., teenaged) drivers and older drivers (e.g., slower reflexes, impaired hearing).
• Work in all weather and lighting conditions.
• Perform effectively in urban, suburban, and rural areas.
• Perform effectively in a wide range of different intersection approach geometries.
• Messages, warnings, icons, and other types of alerts that are effective and compatible with automotive human factors guidelines and OEMs' driver-vehicle interface principles and practices.
• Driver-vehicle interfaces need to follow Human Factors guidelines issued by the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA).</td></tr>
<tr><td>Flashing Red Light</td></tr>
<tr><td>Flashing Yellow Light</td></tr>
<tr><td>Traffic Signal</td></tr>
<tr><td rowspan="4">Traffic Signal Types</td><td>Fixed Signal Timing</td></tr>
<tr><td>Actuated Signal</td></tr>
<tr><td>Emergency Preemption</td></tr>
<tr><td>Advanced Signal Controller</td></tr>
<tr><td rowspan="6">Intersection Conditions</td><td>Right Turn Lane</td></tr>
<tr><td>Left Turn Lane</td></tr>
<tr><td>Positioning Services</td></tr>
<tr><td>Reduced Visibility</td></tr>
<tr><td>Speed Limit</td></tr>
<tr><td>Road Conditions</td></tr>
<tr><td rowspan="2">Driver-Vehicle Interface</td><td>Alert of Approaching Intersection</td></tr>
<tr><td>Warning of Probable Red Light/Stop Sign Violation</td></tr>
<tr><td rowspan="4">System Failure</td><td>Geospatial Database Errors</td><td rowspan="4"></td><td rowspan="4">• If the vehicle receives no messages from the intersection, it must assume that the intersection is not equipped for CICAS-V communications.
• When a CICAS-V intersection takes itself off-line as the result of a self-diagnosed fault, it must report its off-line status.
• A vehicle needs to inform the driver when the in-vehicle CICAS-V system is not working.</td></tr>
<tr><td>GID Errors</td></tr>
<tr><td>Communication Errors</td></tr>
<tr><td>Vehicle Equipment</td></tr>
<tr><td rowspan="2">Maintenance</td><td>Network Interface</td><td rowspan="2"></td><td rowspan="2">• The RSE must be able to communicate with the backend center for security validation and software updates.</td></tr>
<tr><td>Local Interface</td></tr>
</table>

2.8.1 Startup and Intersection Validation Scenarios

Conditions: *The CICAS-V Infrastructure components have been installed successfully as described in the CICAS-V Intersection installation handbook. Before the intersection is put "in service", it is put in Validation Mode to complete the testing of the cooperation* *between vehicles and the infrastructure-side equipment. Maintenance vehicles that are CICAS-V equipped will be used for validating positioning accuracy, WAVE radio communications, messages (timeliness and correctness), signal phase and timing accuracy, and signal head/lane matching accuracy.*

Once CICAS-V has been installed at an intersection, the CICAS-V RSE is set to Validation Mode. A service announcement communicates this state to approaching maintenance vehicles. While the CICAS-V system is in Validation Mode, the maintenance vehicles traversing the intersection will need to provide feedback to the intersection RSE on their movements through the intersection so that the CICAS-V system can correlate these movements with its internal information, including the geospatial database and the signal phase and timing information, to validate that the system is performing as expected. The intersection will normally remain in Validation Mode until the appropriate validation requirements are met. While the CICAS-V system is in Validation Mode, its location will be included in all relevant geospatial databases that are propagated to vehicles that regularly traverse an area.

The specific types of data collection that will be performed as part of the validation process include the following:

Coverage Validation Data: CICAS-V equipped maintenance vehicles will record their location and a measure of data quality, such as packet error rate. They will then send this information to the intersection RSE, which will develop a coverage map for its specific transmitter. This actual coverage map will be compared to the intersection design's minimal required coverage map, which will be defined in the performance specifications. If the coverage is not better than the minimum required coverage, the intersection will remain in Validation Mode.

Positioning Validation Data: CICAS-V equipped maintenance vehicles will record positioning errors, positioning system data, and other available parameters that they detect as they approach that intersection. This information will be sent to the intersection RSE before the vehicle leaves the area. The actual positioning data from vehicles approaching the intersection will be compared to the positioning system requirements in the CICAS-V intersection.

Geospatial Information Validation Data: CICAS-V equipped maintenance vehicles will broadcast a message containing their location, speed, and direction. These messages will show the movement of the vehicles through the intersection at the lane level and this information can be used to determine whether the GID is correct.

Phase and Timing Validation Data: CICAS-V equipped maintenance vehicles will broadcast a message containing their location, speed, and direction. The CICAS-V intersection RSE will receive these messages and develop a control map of the intersection. This control map will correlate movement of vehicles through the intersection with data from the traffic signal controller assembly as to which lights are active. The CICAS-V management system will validate that the control map corresponds to the broadcast signal phase and timing from the intersection.

Once the requirements to put the CICAS-V intersection "in service" are met, the responsible organization will change the intersection from Validation Mode to Normal Operation Mode.

2.8.2 Normal Operation Scenarios

The following scenarios describe the normal operations of the CICAS-V system. In each of these scenarios, the state of the driver is unknown. The driver may be attentive, inattentive, distracted, incapacitated, or impaired. The driver may have the intent to obey or violate the traffic control he or she is approaching.

2.8.2.1 Simple Traffic Signal Approach

Conditions: *The CICAS-V enabled vehicle is approaching a CICAS-V enabled traffic signal at a simple intersection with no dedicated turn lanes, where all vehicles on the same approach have the same traffic signal indication.*

As the vehicle approaches a CICAS-V enabled intersection and comes in range of the system's communications, the vehicle receives a CICAS-V service announcement on the control channel indicating the availability of the intersection's GID, area geospatial information, the status of the intersection, and positioning corrections. The vehicle decides if it needs either or both of the GID or the area geospatial information broadcast. If necessary, the vehicle switches to the service channel and receives the intersection's GID and/or the area geospatial information. The vehicle stores the new GID and/or geospatial information in its data store, replacing any older information. The vehicle decodes the intersection GID and performs geospatial matching to locate itself relative to the intersection at the road or lane level, whichever is appropriate.

The vehicle then determines that the driver is approaching a CICAS-V enabled intersection with a single traffic signal indication, and that the driver has to stop at the signal, if it is red. At an appropriate distance from the intersection, the vehicle may alert the driver that a traffic signal is ahead. If the vehicle determines that the vehicle will come to a stop before a violation occurs, no warning will be issued. If the vehicle continues to approach the signal without slowing down sufficiently to stop when the light is red, the vehicle will issue a warning.

The distance and timing of the alert and warning will be calculated based on the current operating conditions of the vehicle, roadway geometry, and traffic signal state. The calculation may also include roadway conditions, if this information is available.

The alert/warning may be in the form of an audio signal, either tone or voice, possibly coupled with visual and/or haptic indications to the driver, depending on the DVI decisions made by the vehicle's OEM. Also, there may be some preparation for a possible crash of the vehicle, such as pre-tensioning of safety belts or priming of brake assistance systems. This preparation depends on the individual decisions of the vehicle's OEM. The driver may or may not be aware of some of these crash mitigation actions.

With a driver who is willing to violate the traffic control, alerts and warnings of an upcoming traffic control may or may not have an effect on the driver's decision about stopping. For a driver who is distracted or otherwise inattentive, the alerts and warnings are intended to bring the driver's attention back to the driving situation so that the proper decisions can be made.

If CICAS-V, in the future, is implemented with traffic signal adaptation, it may improve the situation by keeping the traffic signal in an 'all-red' phase long enough to permit the violating driver to clear the intersection before the cross-traffic is permitted to enter. However, this may require a mechanism at the intersection to prevent drivers from learning that they can abuse the system.

2.8.2.2 Simple Stop Sign Approach

Conditions: *The CICAS-V enabled vehicle is approaching a CICAS-V enabled, simple stop sign controlled intersection. It is presumed that the vehicle has previously obtained GID for the intersection as described in the prior scenario.*

The vehicle determines that the driver is approaching a CICAS-V enabled intersection with a stop sign control. At an appropriate distance from the intersection, the vehicle may alert the driver that a stop sign is ahead. If the vehicle determines that the driver is going to stop, no warning will be issued. If the vehicle continues to approach the stop sign without slowing down sufficiently to stop, the vehicle issues a warning.

The distance and timing of the alert and warning will be calculated based on the vehicle operating conditions and road geometry. The calculation may also include roadway conditions, if this information is available.

This warning is likely to be in the form of a multi-modality alert. The alert or warning may be in the form of an audio signal, either tone or voice, possibly coupled with visual and/or haptic indications to the driver, depending on the DVI decisions made by the vehicle's OEM. Also, there may be some preparation for a possible crash in the vehicle, such as pre-tensioning of safety belts or priming of brake assistance systems, again depending on the individual decisions of the vehicle's OEM. The driver may or may not be aware of some of these crash mitigation actions.

With a driver who is willing to violate the traffic control, alerts and warnings of an upcoming traffic control may or may not have an effect on the driver's decision about stopping.

2.8.2.3 Intersections with Dedicated Left or Right Turn Lanes

Conditions: *The CICAS-V enabled vehicle is approaching a CICAS-V enabled intersection with multiple traffic signal indications on the approach.*

The normal operation scenario for this case is the same as the one for the simple signal approach since it is assumed that the vehicle is able to lane match itself through positioning and the intersection GID, and therefore identify which traffic signal indication pertains to its current location.

Appropriate protocols will have to be developed for the case in which a warning is needed but it cannot be determined which of the approach lanes the vehicle will take to pass through the intersection (e.g., prior to formation of the turn lane).

Figure 5 illustrates the situation where a vehicle enters a dedicated left turn lane (the eastbound approach in this illustration) that has a red left turn indication when the through lanes on the approach have a green indication. The signal indications for the movements on this approach can be seen just below the approach. A red arrow is shown for left turn and green arrows are shown for the through and right turn movements.

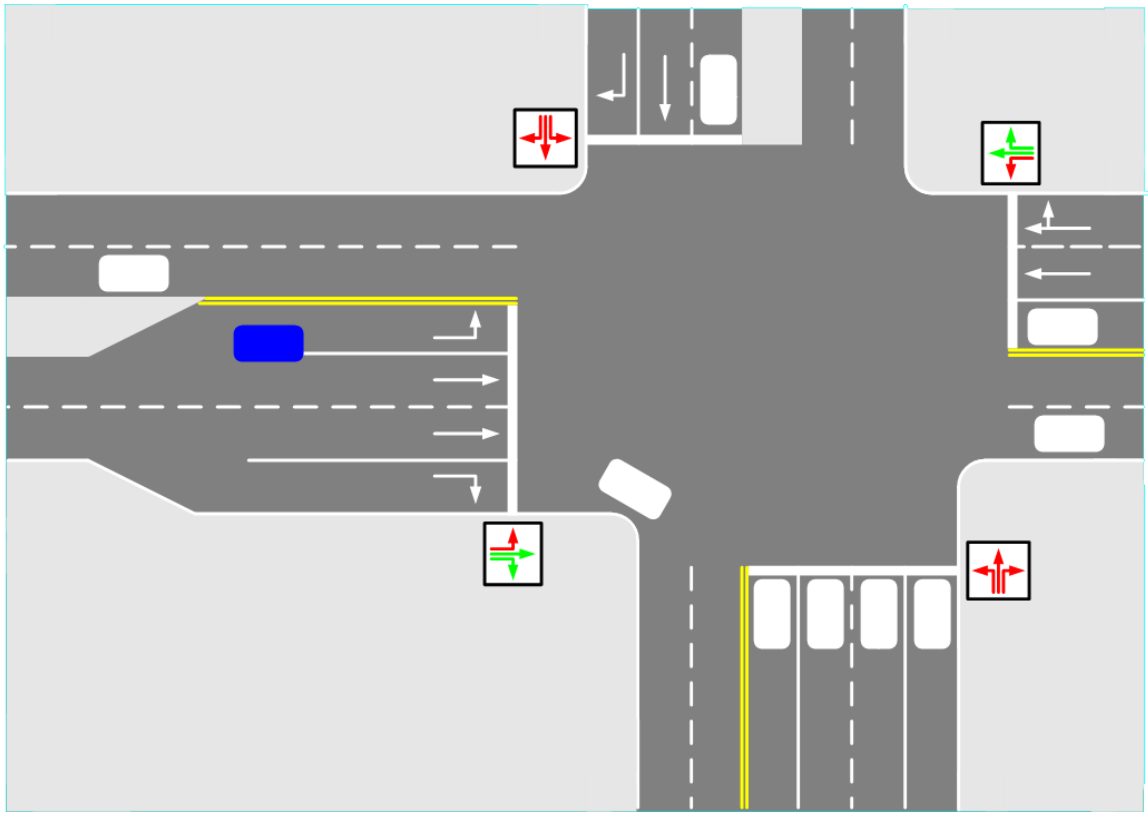

Figure 5 - Vehicle Entering a Dedicated Left Turn Lane

2.8.2.4 Approaching an Intersection with Limited Positioning Services

If the vehicle's positioning system is operating, there are two levels of local positioning limitations:

1. Vehicle is not able to position itself with WhichRoad precision, where needed.
2. Vehicle is not able to position itself with WhichLane precision, where needed.

In the first case, the vehicle's CICAS-V processes will be inactive for this intersection. In the second case, there are three possibilities, if WhichRoad positioning can be maintained:

1. The vehicle's CICAS-V processes are inactive for this intersection.
2. The vehicle's CICAS-V processes will only consider the signals for the through-lanes.
3. The vehicle's CICAS-V processes will determine the violation potential for all reasonable/possible approaches and will consider the signals if there is a consensus for signal state across all approaches. (e.g. "all lights red", "all lights green").

The consistent inability of vehicles to position themselves at a specific intersection should be detected through ongoing monitoring and validation.

2.8.2.5 Flashing Traffic Signal

If a CICAS-V equipped traffic signal goes into flashing mode, the CICAS-V system will recognize the flashing indication (e.g., flashing red light) and broadcast the appropriate information in the message set sent to the vehicle. As in normal CICAS-V operation, the CICAS-V enabled vehicle will receive the message set, recognizing the flashing signal indication and react to this information as prescribed in the CICAS-V warning and alert algorithms. Drivers and CICAS-V should both treat a flashing red traffic signal as a stop sign (i.e., driver must stop the vehicle).

2.8.2.6 Reduced Visibility

There are two types of reduced visibility scenarios that CICAS-V must consider. The first is when the reduced visibility is caused by weather, such as rain, snow, fog, or time of day (for darkness or sun glare). The second is when the reduced visibility is caused by obstructions in the driver’s line of sight to the traffic control, e.g., vegetation, or a temporary object (such as a large parked or moving truck that blocks a driver’s line of sight). In both cases, the presence of CICAS-V in the vehicle and in the intersection enables the driver to be alerted about the presence of the traffic control and alerted to the potential for a violation. The system will react as it would if there was no reduced visibility, although the driver response may differ because the driver may not be able to visually confirm the state of the traffic control device.

2.8.3 System Error and Failure Scenarios

This section describes some of the scenarios that may occur when various aspects of the system fail to operate.

2.8.3.1 Geospatial Database Errors

A CICAS-V geospatial database contains the locations of CICAS-V intersections. Appropriate information from this database will be broadcast to CICAS-V enabled vehicles entering an area, possibly covering multiple intersections. Stop sign information in this database can have two types of failures. These failures are discussed below.

Inclusion of Nonexistent Stop Signs – Inclusion of nonexistent stop signs may increase potential traffic conflicts if drivers stop for no apparent reason. This situation will certainly lead to annoyance and reduced trust, both for the driver responding to the nonexistent stop sign warnings, and other drivers in the area trying to figure out what's going on. This might be detected through statistical analysis of probe data start/stop events as with the omission of stop signs above.

2.8.3.2 GID Errors

GID errors for CICAS-V intersections mean that the geospatial data the vehicle receives from the intersection does not adequately reflect the actual geometry of the intersection or, for signalized intersections, the assignment of signal heads to the lanes. When a new CICAS-V intersection is put online, the validation procedures of the DOT operating the intersection should detect those errors and correct them before the intersection becomes active. However, temporary lane closures or re-routings due to maintenance or construction activities, police actions, or roadway debris may not be reflected in the geospatial information database. When this occurs, a vehicle might experience a false alert. For long-term lane changes, it is the responsibility of the DOT operating the intersection to put the intersection "off-line", i.e., in *inoperative* state, until a correct GID can be uploaded or the lanes are restored to their original states.

- ***Communication Failure***

Communication failure means that the vehicle does not receive some or all messages from the intersection. The cause of the communication failure may be due to the intersection's equipment, the vehicle's equipment, or interference from temporary, radio-blocking objects (e.g., a large truck) in the area. If the vehicle receives no messages from the intersection, it must assume that the intersection is not CICAS-V equipped.

The discussions below address the situation where the communication problem lies with the intersection and the vehicle is able to receive some WAVE messages, but not others.

Service Announcement – If the vehicle does not receive a service announcement, then it will not switch to another channel to receive a GID or geospatial information broadcast. The vehicle can determine, by its reception of other messages (such as signal phase and timing), that it is approaching a CICAS-V enabled intersection. However, the vehicle should communicate the malfunction to the next CICAS-V RSE.

Geospatial Information – If the vehicle does not receive a geospatial information broadcast (whether of the intersection GID or of area-wide geospatial information), then its actions depend on whether the vehicle has a GID of the intersection in on-board data storage. If the intersection's GID is available, then the vehicle can use this GID, although there is a risk that the information may be inaccurate, depending on its age. Otherwise the CICAS-V processes will be inactive for this intersection.

Traffic Signal Phase and Timing – If no traffic signal phase and timing information is received for CICAS-V enabled signalized intersections, then the vehicle's CICAS-V processes will be inactive for that intersection. If one traffic signal phase and timing message is received, then the response will depend on the intersection. If the traffic signal is on a fixed schedule, then the vehicle can determine from the information contained in the message when the light is changing and can function in the default way. If it is a traffic-actuated signal, then the reaction of the vehicle will depend on the current phase and timing information it receives.

Positioning Correction – If the vehicle does not receive a positioning correction message, then the CICAS-V response scenario will be that of an intersection with limited positioning services as described in Section 2.8.2.4.

2.8.4 Maintenance Scenarios

Conditions: *The CICAS-V Intersection is "in service" and a diagnostic self-test is set to trigger at an interval as recommended by the operating entity. This diagnostic functionality is identical to the Validation Mode, but unlike the Validation Mode, where there is manual intervention to put the system "in service", the CICAS-V application at the intersection automatically switches in and out of diagnostic self-testing.*

The positioning accuracy, WAVE radio communications, messages (timeliness and correctness), signal phase and timing accuracy, and signal head/lane matching accuracy of CICAS-V intersections must be periodically verified. Diagnostic data to verify that the system is functioning as required will be collected from vehicles. Maintenance vehicles do not have to be used to communicate with the system for diagnostic testing. However, if a problem is detected, the CICAS-V application must automatically take itself "out of service" and send notification to traffic operations that there is a problem.

3 Decomposition View

The Decomposition View provides the system developers and developers of other interfacing systems with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system. System designers will use this view to design each module so that it performs the required functions and each requirement in this specification will be allocated to one or more of the modules described in this view.

The functional decompositions are illustrated by block diagrams as shown in Figure 6.

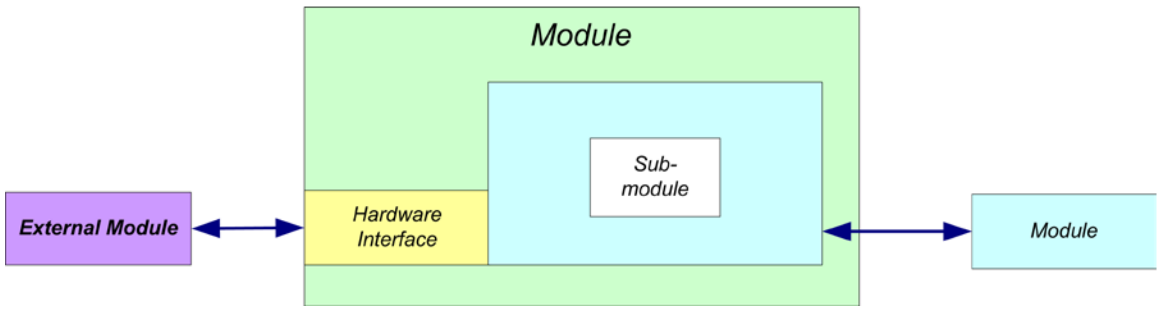

Figure 6 - Legend for Decomposition Diagrams

The modules identified in this view do not represent a mandatory design description. The modules are based on the functional requirements of the system. The final design may further decompose these modules into smaller components to allow for specialization of modules to specific tasks, reuse existing code from other sources, or to optimize how the coding will be performed.

3.1 OBE Functional Decomposition

As shown in Figure 7, the OBE is decomposed into the following functional modules:

- OBE Wireless Communication Module
- OBE Validation Module
- OBE Situation Assessment Module
- OBE Vehicle System Interface Module
- OBE Driver-Vehicle Interface Module

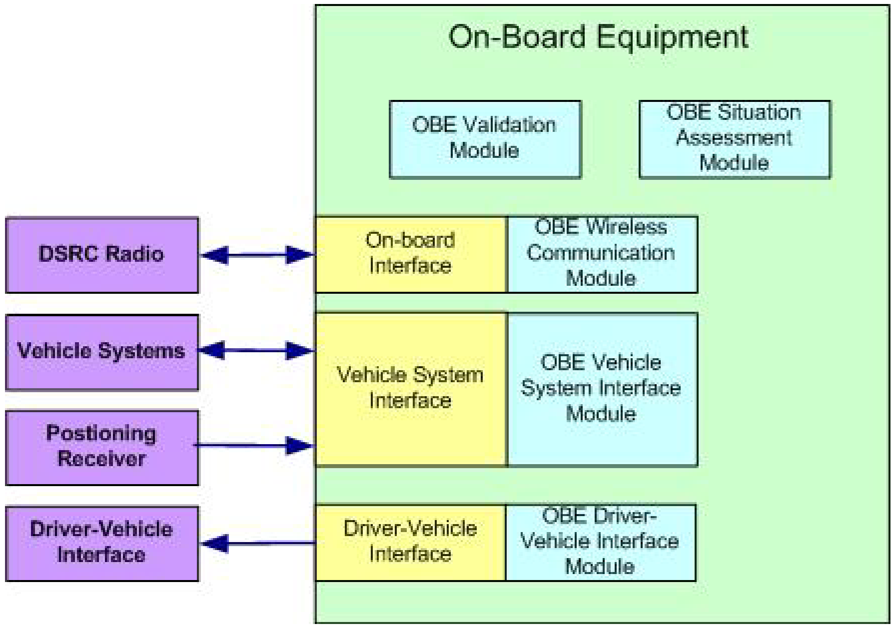

Figure 7 - OBE Functional Modules Overview

These modules and their interconnectivity will be discussed in more detail in the following sections.

3.1.1 OBE Vehicle System Interface Module

The OBE Vehicle System Interface Module, shown in Figure 8, will be responsible for wired vehicle communication between the OBE and all other physical devices.

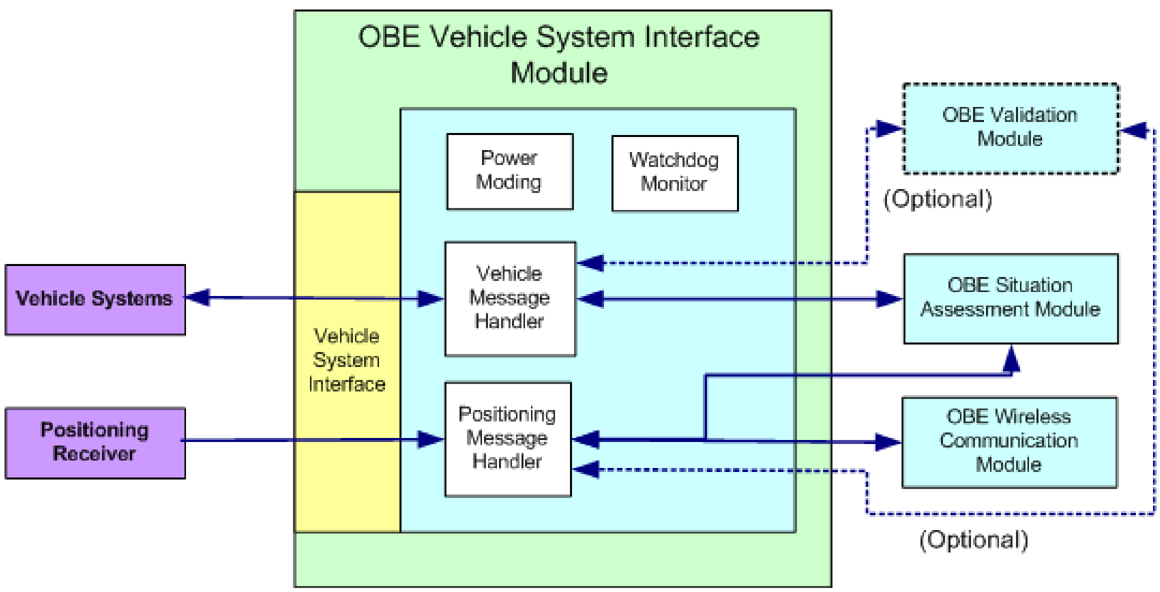

Figure 8 - OBE Vehicle Interface Module

This module will be the initial module to start in the OBE system. It determines the proper operational power mode for the OBE. There are four possible modes:

- System Off – The system has been completely turned off. This is the mode that occurs after "Shutdown" mode. In this mode the OBE will be capable of monitoring the vehicle ignition (IGN) wire state and changing to “Booting” mode within 1 second of a change of IGN state.

- “Booting” – This state is initiated by transition of the IGN signal state to “On”. The system is powered up, modules loaded, and power-on self testing is performed. This mode is transient and cannot take longer than 20 seconds. In this mode, the OBE will ignore all inputs from the IGN wire. The OBE will be capable of ignoring multiple, sporadically timed changes of IGN state while in “Booting” Mode and will only respond to current IGN state once the OBE has entered “System On” mode.
- “System On” – All hardware is fully powered and operational. System is operating fully. The system has loaded the defined applications. When this state is first entered, the OBE will check and act on the IGN signal state.
- ”Shutdown” – This state is initiated by transition of the IGN signal state to “Off”. This is the OBE’s mode during the process of transitioning from “System On” to “System Off”. In this mode final transition occurs. The OBE will be capable of ignoring multiple, sporadically timed changes of IGN state while in “Shutdown” mode. This mode is transient and cannot take longer than 20 seconds.

The module will generate a power mode signal which will indicate to the other modules the power mode of the OBE system.

The module will function as a watchdog for the OBE system. When abnormal operation is detected, it will take corrective action. The corrective action can include:

- determining the cause of the abnormal operation by testing the individual modules for correct operation;
- restarting the OBE system and its drivers; and
- disabling the OBE system and alerting the driver to have the system serviced.

This module will use Controller Area Network (CAN) Message information in the OBE Vehicle System Interface data store to translate OEM-specific information from the vehicle CAN network to a message format. Vehicle parameters that may be reported on a cyclic time schedule will be used by the OBE Situation Assessment Module.

A positioning system may be integrated into the vehicle and the data received from the vehicle CAN network. Alternatively, the positioning receiver could interface directly with the Vehicle System Interface Module or be integrated within the Vehicle System Interface Module.

3.1.2 OBE Wireless Communication Module

The OBE Wireless Communication Module, shown in Figure 9, handles all wireless communication between the OBE components and external systems. These communications will use the WAVE short message protocol as defined in IEEE 1609.3 and DSRC radio communications.

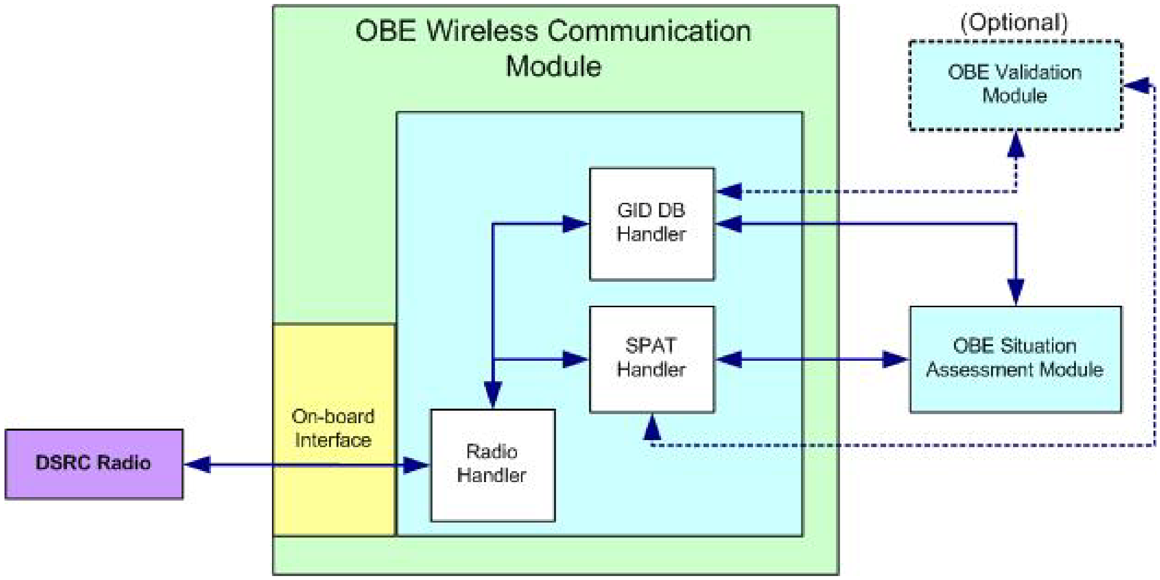

Figure 9 - OBE Wireless Communication Module

The OBE Wireless Communication Module will start after receiving a signal from the OBE Vehicle System Interface Module. The module will run a self-test upon startup to verify that all components are functioning correctly. During normal operation, diagnostic self-testing will be performed continuously. If a failure is detected, the failure will be transmitted to the OBE Vehicle System Interface Module upon request. The module will respond to a status inquiry from the OBE Vehicle System Interface with a status message that indicates normal function or identifies the errors detected. The module will communicate with the DSRC radio which is part of the VII system within the vehicle.

Messages will be received by the on-board interface, authenticated, converted from WAVE protocol standard to internal message format, and grouped according to their function and destination. The module will monitor for receipt of the RSE service announcements and will generate an error message if the announcement is not received. The messages will then be transferred to the appropriate module. The message will be delivered to:

- OBE Situation Assessment Module – all information about the current or future status of intersection violation criteria will be delivered to this module
- OBE Validation Module – all data needed to determine DSRC availability and accuracy will be delivered to this module for validation

When the module receives messages from the OBE system, it will convert the messages as required to meet the WAVE protocol standard and send the message to the on-board interface for delivery to the DSRC radio.

3.1.3 OBE Situation Assessment Module

The OBE Situation Assessment Module will be the core module for the CICAS-V system for intersections and is shown in Figure 10. It will determine the actual location of the vehicle including

- the actual lane of travel;
- any nearby intersection that may be necessary to monitor; and

- the CICAS-V equipped intersection through which the vehicle will next pass.

Using this information and additional data from the OBE Vehicle System Interface Module, algorithms will determine the likelihood that a vehicle will enter an intersection in violation of a traffic control signal or stop sign. If this likelihood is significant it will issue a warning to the OBE Driver-Vehicle Interface Module for driver notification.

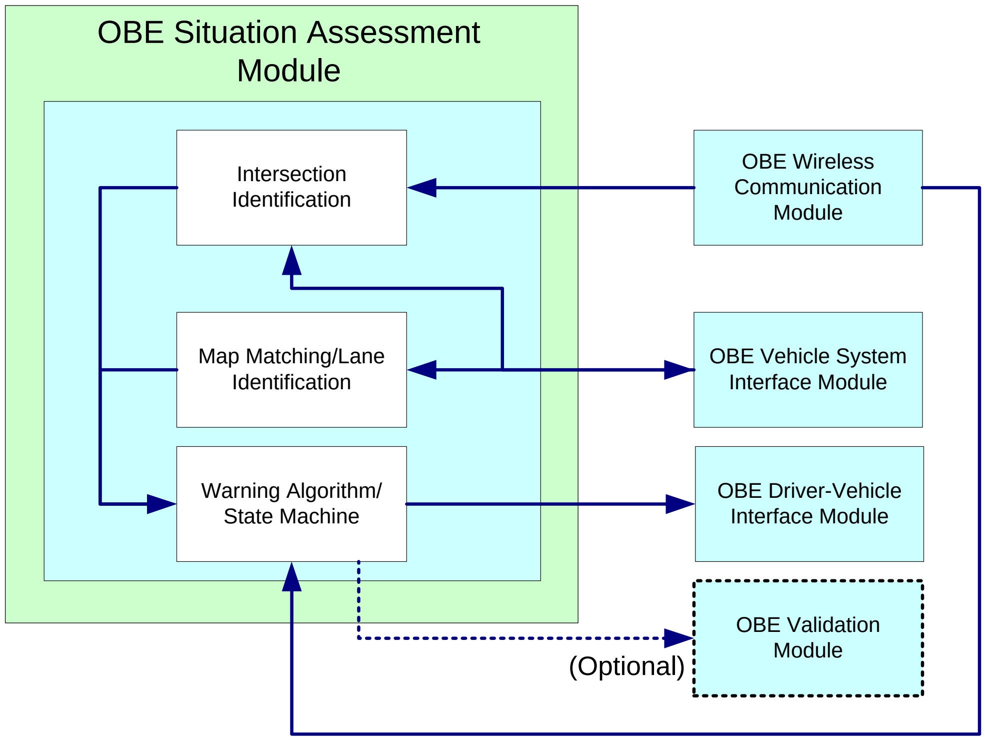

Figure 10 - OBE Situation Assessment Module

The OBE Situation Assessment Module will start after receiving a signal from the OBE Vehicle System Interface Module. The module will run a self-test upon startup to verify that all components are functioning correctly. During normal operation, diagnostic self-testing will be performed continuously.

This module will also have an internal watchdog function which will validate process outputs. Process outputs which are determined to be invalid will be flagged and the process re-run. If an output is invalid twice, the process will be considered to be in failure. If any failure is detected, the failure will be transmitted to the OBE Vehicle System Interface Module.

The module will respond to a status inquiry from the OBE Vehicle System Interface with a status message that indicates normal function or identifies the errors detected.

The OBE Situation Assessment Module will monitor the vehicle status and infrastructure status. This module will receive all geospatial and intersection GID data transmitted via the OBE Wireless Communication Module and all position information received via the OBE Vehicle System Interface Module. This data will be used to update appropriate local data stores when necessary.

The intersection location, nearby intersections, and lane of travel will be mapped to the GID and recorded. The data will be analyzed to determine which intersection the vehicle is most likely to enter next and the likelihood that a vehicle will enter the intersection in violation of a traffic control signal or stop sign.

Positioning correction data will be received from the OBE Wireless Communication Module and the OBE Vehicle System Interface Module. The module will then select one source of corrections depending on the type of correction and where it is generated. Generally speaking, locally-generated correction data is preferred over correction data generated at a city or national level. It is expected that the positioning correction resulting from this data will be more precise.

3.1.4 OBE Driver-Vehicle Interface Module

The OBE Driver-Vehicle Interface Module, shown in Figure 11 will maintain the display and audio interfaces to the driver as needed during normal and alert operations.

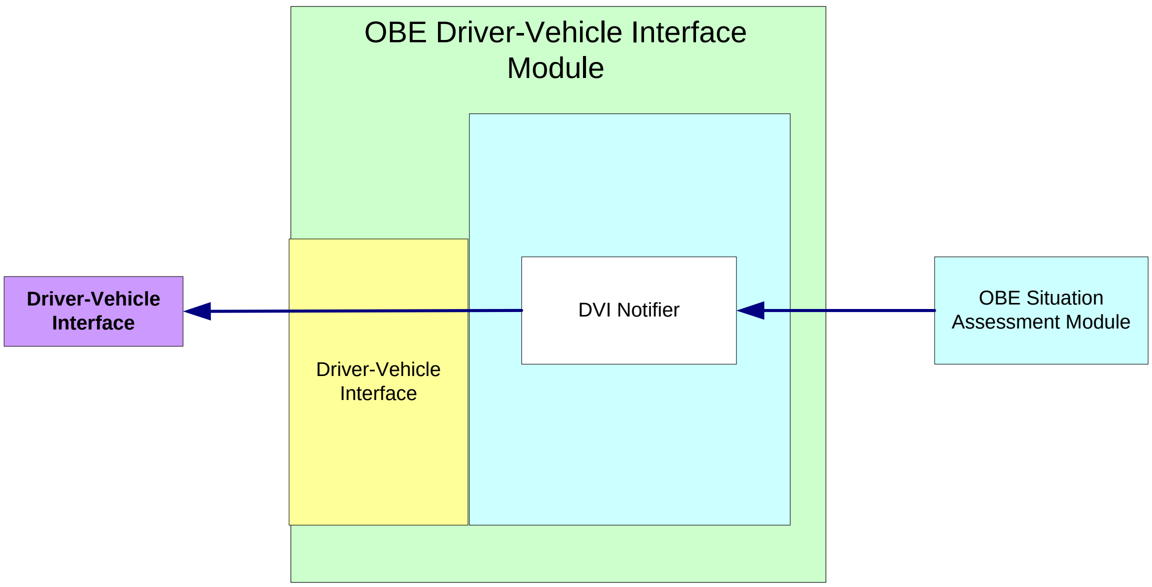

Figure 11 - OBE Driver-Vehicle Interface Module

The OBE Driver-Vehicle Interface Module will start after receiving a signal from the OBE Vehicle System Interface Module. The module will run a self-test upon startup to verify that all components are functioning correctly. During normal operation, diagnostic self-testing will be performed continuously. If a failure is detected, the failure will be transmitted to the OBE Vehicle System Interface Module upon request.

The module will provide the driver with:

- alerts when approaching a CICAS-V intersection;
- multi-modal warnings of potential impending violations; and
- alerts for failure of the OBE system.

The actual driver alert/warning form will be dependent on the OEM vehicle design decisions and the recommendations of the Human Factor Study Group.

3.1.5 OBE Validation Module

The OBE Validation Module, shown in Figure 12, will be used to evaluate the DSRC integrity and positioning availability and accuracy for the CICAS-V system applications at specific intersections.

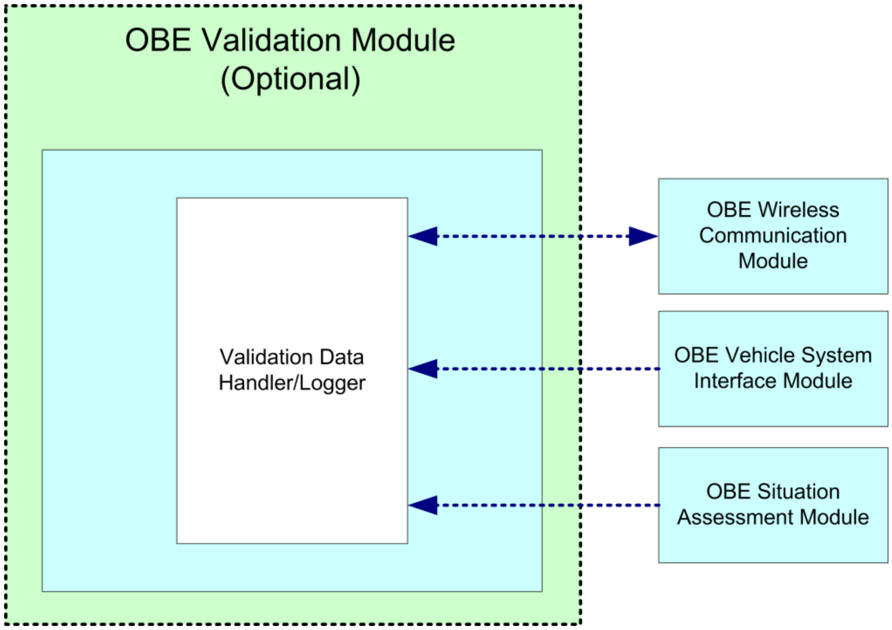

Figure 12 - OBE Validation Module

The functionality of this module is only required for Maintenance Vehicles participating in the CICAS-V validation of intersection equipment and data. This functionality could also be provided by stand-alone components that are not integrated with the other CICAS-V OBE components.

3.2 RSE Functional Decomposition

As shown in Figure 13, the RSE is decomposed into the following functional modules:

- Integrity Module
- Roadside Interface Module
- Traffic Signal Module
- GID Module
- Vehicle Status Module
- Validation Module

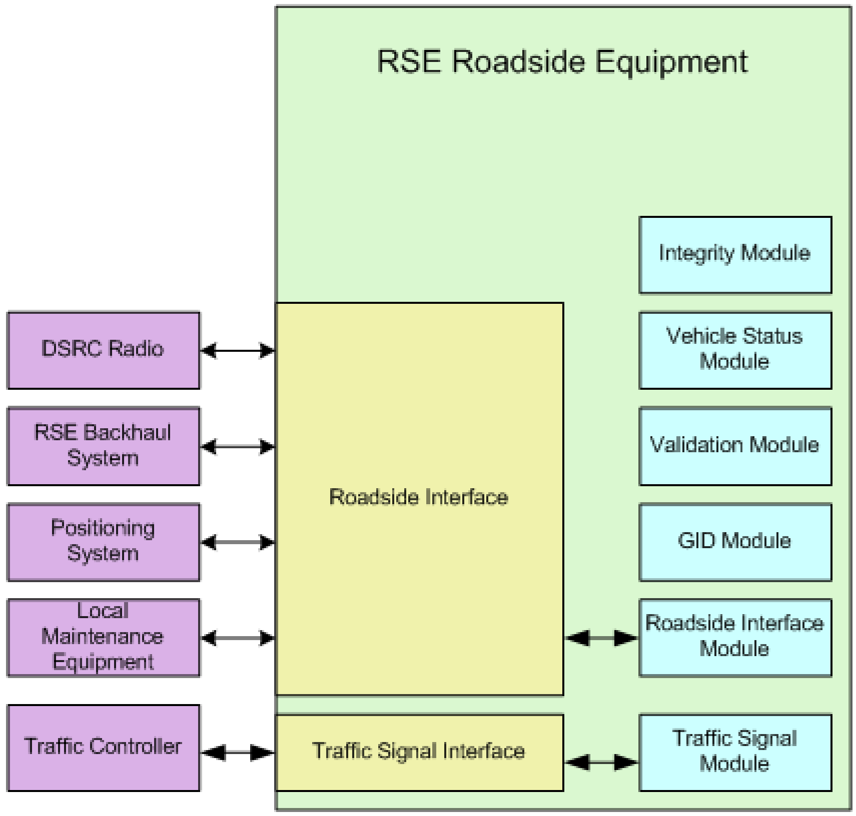

Figure 13 - RSE Functional Modules

These modules will be discussed in more detail in the following sections.

3.2.1 RSE Integrity Module

The Integrity Module is the first process started at system startup. Upon power-up the Integrity Module runs a startup self-test to verify that the hardware is functioning properly. Beginning with the Roadside Interface Module, the Integrity Module starts and monitors the remaining RSE processes.

Periodically, during Normal Operation, the Integrity Module runs additional diagnostic tests to check the system health. The module monitors the health of each process in the system and signals for shutdown or restart of the processes when required. It performs a "watchdog" function by periodically sending a status request message to each module. The other modules respond with a status message which indicates normal function or identifies any process errors that have been detected.

A status response containing an error message indicates that a module is in an error state. Failure of a module to respond to the status request within a preset time also signals an error state. If the Integrity Module detects an error state in another module in two consecutive status requests, the other module is declared "failed" and the system goes into Failure Mode. While in Failure Mode, the Integrity Module tries to restore the system to a normal state. The first response will be to kill and restart the processes that are in an error state. If this does not restore the system, the next step is to reboot.

The Integrity Module records all internal errors and reports them to the CICAS-V management system.

Figure 14 shows a block diagram of the Integrity Module and the other modules with which it communicates.

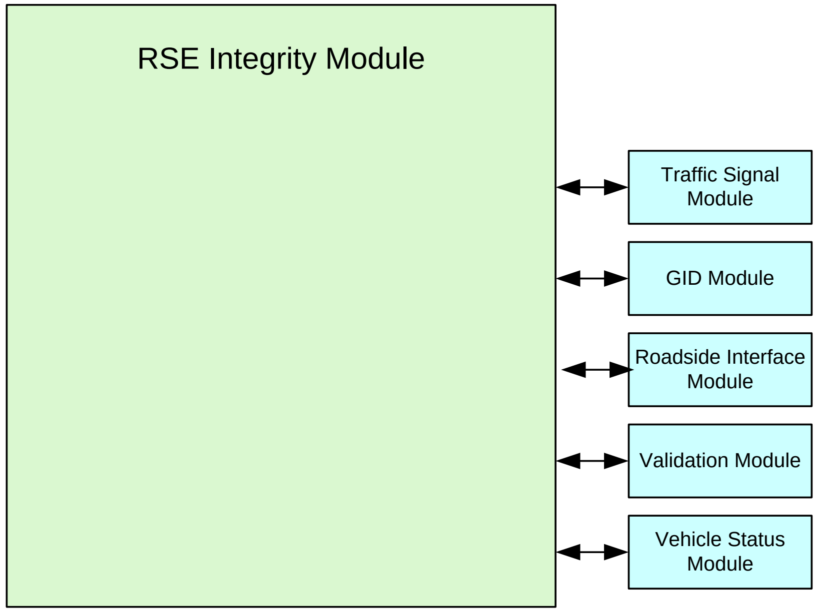

Figure 14 - RSE Integrity Module

3.2.2 RSE Roadside Interface Module

The Roadside Interface Module manages all communications with external devices except the traffic signal control equipment. Figure 15 shows external message sources on the left and the internal message sources on the right. Messages from other modules to the DSRC radio or the roadside network are sent to the Roadside Interface Module, which formats the messages and sends them to the appropriate destinations.

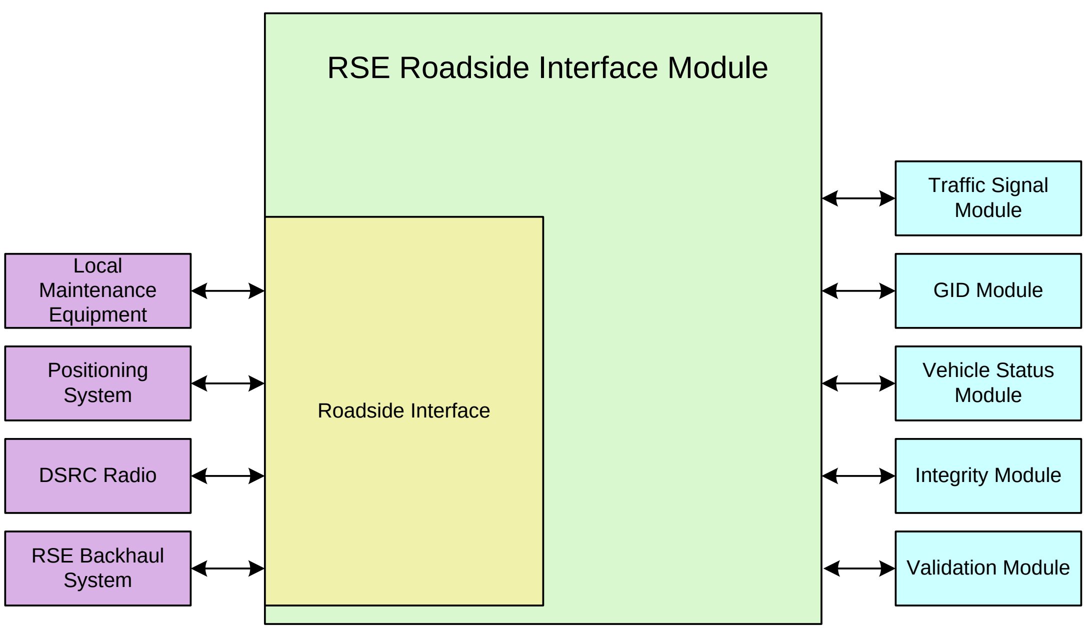

Figure 15 - RSE Roadside Interface Module

The Roadside Interface Module will start after receiving a signal from the Integrity Module. The module receives data from other modules, determines the destination, schedules the broadcast timing for the messages, generates the messages in proper format, and dispatches these messages for delivery.

Messages which are destined for the DSRC radio will meet the WAVE protocol standard. The WAVE short message protocol stack is defined in IEEE Standard 1609.3. Messages which are received from or destined for external networked devices will use Transmission Control Protocol/Internet Protocol (TCP/IP). The Ethernet protocol stack is defined in IEEE Standard 802.3. The hardware interface for the Ethernet interface will be 10/100BaseT. The details of the communication format and interface are to be defined by the VII program.

The WAVE broadcast messages from RSE to OBE will include the following types of messages:

- Service announcement
- Positioning Correction
- Signal phase & timing
- System health & status
- Geometric Intersection Description

At the beginning of the development, a single channel (Control Channel) will be used for all the CICAS-V DSRC messages. If during the development it becomes necessary to use multiple channels to communicate, the scheduler will assign the appropriate channel for outgoing messages.

There are two types of incoming messages from the OBE:

- Validation related messages: When the RSE is in Validation Mode, the RSE may receive validation messages from the testing vehicles.
- Vehicle warning status message: When a vehicle issues a warning to the driver, it also sends this message to the RSE.

Validation related messages and heartbeat messages will be forwarded to the Validation Module.

Positioning information will be received from a positioning system receiver (embedded or a plug-in commercial grade receiver), and possibly another receiver that is capable of receiving positioning correction information from an external link.

The Roadside Interface Module will be designed to allow an engineering team to change parameters for each of the RSE modules without the need to recompile the software. It will receive up-to-date configurable parameter settings for each module and store the settings for the other modules to access. Upon request for configuration data, the module will create and send the data to the requesting module.

3.2.3 RSE Traffic Signal Module

The Traffic Signal Module receives phase, timing, and raw traffic sensor data for all signal heads from the traffic controller. Figure 16 shows the block diagram for the Traffic Signal Processing Module.

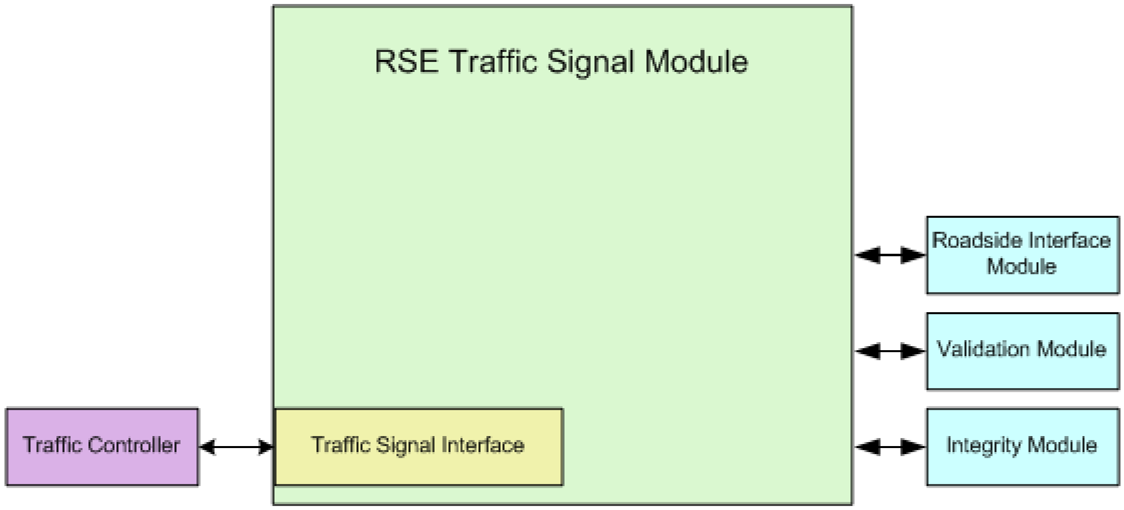

Figure 16 - RSE Traffic Signal Module

The Traffic Signal Module will start after receiving a signal from the Integrity Module. It requests configuration data from the Roadside Interface Module. The module will store the cycle timing data and the calculated predicted phase and timing data received from the traffic controller. When a signal data request is received from the RSE Roadside Interface Module, the module will query the stored data, format a message, and send the information to the requestor.

The Traffic Signal Interface provides a way for the system to obtain information about the current state (color) of traffic signals and the timing information about when the signals will change state. The electrical and data communication interfaces will be determined by their availability on the traffic controller. In some cases, this information may be provided through the physical interface associated with the Roadside Interface. The message set for this interface will need to be defined or suitable message sets within existing standards (e.g. NTCIP 1202 or NTCIP 1210) will need to be identified.

3.2.4 RSE GID Module

The GID Module receives the current geometric intersection description data, stores it, and sends the data to other modules. Figure 17 shows the block diagram for the GID Module.

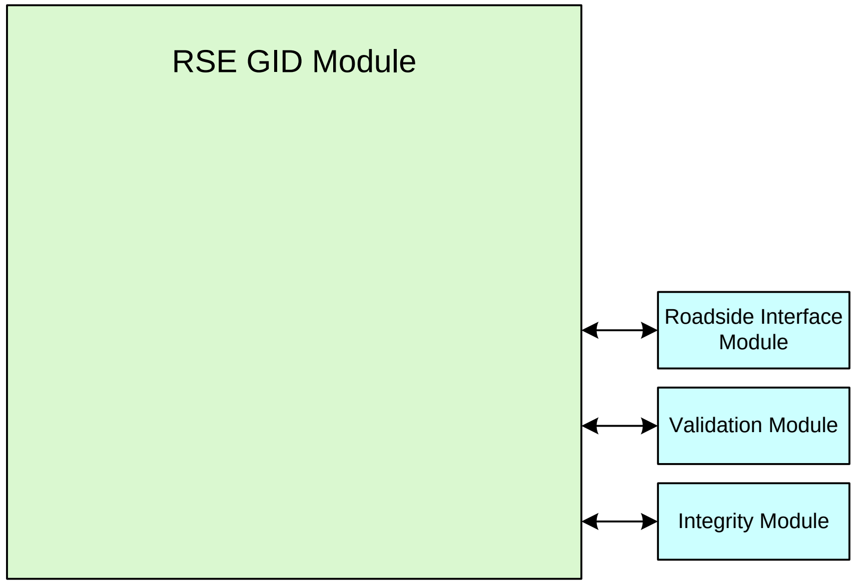

Figure 17 - RSE GID Module

The GID Module will start after receiving a signal from the Integrity Module. It requests configuration data from the Roadside Interface Module.

Using a "push" of the GID data is preferable to a request based distribution strategy and will be used for the implementation of the CICAS-V, although either would be acceptable.

Each time new data is received, the data will have an associated version number. The version numbers will be used to compare the newly uploaded GID data with the existing data and determine if the data has changed. If the data has not changed, the module will discard the newly uploaded data. If the data has changed, the module will save the newly uploaded data in place of the old data. When the GID data is changed, a GID Data message is created and sent to the Validation and Roadside Interface modules. Typically the latest data will be stored and older GID will be discarded. However, in the case of temporary changes, the old GID may be kept.

3.2.5 RSE Vehicle Status Module

The Vehicle Status Module receives vehicle warning messages that a warning has been issued to a driver by the vehicle's OBE. These messages are transmitted from the Roadside Interface Module to the Vehicle Status Module. Figure 18 shows a block diagram for the module.

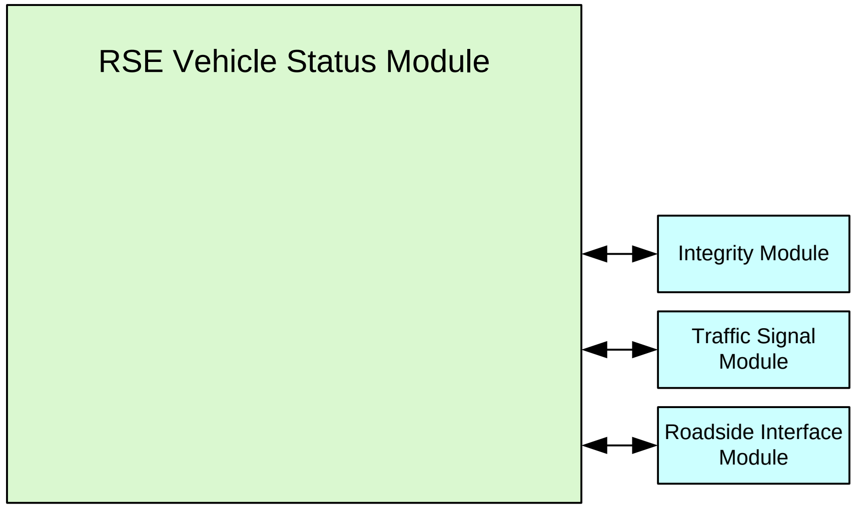

Figure 18 - RSE Vehicle Status Module

The Vehicle Status Module will start after receiving a signal from the Integrity Module. It requests configuration data from the Roadside Interface Module. The vehicle warning message data will be stored.

In addition, the module will store the warning status as a flag. The usage of this flag (such as using it to trigger phase and timing changes on the traffic controller or broadcast it to other vehicles) is not in the scope of this project.

When a Vehicle Status Data request is received, the module will retrieve the data, format the message and send the information to the requestor.

3.2.6 RSE Validation Module

The Validation Module may reside on the RSE, on systems accessed over the backhaul system, or on local maintenance equipment. This module handles the RSE validation process which is conducted when each intersection is being set up, before the intersection goes to full operation. Validation may also be conducted during periodic maintenance after the system is in full operation.

During the validation process, this module receives phase and timing information from the Traffic Signal Module and vehicle validation data and/or heartbeat messages from OBEs through the Roadside Interface Module. Figure 19 shows a block diagram of the Validation Module.

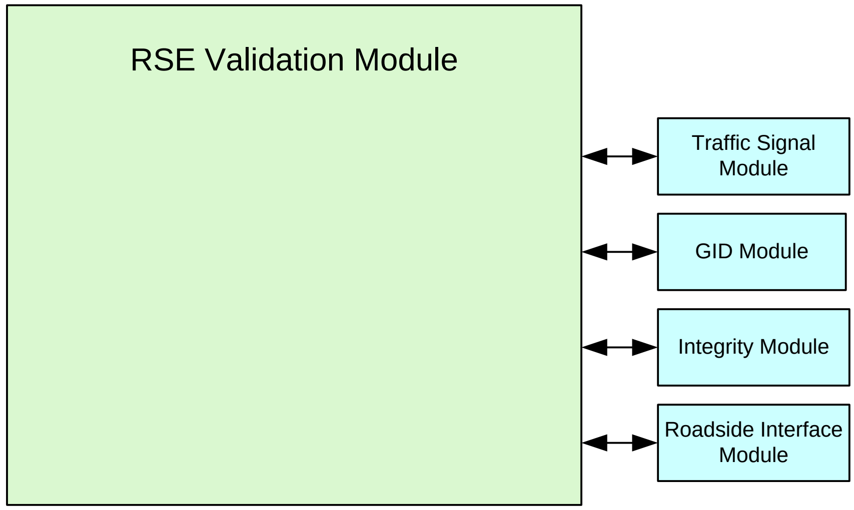

Figure 19 - RSE Validation Module

The Validation Module will support concurrent data input and processing for multiple vehicles. The Validation Module will start after receiving a signal from the Integrity Module. The module will perform the following types of validation:

- Signal Validation – The module will receive signal phase and timing information and vehicle validation data and/or heartbeat messages. This data will be used to determine the observed phase and timing based on the current traffic flow. The calculated phase and timing information is compared with the information provided by the Traffic Signal Module. The results will be stored.
- Intersection Mapping – The module will receive probe vehicle messages from the Roadside Interface Module and compare the movement of vehicles through the intersection with the stored GID data. The results will be stored.
- Position Mapping – The module will create a vehicle location availability map based on the location data received via the Roadside Interface Module. The map will be stored.
- Coverage Mapping – The module will evaluate the quality of the OBE signal received by the Roadside Interface Module from the time the reception starts until it stops. Start and stop locations will be stored so that the RSE transmitter coverage can be analyzed. This information will be used to determine if the system is functioning as designed or needs to be in Failure Mode.
- Diagnostics and Logging – The module will maintain a log of diagnostic messages created by other Validation Module activities.

The Validation Module will retrieve the stored validation data when requested, format the message, and send the information to the requesting module.

4 OBE Module Requirements

The high-level requirements are developed by defining the user needs. From these a list of major requirements is created which, in turn, will have sub-requirements that are identified. This logical partitioning is based on the behavior described in the ConOps document and on the scenarios described in Section 2. These requirements may not be well defined early in a project, but should be refined as the project progresses. Likewise, high-level requirements may not be testable until they are refined in later phases of the project.

The requirements are divided into a number of categories to group the requirements in ways that will facilitate the design process. The requirements have been categorized as follows:

- Constraints – Identifies design constraints imposed by existing systems, standards, regulations, or hardware limitations.
- Data Requirements – Includes requirements pertaining to data, data structures, and databases for the system.
- Functional Requirements – Lists the characteristics that the software must support for each human interface. Identifies what is to be done by the product, what inputs should be transformed to what outputs, and what specific operations are required.
- Hardware Requirements – Provides a list of requirements for the system hardware, including network, power, air conditioning, and other support hardware.
- Interface Requirements – Details physical and logical characteristics of the interfaces between the system and the rest of the world. Specifies communications interfaces and protocols that should be supported. Specifies user interface requirements.
- Life Cycle/End-of-Life Requirements – Lists Requirements for sustaining the system from implementation through disposal.
- Performance Requirements – Specifies static and dynamic capacity for number of users, connections, and other performance related factors.
- Quality Characteristics – Provides requirements which address the general quality, usability, extensibility, flexibility, and maintainability of the system.
- Security Requirements – Includes requirements related to both the facility that houses the system and operational security. Security requirements might specify the security and privacy requirements, including access limitations to the system, such as existence of log-on procedures and passwords, and of data protection and recovery methods.
- Training Requirements – Lists requirements for training, system documentation, system help files, and other documents and features required for users to operate and maintain the system.
- External Requirements – Includes requirements for policies and procedures to support the implementation, operations, training, and institutional requirements to support the system.

Table 3 shows the general layout of the requirements tables, and explains the purpose or content of each column of the requirements table. The requirements in this document are a subset of the requirements information that is tracked in the system "Requirements Matrix". While this document is intended to record the requirements that apply to a particular implementation of the product, the Requirements Matrix tracks all proposed requirements for the product. The Matrix includes requirements that may apply to future versions of the product or which have been deferred due to cost or complexity.

Table 3 - Explanation of the Requirements Tables

ID	Requirement	Source	Comment	Allocation	Priority
The requirement identifier (ID) is a unique identifier used to trace requirements from beginning to end in a system development process.	This column in the table contains the text of the actual requirement.	In this column we list the source(s) of each requirement, either by listing a reference document or identifying a "parent" requirement.	In this column we add any explanations that would help explain the requirement, its priority, or the risks associated with implementing the requirement.	In this column we allocate requirement to the module(s) affected by the requirement.	In this column we assign a priority for each requirement: **H** – indicates that it is essential to the product, **M** – indicates that it should be implemented (budget and schedule permitting), **L** – indicates "nice to have", but only if there is little or no cost impact, and **N/A –** indicates a requirement allocated to an external component associated with the OBE components.

Table 4 shows an explanation of the requirement identification numbering system.

Table 4 - Requirement ID Format

Requirement ID Format	Explanation of Format
XY-NNN-PPP	X – Represents the classification of the requirements within the requirements document. The following classifications have been used in this requirements specification: C Constraints (Section 4.1) D Data Requirements (Section 4.2) F Functional Requirements (Section 4.3) H Hardware Requirements (Section 4.4) I Interface Requirements (Section 4.5) L Life Cycle/End of Life Requirements (Section 4.6) P Performance Requirements (Section 4.7) Q Quality Requirements (Section 4.8) S Security Requirements (Section 4.9 T Training Requirements (Section 4.10) X External Requirements (Section 4.11) Y – Represents the allocation of a requirement to one of the following component classes: R – Roadside Equipment O – On-board Equipment S – CICAS-V System NNN – represents the high-level sequence number within a classification. PPP – The sequence number makes each requirement ID unique. Numbering need not be sequential, and requirements may be grouped by number based on common relationships.

4.1 CO – OBE Design Constraints

The requirements in this section specify design constraints imposed by existing systems, standards, regulations, facilities, or support capabilities.

ID	Requirement	Source	Comment	Allocation	Priority
CO-100	The OBE components shall be compatible with the current VII architecture for signalized intersections.	ConOps 4	Requirement deferred. Not required for field operational testing.	OBE Wireless Communication	H
CO-105	The OBE components shall use the current VII radio communication system for wireless communications between OBE and RSE components.	ConOps 4	This requirement is met if the following requirements are met: HO-205 HO-210 HO-220	OBE Wireless Communication	H
CO-200	The OBE DVI components shall follow Human Factors guidelines issued by the Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA).	ConOps 4		OEM Driver-Vehicle Interface	H
CO-205	The OBE DVI components shall use alerts that are effective and compatible with automotive human factors guidelines and each OEM's driver-vehicle interface principles and practices.	ConOps 4, ConOps 5.1.3		OEM Driver-Vehicle Interface	H
CO-210	The OBE DVI components shall use alerts that are specifically identified with intersection collision avoidance.	ConOps 5.1.3 PDR		OEM Driver-Vehicle Interface	H
CO-300	The OBE components' activation of the DVI driver alert shall be issued before it's too late for driver to react and stop.	ConOps 4	This requirement is met if the following requirements are met: PO-100 PO-105 PO-110 PO-200	OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
CO-305	The OBE components shall minimize false alarms.	ConOps 4, ConOps 5.1.3	This requirement is met if the following requirements are met: FO-340 FO-360 FO-380 FO-385 FO-386 FO-390	OBE Situation Assessment	H
CO-310	The OBE components shall minimize nuisance alarms.	ConOps 4, ConOps 5.1.3	This requirement is met if the following requirements are met: FO-340 FO-360 FO-380 FO-385 FO-386 FO-390	OBE Situation Assessment	H
CO-315	The OBE components shall minimize missed violations.	ConOps 4	This requirement is considered met if the following requirements are met: CO-315-001	OBE Situation Assessment	H
CO-315-001	The Situation Assessment module shall identify all intersection violations with a failure rate of not more than one missed violation per 1,000 actual violations.	CO-315		OBE Situation Assessment	H
CO-320	The OBE components design shall consider the full range of driver characteristics contributing to the effectiveness of the alert.	ConOps 4 PDR	This requirement is considered met if the following requirements are met: CO-320-001 CO-320-002	OEM Driver-Vehicle Interface, OBE Situation Assessment	H
CO-320-001	The OEM Driver-Vehicle Interface shall be designed to provide perceptible warnings for the full range of potential drivers.	CO-320	This requirement applies to an external component, and is not a testable requirement for the OBE components.	OEM Driver-Vehicle Interface	N/A

ID	Requirement	Source	Comment	Allocation	Priority
CO-320-002	The OBE components shall notify the OEM Driver-Vehicle Interface of potential violations within 1 second of determining that a potential violation is to occur	CO-320	This requirement is met if the following requirements are met: PO-100	OBE Situation Assessment	H
CO-325	The OBE components shall be compatible with other collision avoidance systems in the vehicle.	ConOps 4	Requirement deferred. Not required for field operational testing. This requirement applies to an external component, and is not a testable requirement for the OBE components. This requirement will be verified by each OEM during development of a vehicle.	OEM Driver-Vehicle Interface, OEM Vehicle System Interface	N/A
CO-330	The OBE component design shall not preclude interoperability and integration with current in-vehicle safety systems.	ConOps 4	This will presumably be verified by inspecting the design documents to determine that the design is open, non-proprietary, and extensible.	OBE Driver-Vehicle Interface, OBE Situation Assessment, OBE Vehicle System Interface, OBE Wireless Communication	H
CO-331	The OBE component design shall not preclude interoperability and integration with other future VII enabled systems.	ConOps 4	This will presumably be verified by inspecting the design documents to determine that the design is open, non-proprietary, and extensible.	OBE Driver-Vehicle Interface, OBE Situation Assessment, OBE Vehicle System Interface, OBE Wireless Communication	H
CO-332	The OBE component design shall not preclude interoperability and integration with other future in-vehicle safety systems.	ConOps 4	This will presumably be verified by inspecting the design documents to determine that the design is open, non-proprietary, and extensible.	OBE Driver-Vehicle Interface, OBE Situation Assessment, OBE Vehicle System Interface, OBE Wireless Communication	H
CO-335	The OBE components for the DVI shall meet affordability constraints.	ConOps 5.1.3	Requirement deferred. Not required for field operational testing.	OBE Driver-Vehicle Interface	L

4.2 DO – OBE Data Requirements

This section lists the characteristics of the data, data structures, and databases that the software must support. Data Elements (DE) and Data Frames (DF) listed in these requirements are specified in several ITS standards which are listed in Appendix C. The DEs referred to in the requirements are shown in Appendix D in the following tables:

- Table 8 - Positioning Data
- Table 9 - Positioning Correction Data
- Table 10 - Signal Phase and Timing Data
- Table 11 - GID Data
- Table 12 - Area Geospatial Data (Optional)
- Table 13 - Traffic Signal Violation Warning (Optional)
- Table 14 - Vehicle Error Message Data (Optional)
- Table 15 - Weather Data (Optional)

ID	Requirement	Source	Comment	Allocation	Priority
DO-100	The OBE components shall include data elements for time and date for all OBE data records.	ConOps 4, ConOps 5.2.2		OBE Situation Assessment, OBE Vehicle System Interface, OBE Wireless Communication	H
DO-100-001	The data elements for the OBE components shall include time and date elements as shown in Tables 14 and 15 in Appendix D.	ConOps 4, ConOps 5.2.2		OBE Situation Assessment, OBE Vehicle System Interface, OBE Wireless Communication	H
DO-200	The OBE components shall include data elements for the • time, • date, • vehicle speed, • vehicle deceleration, and • vehicle location for the last instance that the DVI warning was triggered.	ConOps 5.2.2		OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
DO-200-001	The OBE components shall, as a minimum, include the data elements shown in Table 14 to support collection of DVI warning data. The data will be used by the RSE to decide on a possible extension of the all-red interval if this optional feature is implemented by the operating entity.	ConOps 5.2.2		OBE Situation Assessment	H
DO-205	The OBE components shall include data elements for positioning correction data received from the RSE.	ConOps 5.2.2		OBE Wireless Communication, OBE Situation Assessment, OBE Validation	H
DO-205-001	The OBE components shall, as a minimum, include the data elements shown in Table 9 to support the receipt and management of positioning correction data.	ConOps 5.2.2		OBE Wireless Communication, OBE Situation Assessment, OBE Validation	H
DO-210	The OBE components shall include data elements for the • time, • date, • error message, and • vehicle location for the last instance that the OBE components were disabled due to error checking.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Situation Assessment, OBE Vehicle System Interface	L
DO-300	The OBE components shall use GID data which shall include standard globally referenced coordinates.	ConOps 5.2.2		OBE Wireless Communication	H
DO-300-001	The OBE components shall, as a minimum, include data elements shown in Table 11 to support the reception and management of GID data.	ConOps 5.2.2		OBE Wireless Communication	H

ID	Requirement	Source	Comment	Allocation	Priority
DO-300-002	The OBE components shall, as a minimum, include data elements shown in Table 12 to support the management of GID data.	ConOps 5.2.2		OBE Wireless Communication	H
DO-305	The OBE components shall include data elements to describe all approach lanes for an intersection.	ConOps 4	This requirement is considered to be met if DO-300-001 is met.	OBE Wireless Communication	H
DO-310	The OBE components shall include data elements for the location of intersection approach lanes.	ConOps 4 ConOps 5.2.2	This requirement is considered to be met if DO-300-001 is met.	OBE Wireless Communication	H
DO-311	The OBE components shall include data elements for the location of stop lines for all traffic control approaches.	ConOps 4 ConOps 5.2.2	This requirement is considered to be met if DO-300-001 is met.	OBE Wireless Communication	H
DO-315	The OBE components shall include data elements for relating lanes in the GID data to lanes in the traffic signal data.	ConOps 5.2.2	This requirement is considered to be met if the following requirements are met: DO-300-001 DO-350-001	OBE Wireless Communication	H
DO-315-001	The OBE components shall use the Approach ID data element to relate lanes in the GID data to lanes in the traffic signal data.	ConOps 5.2.2		OBE Wireless Communication	H
DO-320	The OBE components shall include data elements for the current vehicle location.	ConOps 5.2.2		OBE Vehicle System Interface, OBE Situation Assessment	H
DO-320-001	The OBE components shall, as a minimum, include data elements shown in Table 8 to support collection of current vehicle location data.	ConOps 5.2.2		OBE Vehicle System Interface, OBE Situation Assessment	H
DO-325	The OBE components shall include data elements for the GID data and area geospatial data.	ConOps 5.2.2		OBE Wireless Communication	H
DO-325-001	The OBE components shall include data elements for the area geospatial data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L

ID	Requirement	Source	Comment	Allocation	Priority
DO-325-002	The OBE components shall include data elements for the GID data.	ConOps 5.2.2	This requirement is considered to be met if DO-300-001 is met.	OBE Wireless Communication	H
DO-330	The OBE components shall include data elements for the vehicle status data.	ConOps 5.1.4 ConOps 5.2.2		OBE Vehicle System Interface	H
DO-330-001	The OBE components shall include, as a minimum, the data elements in Table 13 for vehicle status data.	ConOps 5.1.4 ConOps 5.2.2		OBE Vehicle System Interface	H
DO-335	The OBE components shall include data elements for the positioning correction data.	ConOps 5.2.2	This requirement is considered to be met if DO-205-001 is met.	OBE Wireless Communication, OBE Situation Assessment, OBE Validation	H
DO-340	The OBE components shall include data elements for the weather data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
DO-345	The OBE components shall include data elements for the vehicle diagnostic and error message data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Vehicle System Interface	L
DO-350	The OBE components shall include data elements for the traffic signal data.	ConOps 5.2.2		OBE Wireless Communication	H
DO-350-001	The OBE components shall include, as a minimum, the data elements in Table 10 for traffic signal data.	ConOps 5.2.2		OBE Wireless Communication, OBE Situation Assessment	H

4.3 FO – OBE Functional Requirements

This section identifies what is to be done by the product, what inputs should be transformed to what outputs, and what specific operations are required.

Requirements for system functions include actions performed by the system including external actions and data processing. Functions can be allocated to the system as a whole, or to sub-systems or components of the system. The OBE components have requirements relating to each of the following Modes:

- Startup/Validation Mode
- Normal Operation Mode
- System Failure Mode

No Maintenance Mode requirements have been identified for the OBE components at this time.

4.3.1 OBE Startup Mode Requirements

The following requirements apply to the OBE components while the system is powered off or in Startup mode.

ID	Requirement	Source	Comment	Allocation	Priority
FO-050	The OBE components shall determine the operational power mode of the vehicle and respond accordingly.	SAD 5.1.1	All vehicle electronic systems are required to respond to the vehicle power mode.	OBE Vehicle System Interface	H
FO-050-001	The OBE components shall monitor the vehicle ignition wire state even when the components are powered off.	SAD 5.1.1		OBE Vehicle System Interface	H
FO-050-002	The OBE components shall transition from “System Off” mode to “Startup” mode within 1 second of the time the ignition wire state transitions to ON.	SAD 5.1.1		OBE Vehicle System Interface	H
FO-050-004	The OBE components shall transition from “Startup” mode to “Normal Operation” mode regardless of the ignition wire state during the startup time.	SAD 5.1.1		OBE Vehicle System Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-900	The OBE components shall perform startup self-testing to verify that the OBE is functioning properly each time the system is powered-up.	ConOps 4		OBE Vehicle System Interface	H
FO-900-001	The OBE components shall perform a power-on self test prior to entering into Normal Operation mode.	SAD 5.1.1		OBE Vehicle System Interface	H
FO-900-005	The OBE Vehicle System Interface Watchdog monitor shall start and test all OBE components during the startup time.	SAD 5.1.1		OBE Vehicle System Interface	H
FO-900-010	The OBE components shall transition from "Startup" mode to either "Normal Operation" mode or "Failure Mode" within 20 seconds from the time the components transition into Startup mode.	SAD 5.1.1		OBE Vehicle System Interface	H
FO-905	The OBE components shall transition into Failure Mode if the startup test detects a failure.	ConOps 4		OBE Vehicle System Interface	H
FO-905-001	The OBE Vehicle System Interface Watchdog monitor shall send a notification message to the driver via the DVI indicating that the system requires service if any OBE module does not start up and pass testing.	ConOps 4		OBE Vehicle System Interface	H

4.3.2 OBE Normal Operation Mode Requirements

The following requirements apply to the OBE components when they are in the Normal Operation mode.

ID	Requirement	Source	Comment	Allocation	Priority
FO-100	The OBE components shall process each incoming message to: • Authenticate messages • Validate message content • Error check messages • Error correct messages	ConOps 4	Note: “error correction” will consist of requesting or waiting for corrected data.	OBE Wireless Communication	H
FO-100-001	The OBE components shall process each message received through the DSRC radio to authenticate the source of the message.	ConOps 4	This requirement applies to an external component, and is not a testable requirement for the OBE components.	DSRC radio system	N/A
FO-100-002	The OBE components shall process each incoming message to validate that each message is complete and formatted correctly.	ConOps 4		OBE Wireless Communication, OBE Vehicle System Interface	H
FO-100-003	The OBE components shall process each incoming message to validate that the data is within the range established as valid for each data element.	ConOps 4	The valid range for each data element should be documented within the OBE design.	OBE Wireless Communication, OBE Vehicle System Interface	H
FO-100-004	The OBE components shall reject data which is determined to be outside valid bounds or part of an incoming message which fails validation.	ConOps 4		OBE Wireless Communication, OBE Vehicle System Interface	H
FO-105	The OBE components shall perform periodic diagnostic self-testing while in the Normal Operation Mode.	ConOps 4		OBE Situation Assessment, OBE Vehicle System Interface	H
FO-105-001	The OBE Situation Assessment module shall include a watchdog monitor that validates the results of the warning algorithm state machine each time results are produced.	ConOps 4		OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-105-002	The OBE Situation Assessment Watchdog monitor shall prohibit warning messages from being issued based on warning algorithm results which are determined to be invalid.	ConOps 4		OBE Situation Assessment	H
FO-105-003	The OBE Situation Assessment Watchdog monitor shall trigger an immediate re-run of the Situation Assessment algorithm when invalid results are detected.	ConOps 4		OBE Situation Assessment	H
FO-105-004	The OBE Vehicle System Interface module shall include a watchdog monitor to examine the OBE software modules.	ConOps 4		OBE Vehicle System Interface	H
FO-105-005	The OBE Vehicle System Interface Watchdog monitor shall determine the operational status of OBE components by testing the individual modules for correct operation at least once per second.	ConOps 4		OBE Vehicle System Interface	H
FO-105-007	The OBE Vehicle System Interface Watchdog monitor shall restart any module which does not respond to testing or which fails a component test.	ConOps 4		OBE Vehicle System Interface	H
FO-105-008	The OBE Vehicle System Interface Watchdog monitor shall send a notification message to the driver via the DVI indicating that the system requires service if any OBE module does not pass testing after being restarted.	ConOps 4		OBE Vehicle System Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-110	The OBE components shall transition into Failure Mode if the diagnostic self-testing detects an uncorrectable failure.	ConOps 4	Wording modified. Prior wording was "The OBE components shall transition into Failure Mode if the diagnostic self-testing detects a failure."	OBE Situation Assessment, OBE Vehicle System Interface	H
FO-110-001	The OBE Situation Assessment Watchdog monitor shall place the Situation Assessment module in Failure Mode and send a failure message to the Vehicle System Interface module if two consecutive runs of the Situation Assessment Algorithm have invalid outputs.	ConOps 4		OBE Situation Assessment	H
FO-110-002	The OBE Vehicle System Interface Watchdog monitor shall disable the Situation Assessment module if any OBE module does not pass testing after being restarted.	ConOps 4		OBE Vehicle System Interface	H
FO-115	The OBE components shall include diagnostic monitoring that detects and reports the consistent inability of the OBE components to establish valid vehicle positioning at intersections.	ConOps 7.3.2	Reporting will initially consist of writing the diagnostic message to a log file.	OBE Situation Assessment	H
FO-200	The OBE components shall process service announcement messages when they are received and store the data for later use.	ConOps 5.2.2		OBE Wireless Communication	H
FO-201	The OBE components shall send a diagnostic message to the RSE components if the service announcement message indicates the RSE components are operational and the OBE components have error data from the OBE self-testing activities.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L

ID	Requirement	Source	Comment	Allocation	Priority
FO-210	The OBE components shall log a communication error including the time, date, vehicle location, and error message each time it is determined that the service announcement message is not being received when other RSE component messages are being received.	ConOps 7.3.3	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
FO-212	The OBE components shall log a communication error including the time, date, vehicle location, and error message each time it is determined that broadcast from an RSE was expected, but not received.	PDR	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
FO-215	The OBE components shall process signal data messages when they are received and store the data for later use.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
FO-220	The OBE components shall process weather data messages when they are received and store the data for later use.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
FO-225	The OBE components shall process GID data messages when they are received and store the data for later use.	ConOps 5.2.2		OBE Wireless Communication	H
FO-230	The OBE components shall compare the RSE GID data with the OBE GID data and if the RSE GID data is newer than the current OBE GID data, the OBE components shall update the OBE GID data with the RSE GID data.	ConOps 5.2.2		OBE Wireless Communication	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-235	The OBE components shall compare the RSE GID data with the OBE GID data and if current OBE data does not include the GID data for the intersection the OBE components shall add the RSE GID data to the OBE GID data.	ConOps 5.2.2		OBE Wireless Communication	H
FO-240	The OBE components shall process positioning correction messages when they are received and store the data for later use.	ConOps 5.2.2		OBE Wireless Communication	H
FO-245	The OBE components shall process area geospatial messages when they are received.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
FO-250	The OBE components shall compare the RSE area geospatial data with the OBE area geospatial data and if the RSE area geospatial data is newer than the current OBE area geospatial data, the OBE components shall obtain an area geospatial data update from the RSE components.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Situation Assessment	L
FO-255	The OBE components shall compare the RSE area geospatial data with the OBE area geospatial data and if current OBE data does not include the area geospatial data for the current vehicle location, the OBE components shall obtain an area geospatial data update from the RSE components.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Situation Assessment	L
FO-260	The OBE components shall process area geospatial update data as it is received and store the data for later use.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-265	The OBE components shall process GID update data as it is received and store the data for later use.	ConOps 5.2.2	Requirement deferred.	OBE Wireless Communication	H
FO-270	The OBE components shall periodically obtain vehicle status data from the Vehicle Control Systems.	ConOps 5.2.2		OBE Vehicle System Interface	H
FO-275	The OBE components shall process vehicle status data from the Vehicle Control Systems and store the data for later use.	ConOps 5.2.2		OBE Vehicle System Interface	H
FO-280	The OBE components shall periodically obtain vehicle location data from the Positioning System.	ConOps 5.2.2		OBE Vehicle System Interface	H
FO-285	The OBE components shall process the vehicle location data and store the data for later use.	ConOps 5.2.2		OBE Vehicle System Interface	H
FO-300	The OBE components shall decode the intersection GID and perform geospatial matching to locate the vehicle relative to the upcoming intersection.	ConOps 5.2.2		OBE Situation Assessment	H
FO-305	The OBE components shall use the positioning correction data to correct the vehicle positioning calculation when current positioning correction data is available.	ConOps 7.2.1.1		OBE Situation Assessment	H
FO-310	The OBE components shall determine the road currently occupied by the vehicle if the accuracy of the positioning data allows.	ConOps 7.2.1.1		OBE Situation Assessment	H
FO-315	The OBE components shall determine the lane currently occupied by the vehicle if the accuracy of the positioning data allows.	ConOps 7.2.1.1		OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-320	The OBE components shall send a message to the driver if it is determined that the vehicle is approaching a CICAS-V intersection.	ConOps 5.2.2		OBE Driver-Vehicle Interface, OBE Situation Assessment	H
FO-325	The OBE components shall determine whether the intersection approach is controlled by a stop sign or a traffic signal.	ConOps 5.2.2		OBE Situation Assessment	H
FO-330	The OBE components shall determine that a stop is required if the current intersection approach is controlled by a stop sign.	ConOps 3.2.4 ConOps 4 ConOps 5.2.2		OBE Situation Assessment	H
FO-335	The OBE components shall determine that a stop is required if the intersection approach is controlled by a traffic signal and the signal status and timing indicate that the signal for the vehicle's lane will be red at the calculated time for the vehicle reaching the stop line.	ConOps 3.2.4 ConOps 4 ConOps 5.2.2		OBE Situation Assessment	H
FO-340	The OBE components shall determine that a stop is not required if the intersection approach is controlled by a traffic signal and the OBE components have determined that the signal for the vehicle's lane will not be red at the calculated time for the vehicle reaching the stop line.	ConOps 4 ConOps 5.2.2		OBE Situation Assessment	H
FO-350	The OBE components shall calculate the time the vehicle will reach the intersection stop line based on the current vehicle location, stop line location, vehicle speed, and vehicle deceleration.	ConOps 5.2.2		OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-355	The OBE components shall correct the calculated time at which the vehicle will reach the stop line for any difference between the location system time and the vehicle system time.	ConOps 5.2.2		OBE Situation Assessment	H
FO-360	The OBE components shall not determine that a stop is required if the intersection approach is not controlled by a traffic signal or stop sign.	ConOps 5.2.2		OBE Situation Assessment	H
FO-365	The OBE components shall calculate the current vehicle stopping distance based on current speed, and current rate of deceleration.	ConOps 5.2.2		OBE Situation Assessment	H
FO-370	The OBE components shall calculate the current distance from the vehicle to the intersection stop line.	ConOps 5.2.2		OBE Situation Assessment	H
FO-375	The OBE components shall determine that a Driver Warning is required when the vehicle is within the approach to an intersection, and it has been determined that a stop is required, and the current vehicle stopping distance exceeds the current distance to the stop line.	ConOps 3.2.4, ConOps 4, ConOps 5.2.2		OBE Situation Assessment	H
FO-380	The OBE components shall deactivate the DVI Driver Warning if the vehicle speed is below the minimum speed threshold given by the warning algorithm.	ConOps 4		OBE Situation Assessment	H
FO-385	The OBE components shall deactivate the DVI Driver Warning if the vehicle is within 3 meters of the intersection stop line.	ConOps 4, ConOps 5.2.2	Requirement deferred.	OBE Situation Assessment	H
FO-386	The OBE components shall deactivate the DVI Driver Warning if the vehicle has passed the stop line.	ConOps 4, ConOps 5.2.2	Eliminates false alarms if vehicle is in intersection and light turns red.	OBE Situation Assessment	H

ID	Requirement	Source	Comment	Allocation	Priority
FO-390	The OBE component shall deactivate the DVI Driver Warning while deceleration is greater than the deceleration threshold value.	ConOps 4, ConOps 5.2.2	The deceleration threshold value will be set in the OBE performance specification.	OBE Situation Assessment	H
FO-395	The OBE components shall activate the DVI Driver Warning if it has been determined that a driver warning is required and no other condition has caused the Driver Warning to be deactivated.	ConOps 3.2.4, ConOps 4		OBE Driver-Vehicle Interface, OBE Situation Assessment	H
FO-400	The OBE components shall forward to the RSE at signalized intersections the following vehicle status information each time a Driver Warning is sent to the driver: • Time • Date • Vehicle Location • Vehicle Status data	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Situation Assessment	H

4.3.3 OBE System Failure Mode Requirements

ID	Requirement	Source	Comment	Allocation	Priority
FO-910	The OBE components shall disable the DVI Driver Warning functionality if the OBE components go into Failure Mode.	ConOps 4		OBE Vehicle System Interface	H
FO-915	The OBE components shall notify the driver that the system has been disabled if the OBE components go into Failure Mode.	ConOps 4		OBE Driver-Vehicle Interface, OBE Vehicle System Interface	H
FO-920	The OBE components shall store the current time, date, error message, and vehicle location in the vehicle status data if the OBE components go into Failure Mode.	ConOps 5.2.2		OBE Situation Assessment, OBE Vehicle System Interface	H

4.4 HO – OBE Hardware Requirements

Hardware requirements relate to the construction, durability, adaptability of the product and the environmental conditions under which the system is expected to operate.

ID	Requirement	Source	Comment	Allocation	Priority
HO-100	The OBE components shall be able to generate a warning of potential impending violation through the DVI.	ConOps 3.2.4, ConOps4		OBE Driver-Vehicle Interface	H
HO-105	The OBE components shall be able to notify the driver that the CICAS-V system is not operating properly through the DVI.	ConOps 3.2.4		OBE Driver-Vehicle Interface	H
HO-200	The OBE components shall work with light vehicles.	ConOps 4		OBE Driver-Vehicle Interface, OBE Wireless Communication	H
HO-205	The OBE components shall interface with the current VII vehicle architecture.	ConOps 1.6.6		OBE Wireless Communication	H

ID	Requirement	Source	Comment	Allocation	Priority
HO-210	The OBE components shall interface with the current VII radio communication system defined by the WAVE radio standards defined in IEEE 802.11p, and IEEE 1609.x.	ConOps 1.6.5		OBE Wireless Communication	H
HO-215	The OBE components shall function in all roadway weather and lighting conditions.	ConOps 4		OBE Wireless Communication, OBE Driver-Vehicle Interface, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	H
HO-220	The OBE hardware components shall include the following items as a minimum: • WAVE radio assembly capable of broadcasting and receiving at 5.9 GHz • A CICAS-V Vehicle Applications Processor • A device capable of storing the data required for OBE component functions • A positioning system, including a location processor, of specified accuracy and precision • A Driver-Vehicle Interface • A Vehicle Systems Interface • An On-board Interface to the WAVE radio assembly • Other vehicle sensors with an interface to the CICAS-V application processor	ConOps 6.2.3		OBE Wireless Communication, OBE Driver-Vehicle Interface, OBE Situation Assessment, OBE Validation, OBE Vehicle System	H

4.5 IO - OBE Interface Requirements

This section covers the requirements that define logical and functional characteristics of the interfaces between the software and everything else. This includes users, the hardware the system runs on, supporting software, communications interfaces and protocols for external system interfaces.

ID	Requirement	Source	Comment	Allocation	Priority
IO-100	The OBE components shall provide message validation, error detection, and error correction for all incoming messages from the RSE components.	ConOps 4		OBE Wireless Communication	H
IO-105	The OBE components shall include communication authentication to verify authenticity of all incoming messages arriving through the On-board Interface.	ConOps 4		OBE Wireless Communication	H
IO-110	The OBE components shall obtain GID and area geospatial data updates using the service channel indicated by the service announcement message.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
IO-200	The OBE components shall acquire vehicle location data from the Positioning System.	ConOps 5.1.4		OBE Vehicle System Interface	H
IO-205	The OBE components shall acquire vehicle location data from the Positioning System via the vehicle system's positioning component if the Positioning System is a Vehicle Control Systems component.	ConOps 5.1.4		OBE Vehicle System Interface	H
IO-300	The OBE components shall acquire service announcement messages via the On-board Interface.	ConOps 5.2.2		OBE Wireless Communication	H
IO-305	The OBE components shall obtain GID messages and GID update messages via the On-board Interface.	ConOps 5.2.2		OBE Wireless Communication	H

ID	Requirement	Source	Comment	Allocation	Priority
IO-310	The OBE components shall acquire area geospatial messages and area geospatial update messages via the On-board Interface	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
IO-315	The OBE components shall acquire positioning correction messages via the On-board Interface if the Positioning system is part of the VII system.	ConOps 5.2.2		OBE Vehicle System Interface	H
IO-320	The OBE components shall acquire weather data messages via the On-board Interface	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	L
IO-325	The OBE components shall transmit vehicle status data to the RSE components via the On-board Interface.	ConOps 5.1.2	Requirement deferred. Not required for initial FOT.	OBE Wireless Communication	H
IO-330	The OBE components shall request GID and area geospatial data updates from the RSE components via the On-board Interface.	ConOps 5.1.2		OBE Wireless Communication	H
IO-400	The OBE components shall acquire vehicle status data from the Vehicle Control Systems via the Vehicle Systems Interface.	ConOps 5.1.4		OBE Vehicle System Interface	H
IO-405	The OBE components shall acquire vehicle status data including: • Vehicle speed • Vehicle rate of deceleration • Vehicle braking indication	ConOps 5.1.4		OBE Vehicle System Interface	H
IO-500	The OBE components shall issue Driver Warnings and notifications to the driver via the Driver-Vehicle Interface.	ConOps 5.1.3		OBE Driver-Vehicle Interface	H

4.6 LO - OBE System Life Cycle Requirements

This section contains requirements for sustaining the system from deployment through de-commissioning.

ID	Requirement	Source	Comment	Allocation	Priority
LO-100	The OBE components shall include procedures for testing and certifying both hardware and software upgrades before they are presented for deployment.	ConOps 6.7.3	Requirement deferred. Not required for initial FOT.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	H
LO-105	The OBE components shall include procedures for national deployment of software upgrades.	ConOps 6.7.3	Requirement deferred. Not required for initial FOT.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	H

4.7 PO - OBE Performance Requirements

The requirements in this section specify static and dynamic capacity for number of users, connections, and other performance related factors. Performance requirements are used to highlight the critical performance conditions and their associated capabilities.

ID	Requirement	Source	Comment	Allocation	Priority
PO-100	The OBE components shall perform the situation assessment at a configurable interval between 50 and 500 milliseconds.	ConOps 5.2.2		OBE Situation Assessment	H
PO-105	The OBE components shall obtain the vehicle status data from the Vehicle Control Systems at a configurable interval between 50 and 1000 milliseconds.	ConOps 5.2.2		OBE Vehicle System Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
PO-110	The OBE components shall obtain the vehicle location data from the positioning system at a configurable interval between 50 and 500 milliseconds.	ConOps 5.2.2		OBE Vehicle System Interface	H
PO-200	The OBE components shall receive and process all messages from the RSE components within 100 milliseconds of receiving the complete message.	ConOps 4		OBE Wireless Communication	H

4.8 QO - OBE Quality Requirements

The requirements in this section address the general quality, usability, extensibility, flexibility, and maintainability of the system.

ID	Requirement	Source	Comment	Allocation	Priority
QO-100	The OBE components shall support backwards compatibility with previous versions of the OBE components.	ConOps 4	Requirement deferred. Not required for initial FOT.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	L
QO-105	The OBE hardware components, taken as a unit, shall have a Mean Time Between Failure of 20,000 hours or better.	ConOps 4	Requirement deferred. Not required for initial FOT.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	H

4.9 SO – OBE Security Requirements

System security requirements may be related to both the facility that houses the system and operational security. These requirements include the factors that would protect the system from accidental or malicious access, use, modification, destruction, or disclosure.

ID	Requirement	Source	Comment	Allocation	Priority
SO-100	The OBE components shall include a secure operating system meeting the requirements of FIPS 140-2 for operating system security.	ConOps 4, ConOps 6.4.1	Federal Information Processing Standard (FIPS) 140-2 is referenced in the VII Proof of Concept requirements.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Vehicle System Interface	H

4.10 TO – OBE Training and Documentation Requirements

This section lists requirements for training, system documentation, system help files, and other documents and features required for users to operate and maintain the system.

ID	Requirement	Source	Comment	Allocation	Priority
TO-100	The OBE components shall include maintenance and diagnostic instructions for automotive maintenance providers.	ConOps 6.6.1.3	Requirement deferred. Not required for initial FOT.	OBE Driver-Vehicle Interface, OBE Wireless Communication, OBE Situation Assessment, OBE Validation, OBE Vehicle System Interface	L

4.11 XO – OBE External Requirements

This section addresses requirements that are imposed on the system by external factors. The requirements include functions and components of the system that are external to the CICAS-V system, but required for operation of the system. The requirements detail any relevant organizational policies that will affect the operation or performance of the system as well as any relevant external regulatory requirements, or constraints imposed on the design of the system.

By their nature, external requirements are not usually testable. Verification that a system meets these requirements usually requires inspection, calculation, or other verification methods that can ascertain whether the requirement has been met. Requirements on components that are truly external to the specified system can not be used as acceptance testing criteria because they are outside the control boundaries of the project.

ID	Requirement	Source	Comment	Allocation	Priority
XO-100	The vehicle positioning equipment shall provide vehicle location data with an absolute accuracy of 1 meter or better at 95% confidence.	ConOps 4 PDR	This requirement applies to an external component, and is not a testable requirement for the OBE components.	Positioning System	N/A

4.12 XS – External Requirements on CICAS-V System Maintenance Vehicles

While in Validation Mode, maintenance vehicles traversing the intersection will provide information to the roadside equipment. These requirements do not apply to the standard OBE components, but apply to the external support systems required for validation. A maintenance vehicle would not need to be a CICAS-V equipped vehicle to provide these support functions.

ID	Requirement	Source	Comment	Allocation	Priority
XS-100	CICAS-V maintenance vehicles shall record their location, speed, direction, positioning errors, number of satellites, and other available validation parameters as they approach a CICAS-V equipped intersection.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	OBE Validation	H
XS-105	CICAS-V maintenance vehicles shall transmit their current location, speed, direction, positioning errors, number of satellites, and other available validation parameters to the CICAS-V intersection equipment.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	OBE Validation	H

5 RSE Module Requirements

The high-level requirements are developed by defining the end user primary goals. From these a list of major requirements is created which, in turn, will have sub-requirements that are identified. This logical partitioning is based on the behavior described in the ConOps document and on the scenarios described in Section 2. These requirements may not be well defined early in a project, but should be refined as the project progresses. Likewise, high-level requirements may not be testable until they are refined in later phases of the project.

The requirements are divided into a number of categories to group the requirements in ways that will facilitate the design process. The requirements have been categorized as follows:

- Constraints – Identifies design constraints imposed by existing systems, standards, regulations, or hardware limitations.
- Data Requirements – Includes requirements pertaining to data, data structures, and databases for the system.
- Functional Requirements – Lists the characteristics that the software must support for each human interface. Identifies what is to be done by the product, what inputs should be transformed to what outputs, and what specific operations are required.
- Hardware Requirements – Provides a list of requirements for the system hardware, including network, power, air conditioning, and other support hardware.
- Interface Requirements – Details physical and logical characteristics of the interfaces between the system and the rest of the world. Specifies communications interfaces and protocols that should be supported. Specifies user interface requirements.
- Life Cycle/End-of-Life Requirements – Lists Requirements for sustaining the system from implementation through disposal.
- Performance Requirements – Specifies static and dynamic capacity for number of users, connections, and other performance related factors.
- Quality Characteristics – Provides requirements which address the general quality, usability, extensibility, flexibility, and maintainability of the system.
- Security Requirements – Includes requirements related to both the facility that houses the system and operational security. Security requirements might specify the security and privacy requirements, including access limitations to the system, such as existence of log-on procedures and passwords, and of data protection and recovery methods.
- Training Requirements – Lists requirements for training, system documentation, system help files, and other documents and features required for users to operate and maintain the system.
- External Requirements – Includes requirements for policies and procedures to support the implementation, operations, training, and institutional requirements to support the system.

Table 5 shows the general layout of the requirements tables, and explains the purpose or content of each column of the requirements table. The requirements in this document are a subset of the requirements information that is tracked in the system "Requirements Matrix". While this document is intended to record the requirements that apply to a particular implementation of the product, the Requirements Matrix tracks all proposed requirements for the product. The Matrix includes requirements that may apply to future versions of the product or which have been deferred due to cost or complexity.

Table 5 - Explanation of the Requirements Tables

ID	Requirement	Source	Comment	Allocation	Priority
The requirement identifier (ID) is a unique identifier used to trace requirements from beginning to end in a system development process.	This column in the table contains the text of the actual requirement.	In this column we list the source(s) of each requirement, either by listing a reference document or identifying a "parent" requirement.	In this column we add any explanations that would help explain the requirement, its priority, or the risks associated with implementing the requirement.	In this column we allocate requirement to the module(s) affected by the requirement.	In this column we assign a priority for each requirement: **H** – indicates that it is essential to the product, **M** – indicates that it should be implemented (budget and schedule permitting), **L** – indicates "nice to have", but only if there is little or no cost impact, and **N/A –** indicates a requirement allocated to an external component associated with the OBE components.

Table 6 shows an explanation of the requirement identification numbering system.

Table 6 - Requirement ID Format

Requirement ID Format	Explanation of Format
XY-NNN-PPP	X – Represents the classification of the requirements within the requirements document. The following classifications have been used in this requirements specification: C Constraints (Section 5.1) D Data Requirements (Section 5.2) F Functional Requirements (Section 5.3) H Hardware Requirements (Section 5.4) I Interface Requirements (Section 5.5) L Life Cycle/End of Life Requirements (Section 5.6) P Performance Requirements (Section 5.7) Q Quality Requirements (Section 5.8) S Security Requirements (Section 5.9 T Training Requirements (Section 5.10) X External Requirements (Section 5.11) Y – Represents the allocation of a requirement to one of the following component classes: R – Roadside Equipment O – On-board Equipment S – CICAS-V System NNN – represents the high-level sequence number within a classification. PPP – The sequence number makes each requirement ID unique. Numbering need not be sequential, and requirements may be grouped by number based on common relationships.

5.1 CR – Constraints on the RSE Components Design

ID	Requirement	Source	Comment	Allocation	Priority
CR-100	The RSE components shall be compatible with the current VII architecture for signalized intersections.	ConOps 5.1.1		RSE Roadside Interface	H
CR-105	The RSE components shall use the current VII radio communication system for wireless communications between RSE and OBE components.	ConOps 6.2		RSE Roadside Interface	H
CR-110	The RSE components shall work with transit signal priority and emergency vehicle signal preemption systems.	ConOps 4	Signal priority and preemption present a dynamic change in the signal timing plan.	RSE Traffic Signal	H
CR-115	The RSE components shall work with fixed, locally-actuated, and true adaptive signal timing.	ConOps 4, ConOps 5.2.1 PDR	Requirement deferred. Not required for initial FOT.	RSE Traffic Signal	H
CR-405	The CICAS-V System shall be designed for a high degree of reliability.	ConOps 4	Requirement deferred. Not required for field operational testing. This requirement is considered to be met if requirement QR-105 is met. Original requirement CS-105 was split into CR-405 and CR-406 for the RSE.	RSE Integrity	H
CR-406	The CICAS-V System shall be designed for a high degree of availability.	ConOps 4	Requirement deferred. Not required for field operational testing. This requirement is considered to be met if requirement QR-105 is met. Original requirement CS-105 was split into CR-405 and CR-406 for the RSE.	RSE Integrity	H

5.2 DR – RSE Data Requirements

This section lists the characteristics of the data, data structures, and databases that the software must support. Data Elements (DE) and Data Frames (DF) listed in these requirements are specified in several ITS standards which are included in Appendix C. The DEs referred to in the requirements are shown in Appendix D in the following tables:

- Table 8 - Positioning Data
- Table 9 - Positioning Correction Data
- Table 10 - Signal Phase and Timing Data
- Table 11 - GID Data
- Table 12 - Area Geospatial Data (Optional)
- Table 13 - Traffic Signal Violation Warning (Optional)
- Table 14 - Vehicle Error Message Data (Optional)
- Table 15 - Weather Data (Optional)
- Table 16 - RSE Configuration Data
- Table 17 - RSE Validation Data

ID	Requirement	Source	Comment	Allocation	Priority
DR-100	The RSE components shall include data elements for time and date for all RSE data records.	ConOps 4	.	RSE Traffic Signal, RSE Roadside Interface, RSE Vehicle Status, RSE Validation	H
DR-200	The RSE components shall include data elements for traffic signal states and traffic signal timing for each lane at a signalized intersection.	ConOps 4		RSE Traffic Signal	H
DR-200-001	The RSE components shall include, as a minimum, the data elements in Table 10 for traffic signal data.	ConOps 4		RSE Traffic Signal	H
DR-205	The RSE components shall include data elements for relating lanes in the GID data to lanes in the traffic signal data.	ConOps 4 ConOps 5.2.2	This requirement is considered to be met if the following requirements are met: DO-200-001 DR-255-005	RSE GID, RSE Traffic Signal	H

ID	Requirement	Source	Comment	Allocation	Priority
DR-210	The RSE components shall include data elements for the current vehicle location.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
DR-215	The RSE components shall include data elements for the GID data and area geospatial data.	ConOps 5.2.2		RSE GID	H
DR-215-005	The RSE components shall include, as a minimum, the data elements in Table 11 for GID data.	ConOps 5.2.2		RSE GID	H
DR-215-010	The RSE components shall include, as a minimum, the data elements in Table 12 for area geospatial data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	RSE GID	H
DR-220	The RSE components shall include data elements for the vehicle status data.	ConOps 5.1.4	Requirement deferred. Not required for initial FOT.	RSE Vehicle Status	L
DR-220-005	The RSE components shall include, as a minimum, the data elements in Table 13 for vehicle warning status.	ConOps 5.1.4		RSE GID	H
DR-225	The RSE components shall include data elements for the positioning correction data.	ConOps 5.2.2		RSE Roadside Interface	H
DR-225-005	The RSE components shall include, as a minimum, the data elements in Table 9 for positioning correction data.	ConOps 5.2.2		RSE Roadside Interface	H
DR-230	The RSE components shall include data elements for the weather data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
DR-235	The RSE components shall include data elements for the vehicle diagnostic and error message data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT. These data elements are required to support receiving messages from vehicles to collect OBE diagnostic and error messages and report them to the operations center	RSE Vehicle Status	L
DR-245	The RSE components shall include data elements for the RSE configuration data.	ConOps 5.2.2		RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
DR-245-005	The RSE components shall include, as a minimum, the data elements in Table 16 for RSE configuration data.	ConOps 5.2.2		RSE Roadside Interface	H
DR-250	The RSE components shall include data elements for the intersection validation data.	ConOps 5.2.2	Requirement deferred. Not required for initial FOT.	RSE Validation	H
DR-255	The RSE components shall use GID data which shall include standard globally referenced coordinates.	ConOps 4		RSE GID	H
DR-255-005	The RSE components shall include, as a minimum, the data elements in Table 11 for GID data.	ConOps 4		RSE GID	H
DR-255-010	The RSE components shall include, as a minimum, the data elements in Table 12 for area geospatial data.	ConOps 4		RSE GID	H
DR-260	The RSE components shall include data elements to describe all approach lanes for an intersection.	ConOps 4	This requirement is considered to be met if DR-255-005 is met.	RSE GID	H
DR-265	The RSE components shall include data elements for the location of intersection approach lanes and stop lines for all traffic control approaches.	ConOps 5.2.2	This requirement is considered to be met if DR-255-005 is met.	RSE GID	H

5.3 FR – RSE Functional Requirements

This section identifies what is to be done by the product, what inputs should be transformed to what outputs, and what specific operations are required.

Requirements for system functions include actions performed by the system, including external actions and data processing. Functions can be allocated to the system as a whole, or to sub-systems or components of the system. The RSE components have functional requirements relating to each of the following Modes:

- Startup/Validation Mode
- Normal Operation Mode

- Maintenance Mode
- System Failure Mode

5.3.1 RSE Startup/Validation Mode Requirements

The RSE components will startup automatically when power is supplied, and the RSE components will perform a self-test upon power-up. After successful completion of the self-test, the system goes into Normal Operation Mode.

To validate the RSE configuration and intersection data, maintenance staff will manually place the RSE in Validation Mode and either drive or walk the intersection with equipment to provide data to the RSE. The CICAS-V system shall correlate this data with its internal information to validate that the system is performing as expected.

The following requirements apply to the RSE components while they are in Startup/Validation Mode.

ID	Requirement	Source	Comment	Allocation	Priority
FR-050	The RSE components shall perform startup self-testing upon power-up.	ConOps 4		RSE Integrity	H
FR-055	The RSE components shall go into Failure Mode if the startup test detects an error condition.	ConOps 4		RSE Integrity	H
FR-060	The RSE Components shall go into Normal Operation Mode if the RSE components pass the startup test.	ConOps 7.1		RSE Integrity	H
FR-300	The RSE components shall receive messages from maintenance vehicles and record the message data while the RSE components are in Validation Mode.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface, RSE Validation	H
FR-305	The RSE components shall periodically broadcast CICAS-V service announcement message to the OBE components.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	H
FR-310	The RSE components shall periodically broadcast a CICAS-V service announcement message to the OBE components.	ConOps 7.1	Requirement deferred. Not required for initial FOT. See PR-100	RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
FR-315	The RSE components shall compare the data from maintenance vehicles with internal data to validate that the system is performing as expected.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	H
FR-320	The RSE components shall create a control map of the intersection using the validation data received from the maintenance trucks.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	L
FR-325	The RSE components shall create a control map of the intersection which correlates movement of vehicles through the intersection with data from the traffic signal controller assembly as to which lights are active.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	H
FR-330	The RSE components shall create a coverage map of the intersection using the validation data received from the maintenance trucks.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	L
FR-335	The RSE components shall create a coverage map of the intersection which correlates movement of vehicles through the intersection with signal quality data from the maintenance trucks.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	L
FR-340	The RSE components shall monitor lane level movement of vehicles to validate whether the GID is correct.	ConOps 7.1	Requirement deferred. Not required for initial FOT.	RSE Validation	L
FR-345	The RSE components shall periodically broadcast signal data messages to the OBE components.	ConOps 5.2.1.2	Requirement deferred. Not required for initial FOT. See: PR-105	RSE Roadside Interface	H
FR-350	The RSE components shall periodically obtain intersection signal data from the traffic control assembly if the RSE components are configured for a signalized intersection.	ConOps 4 ConOps 5.2.1.2	See: PR-100	RSE Roadside Interface	H

5.3.2 RSE Normal Operation Mode Requirements

The following requirements apply to the RSE components while they are in Normal Operation Mode.

ID	Requirement	Source	Comment	Allocation	Priority
FR-105	The RSE components shall perform continuous diagnostic self-testing.	ConOps 4	See PR-300	RSE Integrity	H
FR-105-001	The RSE Integrity module shall include a Watchdog monitor to monitor the RSE modules.	ConOps 4		RSE Integrity	H
FR-105-005	The RSE Integrity module Watchdog monitor shall restart any module which does not respond to testing or which fails a component test.	ConOps 4		RSE Integrity	H
FR-105-010	The RSE Integrity module Watchdog monitor shall log a notification message indicating that the system requires service if any RSE module does not pass testing after being restarted.	ConOps 4		RSE Integrity	H
FR-110	The RSE components shall transition into Failure Mode if the diagnostic self-testing detects an uncorrectable failure.	ConOps 4, ConOps 7.4	Wording modified. Prior wording was: "The RSE components shall transition into Failure Mode if the diagnostic self-testing detects a failure."	RSE Integrity	H
FR-115	The RSE components shall stop broadcasting signal data messages if the RSE components do not receive a valid message or response from the traffic signal controller assembly for 15 seconds.	ConOps 4	Wording modified. Prior wording was: "The RSE components shall transition the Traffic Signal Interface to Failure Mode if the RSE components do not receive a valid message or response from the traffic signal controller assembly for 15 seconds."	RSE Traffic Signal, RSE Roadside Interface	H
FR-200	The RSE components shall periodically broadcast a service announcement message to the OBE components.	ConOps 5.2.1.1	See PR-100.	RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
FR-205	The RSE components shall periodically broadcast signal data messages to the OBE components.	ConOps 5.2.1.2	See PR-105.	RSE Roadside Interface	H
FR-210	The RSE components shall periodically obtain intersection signal data from the traffic control assembly if the RSE components are configured for a signalized intersection.	ConOps 4, ConOps 5.2.1.2	See PR-100.	RSE Traffic Signal	H
FR-215	The RSE components shall periodically broadcast weather data messages to the OBE components.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT. See PR-115.	RSE Roadside Interface	L
FR-220	The RSE components shall periodically broadcast intersection GID messages to the OBE components.	ConOps 5.2.1.1	See PR-120.	RSE Roadside Interface	H
FR-225	The RSE components shall periodically broadcast positioning correction messages to the OBE components.	ConOps 5.2.1.1	See PR-125	RSE Roadside Interface	H
FR-235	The RSE components shall periodically broadcast area geospatial data messages to the OBE components.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT. See PR-130.	RSE Roadside Interface	H
FR-520	The RSE components shall broadcast service announcement messages which indicate that the CICAS-V capability is not operational if the RSE components do not receive a valid message or response from the traffic signal controller assembly for 15 seconds.	ConOps 5.2.1.1	Wording modified. Prior wording was: "The RSE components shall stop broadcasting signal data messages and shall broadcast service announcement messages which indicate that the CICAS-V capability is not operational if the Traffic Signal Interface is in failure mode." See requirement FR-115.	RSE Traffic Signal, RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
FR-525	The RSE components shall resume broadcasting signal data messages if the RSE components receive two consecutive valid messages from the signal system controller assembly.	ConOps 4	FR-525 was split and wording was modified. Prior wording was: “The RSE components shall transition the Traffic Signal Interface to Normal Operation Mode if the RSE components receive two consecutive valid messages from the signal system controller assembly.” See requirement FR-115.	RSE Roadside Interface, RSE Traffic Signal	H
FR-530	The RSE components shall resume broadcasting service announcement messages which indicate that the CICAS-V capability is operational if the RSE components receive two consecutive valid messages from the signal system and the RSE is not in Failure Mode.	ConOps 4	FR-525 was split and wording was modified. Prior wording was: “The RSE components shall transition the Traffic Signal Interface to Normal Operation Mode if the RSE components receive two consecutive valid messages from the signal system controller assembly.” See requirement FR-115.	RSE Roadside Interface, RSE Traffic Signal	H
FR-600	The RSE components shall receive, process, and store vehicle status data received from vehicles.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Vehicle Status	L
FR-605	The RSE components shall transfer vehicle status data to other systems upon receiving a validated request for the vehicle status data.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Vehicle Status	L

5.3.3 RSE Maintenance Mode Requirements

Maintenance users must be able to change the CICAS-V operation state. This includes making the intersection inactive or placing it into Validation Mode. Maintenance users must be able to retrieve validation results and error reporting data and be able to make changes to the intersection geometry.

ID	Requirement	Source	Comment	Allocation	Priority
FR-400	The RSE components' Maintenance User Interface shall provide a way for maintenance users to set the RSE mode to Normal Operation, Diagnostic, and Validation modes.	ConOps 7.1	Requirement deferred. Wording modified for clarity. Prior wording was: "The RSE components' Maintenance User Interface shall include provisions for setting the RSE mode to Normal Operation, Diagnostic, and Validation modes."	RSE Roadside Interface	H
FR-405	The RSE components' Maintenance User Interface shall provide a way for maintenance users to retrieve validation results and data.	ConOps 7.1	Requirement deferred. Wording modified for clarity. Prior wording was: "The RSE components' Maintenance User Interface shall include provisions for retrieving validation results and data."	RSE Roadside Interface	H
FR-410	The RSE components' Maintenance User Interface shall provide a way for maintenance users to make changes to the CICAS-V intersection geometry data.	ConOps 7.1	Requirement deferred. Wording modified for clarity. Prior wording was: "The RSE components' Maintenance User Interface shall include provisions for making changes to the CICAS-V intersection geometry data."	RSE Roadside Interface	H

5.3.4 RSE System Failure Mode Requirements

The RSE components must not provide information to vehicles until the system has been diagnosed and returned to Normal Operation Mode.

ID	Requirement	Source	Comment	Allocation	Priority
FR-500	The RSE components shall not transmit any messages other than the service announcement messages to the OBE components while the RSE components are in Failure Mode.	ConOps 7.4	Wording modified for clarity. Prior wording was: "The RSE components shall not transmit any messages other than the service announcement messages to the OBE components while in Failure Mode."	RSE Roadside Interface	H
FR-500-001	The RSE components shall broadcast service announcement messages which indicate that the CICAS-V capability is not operational while the RSE components are in Failure Mode.	ConOps 7.4	Wording modified for clarity. Prior wording was: "The RSE components shall broadcast service announcement messages which indicate that the CICAS-V capability is not operational while in Failure Mode."	RSE Roadside Interface	H
FR-510	The RSE components shall store the current time, date, and error message in the RSE status data if the RSE components go into Failure Mode.	ConOps 4		RSE Integrity	H
FR-515	The RSE components shall send the Failure Mode status data to the owner/operator of that RSE installation if the RSE components go into Failure Mode.	ConOps 4 PDR	Requirement deferred.	RSE Integrity	L
FR-520	See comment		FR-520 has been moved to the Normal Operation mode requirements. The RSE is not in "Failure" mode if the traffic signal data is not available.		
FR-525	See comment		FR-525 has been moved to the Normal Operation mode requirements. The RSE is not in "Failure" mode if the traffic signal data is not available.		

5.4 HR – RSE Hardware Requirements

Hardware requirements relate the construction, durability, and adaptability of the product and the environmental conditions under which the system is expected to operate.

ID	Requirement	Source	Comment	Allocation	Priority
HR-100	The RSE components shall include one port for backhaul network access and one port for local maintenance access.	ConOps 4 PDR		RSE Roadside Interface	H
HR-200	The RSE components shall interface with the current VII roadside architecture.	ConOps 1.6.3		RSE Roadside Interface	H
HR-205	The RSE components shall interface with the current VII radio communication system defined by the WAVE radio standards defined in IEEE 802.11p, and IEEE 1609.x.	ConOps 1.6.6		RSE Roadside Interface	H
HR-210	The RSE components shall operate normally under the following environmental conditions: • Temperature between -34 C and +74 C • Relative Humidity between 5% and 95% non-condensing • Shock per MIL-STD-810E, Method 516.4 • Vibration per MIL-STD-810E, Method 514.4, equipment class G	AASHTO/ ITE/ NEMA standards for traffic controller equipment.		RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status	H
HR-215	The RSE components shall operate normally when powered from sources meeting the following power conditions: • Line voltage 89 to 135 VAC • Line frequency 60.0 +/- 3.0 Hz	AASHTO/ ITE/ NEMA standards for traffic controller equipment.		RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status	

ID	Requirement	Source	Comment	Allocation	Priority
HR-221	The RSE hardware components shall include a WAVE radio assembly capable of broadcasting and receiving at 5.9 GHz.	ConOps 6.2.1 PDR		RSE Roadside Interface	
HR-222	The RSE hardware components include a CICAS-V Roadside Applications Processor.	ConOps 6.2.1 PDR		RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status	
HR-223	The RSE hardware components include a device capable of storing the data required for RSE component functions.	ConOps 6.2.1 PDR		RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status	
HR-224	The RSE hardware components shall include a service capable of producing positioning corrections.	ConOps 6.2.1 PDR		RSE Roadside Interface	
HR-225	The RSE hardware components shall include an interface to the roadside network.	ConOps 6.2.1 PDR		RSE Roadside Interface	

5.5 IR – RSE Interface Requirements

This section covers the requirements that define logical and functional characteristics of the interfaces between the software and everything else. This includes users, the hardware the system runs on, supporting software, communications interfaces, and protocols for external system interfaces.

ID	Requirement	Source	Comment	Allocation	Priority
IR-100	The RSE components shall provide message validation, error detection, and error correction for all messages received from the OBE components.	ConOps 4	Requirement deferred.	RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
IR-100-001	The RSE components shall process each message received through the DSRC radio to authenticate the source of the message.	ConOps 4	Requirement deferred. This requirement applies to an external component, and is not a testable requirement for the OBE components.	DSRC radio system	N/A
IR-100-002	The RSE components shall process each incoming message received through the DSRC radio to validate that each message is complete and formatted correctly.	ConOps 4	Requirement deferred.	RSE Roadside Interface	H
IR-100-003	The RSE components shall process each incoming message received through the DSRC radio to validate that the data is within the range established as valid for each data element.	ConOps 4	Requirement deferred. The valid range for each data element should be documented within the RSE design.	RSE Roadside Interface	H
IR-100-004	The RSE components shall reject data which is determined to be outside valid bounds or part of an incoming message which fails validation.	ConOps 4	Requirement deferred.	RSE Roadside Interface	H
IR-105	The RSE components shall include communication authentication to verify authenticity of all incoming messages arriving through the Roadside Interface.	ConOps 4		RSE Roadside Interface	H
IR-200	The RSE components shall acquire intersection signal status, signal state, and signal timing data from the Traffic Signal Interface.	ConOps 5.1.5		RSE Traffic Signal	H
IR-205	The RSE components shall send warning status messages to the traffic signal controller via the Traffic Signal Interface.	ConOps 5.1.5	Requirement deferred. Not required for initial FOT.	RSE Traffic Signal Interface	L
IR-300	The RSE components shall broadcast service announcement messages via the Roadside Interface.	ConOps 5.1.1		RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
IR-305	The RSE components shall broadcast service announcement messages which include: • Intersection identification code • Indication of whether the CICAS-V capability is operational • Indication of whether GID and geospatial data is available • Version number of the GID data • Version number of the geospatial data • Channel on which the GID and geospatial data can be downloaded	ConOps 5.2.1.1		RSE Roadside Interface	H
IR-310	The RSE components shall broadcast signal data messages via the Roadside Interface.	ConOps 5.2.1.2		RSE Roadside Interface	H
IR-315	The RSE components shall broadcast signal data messages which include: • Traffic signal state (red, yellow, or green) for each approach lane in the intersection • Traffic signal phase and timing data for each approach lane in the intersection • Lane identification for all approach lanes that corresponds to the GID lane identification • Predicted time before a change in signal state for each approach lane in the intersection if such data is available	ConOps 5.2.1.2		RSE Roadside Interface, RSE Traffic Signal	H

ID	Requirement	Source	Comment	Allocation	Priority
IR-320	The RSE components shall periodically broadcast weather data messages to the OBE components via the Roadside Interface.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
IR-325	The RSE components shall broadcast weather data messages which include: • Road surface coefficient of friction data if such data is available • Dew point data if such data is available • Temperature data if such data is available • Visibility data if such data is available • Rain data if such data is available • Snow data if such data is available	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
IR-330	The RSE components shall broadcast GID data messages and GID data update messages via the Roadside Interface.	ConOps 5.2.1.1		RSE Roadside Interface	H
IR-335	The RSE components shall broadcast GID data messages which include: • GID version ID • Intersection ID • Road/lane geometry for all approach roads • Location of the intersection stop lines • Lane identification for all approach lanes that corresponds to the traffic signal lane identification • Geometry of any obstacles or dividers in the intersection box	ConOps 5.2.1.1		RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
IR-340	The RSE components shall broadcast positioning correction messages via the Roadside Interface.	ConOps 5.2.1.1		RSE Roadside Interface	H
IR-345	The RSE components shall broadcast positioning correction messages which include positioning correction data that can be used to improve positioning accuracy.	ConOps 5.2.1.1		RSE Roadside Interface	H
IR-350	The RSE components shall broadcast area geospatial data messages and area geospatial data update messages via the Roadside Interface.	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
IR-355	The RSE components shall broadcast area geospatial data messages which include: • Geospatial information version ID • Intersection ID and type for all CICAS-V intersections within a specified area • Intersection GID data for all CICAS-V controlled intersections within a specified area	ConOps 5.2.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
IR-360	The RSE components shall receive GID data updates from the Maintenance User Interface via the Roadside Interface.	ConOps 5.1.1		RSE Roadside Interface	H
IR-365	The RSE components shall receive vehicle status data via the Roadside Interface.	ConOps 5.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
IR-370	The RSE components shall transmit RSE status, vehicle status, and system validation data to the Maintenance User Interface via the Roadside Interface.	ConOps 5.1.1	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L

ID	Requirement	Source	Comment	Allocation	Priority
IR-375	The RSE components shall receive positioning correction data via the Roadside Interface	ConOps 5.1.1		RSE Roadside Interface	H
IR-400	The RSE components shall broadcast messages to the OBE components using the radio channels indicated in the RSE configuration data for each message type.	ConOps 5.2.1		RSE Roadside Interface	H

5.6 LR – RSE System Life Cycle Requirements

This section contains requirements for sustaining the system from deployment through de-commissioning.

ID	Requirement	Source	Comment	Allocation	Priority
LR-100	The RSE components shall include procedures for testing and certifying both hardware and software upgrades before they are presented for deployment.	ConOps 6.7.3	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface, RSE Integrity, RSE Validation, RSE GID, RSE Vehicle Status RSE Traffic Signal	H
LR-105	The RSE components shall include procedures for national deployment of software upgrades.	ConOps 6.7.3	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface, RSE Integrity, RSE Validation, RSE GID, RSE Vehicle Status, RSE Traffic Signal	H

5.7 PR – RSE Performance Requirements

The requirements in this section specify static and dynamic capacity for number of users, connections, and other performance related factors.

ID	Requirement	Source	Comment	Allocation	Priority
PR-100	The RSE components shall obtain signal data from the Traffic Signal Interface within 100 milliseconds of that data being available at that interface.	ConOps 5.2.1.2		RSE Traffic Signal	H
PR-105	The RSE components shall broadcast the intersection signal data at a configurable interval between 50 and 1000 milliseconds.	ConOps 5.2.1.2		RSE Roadside Interface	H
PR-110	The RSE components shall periodically broadcast the service announcement message based on the schedule in the RSE component configuration data.	ConOps 5.2.1.1		RSE Roadside Interface	H
PR-115	The RSE components shall periodically broadcast the weather data message based on the schedule in the RSE component configuration data.	ConOps 5.2.1.1		RSE Roadside Interface	H
PR-120	The RSE components shall periodically broadcast Intersection GID messages based on the schedule in the RSE component configuration data.	ConOps 5.2.1.1		RSE Roadside Interface	H
PR-125	The RSE components shall periodically broadcast positioning correction messages based on the schedule in the RSE component configuration data.	ConOps 5.2.1.1		RSE Roadside Interface	H
PR-130	The RSE components shall periodically broadcast Area Geospatial Data messages based on the schedule in the RSE component configuration data.	ConOps 5.2.1.1		RSE Roadside Interface	H
PR-200	The RSE components shall receive, process, store, and transmit all signal timing and status data within 100 milliseconds of receiving the data from the traffic controller assembly.	ConOps 4 ConOps 5.2.1.1		RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
PR-300	The RSE Integrity module Watchdog monitor shall determine the operational status of RSE components by testing the individual modules for correct operation at least once per second.	ConOps 4		RSE Integrity	H

5.8 QR – RSE Quality Requirements

The requirements in this section address the general quality, usability, extensibility, flexibility, and maintainability of the system.

ID	Requirement	Source	Comment	Allocation	Priority
QR-100	The RSE components shall support backwards compatibility with previous versions of the RSE components.	ConOps 4	Requirement deferred. Not required for initial FOT.	RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status Interface	L
QR-105	The RSE hardware components, taken as a unit, shall have a Mean Time Between Failure of 100,000 hours or better.	ConOps 4	Requirement deferred. Not required for initial FOT.	RSE Integrity, RSE Roadside Interface, RSE Traffic Signal, RSE GID, RSE Validation, RSE Vehicle Status Interface	H

5.9 SR – RSE Security Requirements

System security requirements may be related to both the facility that houses the system and operational security. These requirements include the factors that would protect the system from accidental or malicious access, use, modification, destruction, or disclosure.

ID	Requirement	Source	Comment	Allocation	Priority
SR-100	The RSE components shall include access security to limit electronic access of RSE components to authorized users.	ConOps 4	Access security shall meet the requirements established by the owner/operating authority for the RSE.	RSE Roadside Interface	H

ID	Requirement	Source	Comment	Allocation	Priority
SR-105	The RSE components shall include access security to allow owners/operators of the components to know that unauthorized access has been attempted.	ConOps 4	Access security shall meet the requirements established by the owner/operating authority for the RSE.	RSE Roadside Interface	H
SR-110	The RSE components shall include a secure operating system meeting the requirements of FIPS 140-2 for operating system security.	ConOps 4, ConOps 6.4.2	Federal Information Processing Standard 140-2 is referenced in the VII Proof of Concept requirements.	RSE Roadside Interface	H

5.10 TR – RSE Training and Documentation Requirements

This section lists requirements for training, system documentation, system help files, and other documents and features required for users to operate and maintain the system.

ID	Requirement	Source	Comment	Allocation	Priority
TR-100	The RSE components shall include a Training Plan which addresses initial training and continuing education.	ConOps 6.7.2	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
TR-105	The RSE components shall include training materials addressing the deployment and maintenance of the RSE components.	ConOps 6.7.2	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L
TR-110	The RSE components shall include maintenance and diagnostic instructions for state and local DOTs.	ConOps 6.6.2.5	Requirement deferred. Not required for initial FOT.	RSE Roadside Interface	L

5.11 XR – RSE External Requirements

This section addresses requirements that are imposed on the system by external factors. The requirements include functions and components of the system that are external to the CICAS-V system, but required for operation of the system. The requirements detail any relevant organizational policies that will affect the operation or performance of the system as well as any relevant external regulatory requirements, or constraints imposed on the design of the system.

By their nature, external requirements are not usually testable. Verification that a system meets these requirements usually requires inspection, calculation, or other verification methods that can ascertain whether the requirement has been met. Requirements on components that are truly external to the specified system can not be used as acceptance testing criteria because they are outside the control boundaries of the project.

ID	Requirement	Source	Comment	Allocation	Priority
XR-100	The WAVE Radio System range shall be great enough that the Situation Assessment algorithm has sufficient time to perform situational assessment and DVI activation when vehicles are traveling at up to 120% of legal speeds.	ConOps 5.2.1.1 PDR	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A
XR-105	The WAVE Radio System latency shall be small enough that the Situation Assessment algorithm has sufficient time to perform situational assessment and DVI activation when vehicles are traveling at legal speeds.	ConOps 4	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A
XR-110	The WAVE Radio System shall provide secure messaging.	ConOps 4	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A
XR-111	The WAVE Radio System shall provide a mechanism for message authentication.	ConOps 4	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A
XR-115	The RSE shall be housed in an enclosure meeting the physical security requirements of the agency which owns the RSE.	ConOps 4	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A
XR-120	The RSE components shall be provided with suitable power, environmental conditioning, and lightning protection.	ConOps 6.2.1	This requirement applies to an external component, and is not a testable requirement for the RSE components.	DSRC Radio system	N/A

ID	Requirement	Source	Comment	Allocation	Priority
XR-125	CICAS-V equipped signalized intersections shall include the following support components: • A data-accessible traffic signal controller assembly • A sensor to provide signal phase change information if this information is not available from the traffic signal controller assembly • An interface to a traffic signal controller, conflict monitor, or a signal phase sensor.	ConOps 6.2.2	This requirement applies to an external component, and is not a testable requirement for the OBE components.	Traffic Signal Controller Assembly	N/A

ID	Requirement	Source	Comment	Allocation	Priority
XR-130	The CICAS-V Management System components shall include the following CICAS-V System support components: • Secure, real-time operating systems • Computer systems to manage system upgrades and software downloads • Computers running the geographic information system software • Network routers • Network firewall hardware and software • Network monitoring hardware and software • Data connections to the RSE installations with sufficient bandwidth to accommodate communication traffic between the Management System and the RSE installations • Uninterruptible power supply protection for all Management System computers with a 15 minute protection capacity and surge protection • Environmentally controlled facility to house the equipment	ConOps 6.3 ConOps 6.4.3	This requirement applies to an external component, and is not a testable requirement for the OBE components.	CICAS-V Management System	N/A

Appendix A: List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ATIS	Advanced Traveler Information Systems
CAMP	Crash Avoidance Metrics Partnership
CAN	Controller Area Network
CICAS	Cooperative Intersection Collision Avoidance System
CICAS-V	Cooperative Intersection Collision Avoidance System for Violations
ConOps	Concept of Operations
CVO	Commercial Vehicle Operations
DE	Data Elements
DF	Data Frames
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FIPS	Federal Information Processing Standard
FISMA	Federal Information Security Management Act
FOT	Field Operational Test
GHz	Gigahertz
GID	Geometric Intersection Description
GPS	Global Positioning System
HRS	High-Level Requirements Specification
Hz	Hertz
ID	Identification or Identifier
IEEE	Institute of Electrical and Electronics Engineers
IGN	Ignition
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MTBF	Mean Time Between Failure
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NTCIP	National Transportation Communications for intelligent transportation system Protocol
OBE	On-board Equipment
OEM	Original Equipment Manufacturer
POC	Proof of Concept
RITA	Research and Innovative Technology Administration
RSE	Roadside Equipment
RTCM	Radio Technical Commission for Maritime Services
SAD	System Architecture Description
SAE	SAE International, an organization formerly known as Society of Automotive Engineers
SPaT	Signal Phase and Timing

TCP/IP	Transmission Control Protocol/Internet Protocol
USDOT	United States Department of Transportation
VAC	Volts – Alternating Current
VII	Vehicle Infrastructure Integration
VNTSC	Volpe National Transportation Systems Center
VSC2	Vehicle Safety Communications 2
VTTI	Virginia Tech Transportation Institute
WAVE	Wireless Access in Vehicular Environments
WSA	WAVE Service Announcement

Appendix B: Glossary of Terms

Component: One of the parts that make up a system. A component may be hardware, software, firmware, documentation, or other related artifact required to design, build, operate, maintain, or decommission a system over the life of the system.

Dedicated Short Range Communications (DSRC): DSRC or Dedicated Short Range Communications is a short to medium range wireless protocol operating in the licensed 5.9 GHz band and specifically designed for automotive use. It offers communication between the vehicle and roadside infrastructure.

Driver-Vehicle Interface (DVI): A device within the vehicle that communicates information to the driver or alerts the driver to a situation, such as a potential violation of a traffic control.

False Alarm: An indicated fault where no fault exists. A false negative is a situation when a traffic control violation warning should have been issued, but was not. A false positive is a situation where a traffic control violation warning was unnecessarily issued.

Geometric Intersection Description (GID): A digital representation of the geometry of the intersection that enables the vehicle to match itself to the correct approach road and to the correct approach lane on that approach road. It includes such information as the location of the stop line, a lane numbering scheme, the orientation of the intersection to north, a version number and possibly other additional features.

Geospatial Database: A database with geospatial information about CICAS-V intersections. The database contains information such as the intersection IDs for all the CICAS-V intersections within a defined area, intersection type IDs (signalized, stop sign controlled), the GIDs for all CICAS-V stop sign controlled intersections in the specified area, a version ID and other information that may become important in the future.

Global Positioning System (GPS): A satellite-based navigational system allowing the determination of a unique point on the earth's surface with a high degree of accuracy. The network of satellites is owned by the US Department of Defense. It uses a satellite constellation of at least 24 satellites.

Intersection: For CICAS-V, an intersection is a junction of two or more public roads where at least one approach is controlled by either a stop sign or a traffic signal. The “intersection” in this context includes the approaches and exits from the junction.

Roadside Equipment: A piece of equipment at the roadside or in the intersection that includes a WAVE radio and the software to operate that radio.

Stop line: Demarcated location on an approach to an intersection where a vehicle needs to stop for appropriate traffic control devices. The stop line location will be included in the geometric intersection description. For intersection approaches that do not have a stop line, an appropriate stopping location will be included in the geometric intersection description.

Traffic Signal Related Terms:

- Traffic signal controller: Hardware located at the intersection that is responsible for controlling the traffic signal indications displayed on the traffic signal head.
- Traffic signal controller assembly: The complete set of components required to monitor and control the traffic signal indications displayed on the traffic signal head including: a traffic signal controller, conflict monitor, and power distribution assembly.
- Traffic signal indication: the illumination of a signal lens or equivalent device.
- Traffic signal head: A housing that contains light sources, lens, and other components to be used for providing signal indications. A traffic signal head may contain one or more signal faces.
- Traffic signal face: the part of the traffic signal provided for controlling one or more traffic movements on a single approach.
- Traffic signal cycle: a complete sequence of signal indications.
- Traffic signal phase: the green, yellow, and red clearance intervals in cycle that are assigned to an independent traffic movement or combination of movements.
- Traffic signal timing: the amount of time allocated for the display of a signal indication.
- Fixed time signal control: Traffic signal timing such that the signal phase durations do not change from one cycle to the next. None of the phases function on the basis of actuation. (Also known as pre-timed control.)
- Traffic actuated signal control: traffic signal timing where the initiation of a change in or an extension of some or all signal phases can be accomplished through any type of detector.

Vehicle Sensors: Sensors on a vehicle installed by the automobile original equipment manufacturer.

Vehicle-to-Vehicle Communication: Communication between vehicles using 5.9 GHz Dedicated Short Range Communications WAVE radios.

Violation: A violation is operationally defined under CICAS-V as crossing the stopping location at a stop sign before stopping or as passing the stopping location on a red light for a signalized intersection. Note that legal definitions may vary by locality.

Wireless Access in Vehicular Environments (WAVE): WAVE standards (IEEE 1609) provide a radio communication component to support the U.S. Department of Transportation's Vehicle-Infrastructure Initiative and Intelligent Transportation System program. IEEE 1609.3 is part of a standards family to support vehicle-to-vehicle and vehicle-to-roadside communications that will allow motor vehicles to interact with each other and roadside systems to access safety and travel-related information.

See DSRC.

Appendix C: System Message Standards and Sets

The following table identifies the applicable ITS message standards and message sets as described in the *System Architecture Description*.

Table 7 - CICAS-V Data Flow Message Sets

Data Flow	ITS Message Standard	ITS Standard Message Set
RSE Data Request	To be determined	New Message Set Required
RSE Data Response	To be determined	New Message Set Required
RSE Data Update	To be determined	New Message Set Required
RSE Configuration Request	To be determined	New Message Set Required
RSE Configuration Response	To be determined	New Message Set Required
RSE Configuration Update	To be determined	New Message Set Required
Service Announcement	SAE J2735	New Message Set Required
GID Data	SAE J2735 *	MSG_SPAT *
Area Geospatial Data	SAE J2735 *	MSG_MapFragment *
Weather Data	SAE J2354	WeatherInformation
Coverage Validation Data	SAE J2735 *	MSG_ProbeVehicleData *
Positioning Validation Data	SAE J2735 *	MSG_ProbeVehicleData *
Geospatial Information Validation Data	SAE J2735 *	MSG_ProbeVehicleData *
Positioning Correction The SAE standard defines the message wrapper for the Radio Technical Commission for Maritime Services (RTCM) message.	RTCM SC-104 SAE J2735 *	SC-104_1001 SC-104_1005 MSG_RTCM_Corrections *
Signal Data Request???	To be determined	New Message Set Required (May not be required if signal data is "pushed" to the CICAS-V components.)
Signal Data Response	NTCIP 1202 **	To be determined
Signal Phase and Timing Data	SAE J2735	MSG_SPAT
Driver Warning	ISO 11519-2:1994 ISO 11519-3:1994	To be determined
Driver Notification	ISO 11519-2:1994 ISO 11519-3:1994	To be determined
Vehicle Status Request	ISO 11519-2:1994 ISO 11519-3:1994	To be determined (May not be required if vehicle data is "pushed" to the CICAS-V components.)
Vehicle Status Response	ISO 11519-2:1994 ISO 11519-3:1994	To be determined
Vehicle Position Request	ISO 11519-2:1994 ISO 11519-3:1994	To be determined (May not be required if vehicle data is "pushed" to the CICAS-V components.)
Vehicle Position Response	NMEA-183	RMC

Appendix D: System Data Elements

The following tables list the characteristics of the data elements and data structures that have been identified based on the *Concept of Operations* and the *High-Level Requirements Specification*.

The following tables represent the preliminary understanding of the data elements that are required for each data structure. The tables and data elements may require modification to meet the requirements of the final design. In this model, most of the data elements are defined by a standard. Whenever possible, the standard reference, standard data element name, and standard data type are used in the data element descriptions. For example, *NMEA:UTC_position_fix* indicates a data element defined in the NMEA-183 standard with the standard element name of *UTC_position_fix*. Data elements that are not defined by a standard are left blank in the tables.

Table 8 shows the preliminary list of data elements associated with the positioning system data.

Table 8 - Positioning Data

Positioning Data - Data Elements	Data Type
UTC_position_fix (time)	Char: hhmmss.ss
Data_status (V=navigation receiver warning)	Char: A
Latitude of fix	Float: nnnn.nn
N or S	Char: A
Longitude of fix	Float: nnnnn.nn
E or W	Char: A
Speed over ground	Float: nnn.n
Track made good in degrees True	Float: nn.n
UT date	Char: ddmmyy
Magnetic variation degrees	Float: nn.n
E or W	Char: A

Table 9 shows the preliminary list of data elements associated with the positioning correction data.

Table 9 - Positioning Correction Data

Positioning Correction Data - Data Elements	Data Type
Status	Bin: 16 bit
Week_Number	Int: 16 bit
Milliseconds_in_Week	Int: 32 bit
RTCM_1005_Message	Char: 25 bytes
RTCM_1001_Message	Char: 101 bytes

Table 10 shows the preliminary list of data elements associated with the intersection signal state, phase, and timing.

Table 10 - Signal Phase and Timing Data

Signal Data - Data Elements	Data Type
Intersection_ID	Int: 32 bit
Approach_ID	Int: 8 bit
Signal_Phase_Indication	Bin: 32 bit
Countdown_Timer_Confidence	Int: 4 bit
Yellow_Duration_Confidence	Int: 4 bit
Time_To_Next_Phase_change	Int: 16 bit (signed)
Yellow_Duration	Int: 8 bit
Week_Number	Int: 16 bit
Milliseconds_in_Week	Int: 32 bit

Table 11 shows the preliminary list of data elements associated with the GID.

Table 11 - GID Data

GID Data - Data Elements	Data Type
Intersection_ID	Int: 32 bit
GID_Content_Version	Int: 8 bit
Reference_Point	Int: 8 bit
Reference_Point_ID	Int: 8 bit
Approach_ID	Int: 8 bit
Intersection_Attributes	Bin: 8 bit
Latitude	Int: 32 bit (signed)
Longitude	Int: 32 bit (signed)
Altitude	Int: 16 bit (signed)
Label (optional)	Char: 252 byte limit
Lane_Number	Int: 8 bit
Lane_Width	Int: 16 bit
Lane_Attributes	Bin: 16 bit

Note: “Label” is an optional object used only for demonstration circumstances where a label was needed to tell the RSE Monitor something, in English, about each approach during the initial testing. The Label object is deprecated in final versions of the GID messages, but may be kept in the RSE data store to provide human readable tags for the GID data.

Table 12 shows the preliminary list of data elements associated with the Area Geospatial Data.

Table 12 - Area Geospatial Data (Optional)

Area Geospatial Data - Data Elements	**Data Type**
Geospatial_Dataset_ID	Int: 16 bit
Geospatial_Content_Version	Int: 8 bit
Intersection_ID	Int: 32 bit
GID_Content_Version	Int: 8 bit
Reference_Point	Int: 8 bit
Reference_Point_ID	Int: 8 bit
Approach_ID	Int: 8 bit
Intersection_Attributes	Bin: 8 bit
Latitude	Int: 32 bit (signed)
Longitude	Int: 32 bit (signed)
Altitude	Int: 16 bit (signed)
Label (optional)	Char: 252 byte limit
Lane_Number	Int: 8 bit
Lane_Width	Int: 16 bit
Lane_Attributes	Bin: 16 bit

Table 13 shows the preliminary list of data elements associated with the Traffic Signal Violation Warning Data. This data is optional.

Table 13 - Traffic Signal Violation Warning (Optional)

Traffic Signal Violation Warning - Data Elements	**Data Type**
UT_Time_Stamp	Char: hhmmss.ss
UT_Date_Stamp	Char: ddmmyy
Warning Given	Int: 32 bit
Intersection_ID	Int: 32 bit
Approach ID0	Int: 8 bit
Approach ID1	Int: 8 bit
Approach ID2	Int: 8 bit

Table 14 shows the preliminary list of data elements associated with the Vehicle Status Data.

Table 14 - Vehicle Error Message Data (Optional)

Vehicle Error Message Data - Data Elements	Data Type
UT_Time_Stamp	Char: hhmmss.ss
UT_Date_Stamp	Char: ddmmyy
Error_Message_Type	Int: 32 bit
Intersection_ID	Int: 32 bit
Approach_ID0	Int: 8 bit
Approach_ID1	Int: 8 bit
Approach_ID2	Int: 8 bit

Table 15 shows the preliminary list of data elements associated with the Weather Data.

Table 15 - Weather Data (Optional)

Weather Data - Data Elements	Data Type
UT_Time_Stamp	Char: hhmmss.ss
UT_Date_Stamp	Char: ddmmyy
Intersection_ID	Int: 32 bit
NTCIP:EssAirTemperature (in tenths of degree C)	Int: (0…9999)
NTCIP:EssVisibility (in tenths of meters)	Int: (0…999999)
NTCIP:EssRoadwaySnowDepth (in centimeters)	Int: (0…999)
NTCIP:EssIceThickness (in millimeters)	Int: (0…999)
NTCIP:EssSurfaceBlackIceSignal (in millimeters)	Int: (0…99)
NTCIP:EssPrecipRate (tenths of grams per sq. meter per sec.)	Int: (0…99999)
NTCIP:EssMobileFriction	

Table 16 shows the preliminary list of data elements associated with the RSE Configuration Data.

Table 16 - RSE Configuration Data

RSE Configuration Data - Data Elements	Data Type
UT_Time_Stamp	Char: hhmmss.ss
UT_Date_Stamp	Char: ddmmyy
RSE_CICAS-V_Software_Version	Bin: 64 bit
GID_Content_Version	Int: 8 bit
Intersection_ID	Int: 32 bit
Geospatial_Content_Version	Int: 8 bit
Geospatial_Dataset_ID	Int: 32 bit
RSE_Security_Certificate	To be determined

Table 17 shows the preliminary list of data elements associated with the RSE Validation Data.

Table 17 - RSE Validation Data

Validation Data - Data Elements	**Data Type**
UT_Time_Stamp	Char: hhmmss.ss
UT_Date_Stamp	Char: ddmmyy
Other Data Elements to be determined	

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ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

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