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

System Architecture Description

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Michael Maile, PI, Farid Ahmed-Zaid, Lorenzo Caminiti, John Lundberg, Priyantha Mudalige, Chuck Pall

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Crash Avoidance Metrics Partnership on behalf of the
Vehicle Safety Communications 2 Consortium
39255 Country Club Drive Suite B-40
Farmington Hills, MI 48331

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Contributing Authors: J. Kyle Garrett, June L. Kaiser, Lee T. Mixon, Gary D. Smith

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 purpose of this document is to describe the system architecture for the Roadside Equipment and the On-board Equipment that will be used in the field operational test for the CICAS-V project under the auspices of the Vehicle Safety Communications 2 Consortium Crash Avoidance Metrics Partnership and the Joint Program Office of the United States Department of Transportation.

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Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Purpose

The purpose of this document is to describe the system architecture for the Roadside Equipment (RSE)[1] and the On-board Equipment (OBE) that will be used in the field operational test (FOT) for the Cooperative Intersection Collision Avoidance System (CICAS) for Violations (CICAS-V) project. 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).

A System Architecture provides a conceptual framework, or frame of reference, for the planning, analysis, and design of a system. The framework of this System Architecture is organized into one or more constituents called (architectural) viewpoints. Each view addresses one or more of the design objectives of the system stakeholders. The term "view" is used to refer to the expression of a system's architecture with respect to a particular viewpoint.

1.2 Scope of This Project

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 for the second phase, a larger FOT.

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 a 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.

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[1] 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 other RSE will be identified with a specific context. The VII RSE, for example, will be explicitly referred to as the "VII RSE".

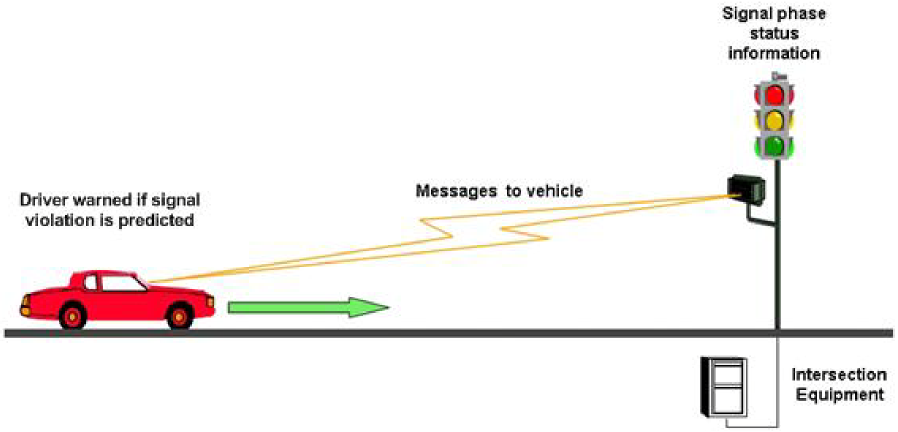

Figure 1 - Basic Concept of the CICAS-V System at a Signalized Intersection

In the figure, 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 intersections.

1.3 Definitions, Acronyms, and Abbreviations

This document may contain terms, acronyms, and abbreviations that are unfamiliar to the reader. Definitions of acronyms are listed in Appendix A; a glossary of terms is provided in Appendix B.

1.4 References

Documents referenced herein or containing additional information relevant to this project are listed in Appendix C.

1.5 Document Overview

The organization and content of this System Architecture Description, and the selection of viewpoints, is based on Institute of Electrical and Electronic Engineers (IEEE) standard 1471-2000 and Federal Highway Administration (FHWA) requirements as expressed in 23 CFR 940.11. Each view in this System Architecture Description has been chosen to serve a specific purpose. The following paragraphs identify the views and provide the rationale for including each view in this document.

Section 2 - Stakeholder View identifies the stakeholders and their interests with regard to the system development, operation, policies, and other impacts of the system. This information is used by the system designers to formulate the architectural concepts for the system and prepare the System Architecture Description. The view establishes a context for the other architectural views.

Section 3 - Operational View provides the participating agencies with an overview of the purpose, scope, and roles played by the system. It also addresses policy statements about the system and policies governing the interactions between the system and external systems, agencies, and users. This viewpoint provides the system designers and stakeholders with a common view of how the system is intended to function. Designers will use this view to validate the detailed design and to establish a context for design decisions that may not be covered in the detailed requirements. Participating agencies will use this viewpoint to confirm their understanding of the system operational characteristics, and to explain the purpose of the system to the public.

Section 4 - Information View provides the system developers and developers of other interfacing systems with an overview of the data schemas, data interfaces, and data flows for the system. This view will be used by CICAS-V system designers to design the system and prepare interface specifications to coordinate the design of interfaces between CICAS-V components and other systems. The view will also provide a basis for revision or development of standards for the CICAS-V message sets and data dictionaries.

Section 5 - 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. Test engineers will use this view to prepare the System Test Plan and the System Test Procedures for each module. System designers will use this view to design each module so that it performs the required functions.

Section 6 – Physical View provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of the planning for the hardware, communications, and operational support for the system. Designers use this view to plan procurement and installation of the equipment required for the CICAS-V system. Test engineers use this view to prepare appropriate verification procedures for the equipment and construction associated with the equipment installation.

Section 7 - Technology View provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of what relevant technologies will be used, how industry standards and specifications will be implemented, and what technologies will be required to support testing of the system. Designers use this view to identify design constraints imposed by standards, specifications, and regulatory rules. Designers also use this view to identify design constraints imposed by the technologies selected for the system implementation. FHWA uses this view to verify that appropriate Intelligent Transportation Systems (ITS) standards are being used in compliance with FHWA regulations.

Section 8 - National ITS Architecture View provides FHWA, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National Intelligent Transportation Systems Architecture. This includes the system’s relationship to the standard Market Packages and to the National ITS Physical and

Logical Architectures. This viewpoint provides the US Department of Transportation, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National ITS Architecture and how the system might relate to the Regional ITS Architectures where it is deployed.

2 Stakeholder View

The Stakeholder View serves the following stakeholders:

- System Designers
- CICAS-V Stakeholders

The Stakeholder View addresses:

- The mission of the CICAS-V project
- Identification of the CICAS-V stakeholders and the roles associated with each stakeholder
- Stakeholder concerns which provide the basis for the project

This information is used by the system designers to formulate the architectural concepts for the system and prepare the System Architecture Description. The view establishes a context for the other architectural views.

2.1 Mission

The purpose of implementing CICAS-V is to reduce crashes at intersections due to violation of traffic control devices, including both traffic signals and stop signs. When deployed, this system is intended to do the following:

- 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 National Highway Traffic Safety Administration (NHTSA) intersection 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 with sufficient time to stop the vehicle.

2.2 Stakeholders

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

- 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 Departments of Transportation (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

2.3 Stakeholder Considerations

The following stakeholder objectives, as derived from the ConOps, have been considered in formulating the architectural concept for the system:

- Current national standards that are relevant to the implementation must be clearly identified
- New standards must be identified and established for interfaces, data, and message sets associated with communication between vehicles and roadside equipment
- New standards must be identified and established for interfaces, data, and message sets associated with communication between traffic signal systems and CICAS-V roadside equipment
- New standards must be identified and established for interfaces, data, and message sets associated with communication between traffic operations centers and CICAS-V roadside equipment
- The RSE architecture and design must clearly establish the software modules, algorithms, interfaces, and hardware constraints for compliance with the CICAS-V requirements
- The RSE architecture and design must address the need for appropriate processing resources and processing priority to support timely communication of information

between vehicles and RSE systems to support the CICAS-V safety related functions

- The RSE architecture and design must support ease of deployment and maintenance of the CICAS-V system
- The RSE architecture and design must support the CICAS-V vision described in the Concept of Operations (ConOps) for the evolution and enhancement of the system
- The OBE architecture and design must support vehicle safety and support the communication link to enable the CICAS-V and other cooperative safety systems

3 Operational View

The Operational View serves the following stakeholders:

- System Designers
- CICAS-V Stakeholders

The Operational View addresses:

- Purpose, scope, and roles of the system
- Policy statements about the system
- Interactions between the system and external systems, agencies, and users

This view provides the system designers with a common view of how the system is intended to function. Designers will use this view to validate the detailed design requirements and to establish a context for design decisions that may not be covered in the detailed requirements. Participating agencies will use this view to confirm their understanding of the system operational characteristics, and to explain the purpose of the system to the public.

3.1 Objectives

Specific measurable objectives to support national deployment of the designed system associated with the above goals for CICAS-V include:

- **Reduction in frequency and severity of crashes at CICAS-V intersections**
  - Measures:
    - Direct: Reduction in crash frequency and severity
    - Surrogate: Reduction in traffic signal and stop sign conflicts
- **A system that drivers understand and find useful, so as to elicit a timely and appropriate response from the driver**
  - Measures: Effectiveness, user acceptance, understanding, and usability
- **A system that displays information consistent with other relevant established safety countermeasures, e.g., information provided by a traffic signal or a dynamic message sign**
  - Measures: Effectiveness, user acceptance, understanding, and usability

3.2 Operational Policies and Constraints

Operational policies will need to be established by each agency that deploys CICAS-V roadside infrastructure. These policies should include how the agency will address privacy issues associated with data created and used by the system. Legislation may be necessary in some areas to permit or regulate deployment of the CICAS-V system. Agencies responsible for CICAS-V capable intersections are responsible for maintaining accurate and up-to-date geometric intersection description (GID) data with sufficient accuracy to allow vehicles to clearly resolve which approach (lane) is associated with each signal or signal head.

The CICAS-V system is initially intended to work with light vehicles, and does not currently address other vehicle types. Likewise, the system is initially intended for deployment in new vehicles, and not all vehicles on the roadway will be CICAS-V equipped.

Due to the large number of controlled intersections and the time and cost associated with identification, documentation, and implementation of CICAS-V roadside systems, the initial deployment of the system will have the following constraints:

- Not all signalized intersections will have CICAS-V capabilities
- Not all intersections with stop signs will have CICAS-V capabilities
- Not all intersections designated for CICAS-V capabilities will be VII-equipped
- Not all VII-equipped intersections will have CICAS-V capabilities
- Not all CICAS-V equipped intersections will have continuous network connectivity or access to any backend services
- In order for a controlled intersection to be CICAS-V equipped, the intersection must have:
    - Adequate positioning system coverage on all approaches to the intersection
    - Adequate Dedicated Short Range Communications (DSRC) coverage for all approaches to the intersection
    - A GID that includes clear stopping locations for each lane in the intersection
    - A GID that includes clear correlations between each lane and each signal indication at the intersection (signalized intersections only)

3.3 Description of the Proposed System

The CICAS-V project will develop and evaluate a candidate system to prevent crashes due to violations of traffic control devices at intersections. 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.

Figure 2 shows the infrastructure and vehicle components that comprise the CICAS-V system. Components within the dashed line labeled “CICAS-V boundaries” are dedicated CICAS-V components, and those outside this boundary are components shared between CICAS-V and other systems and functions.

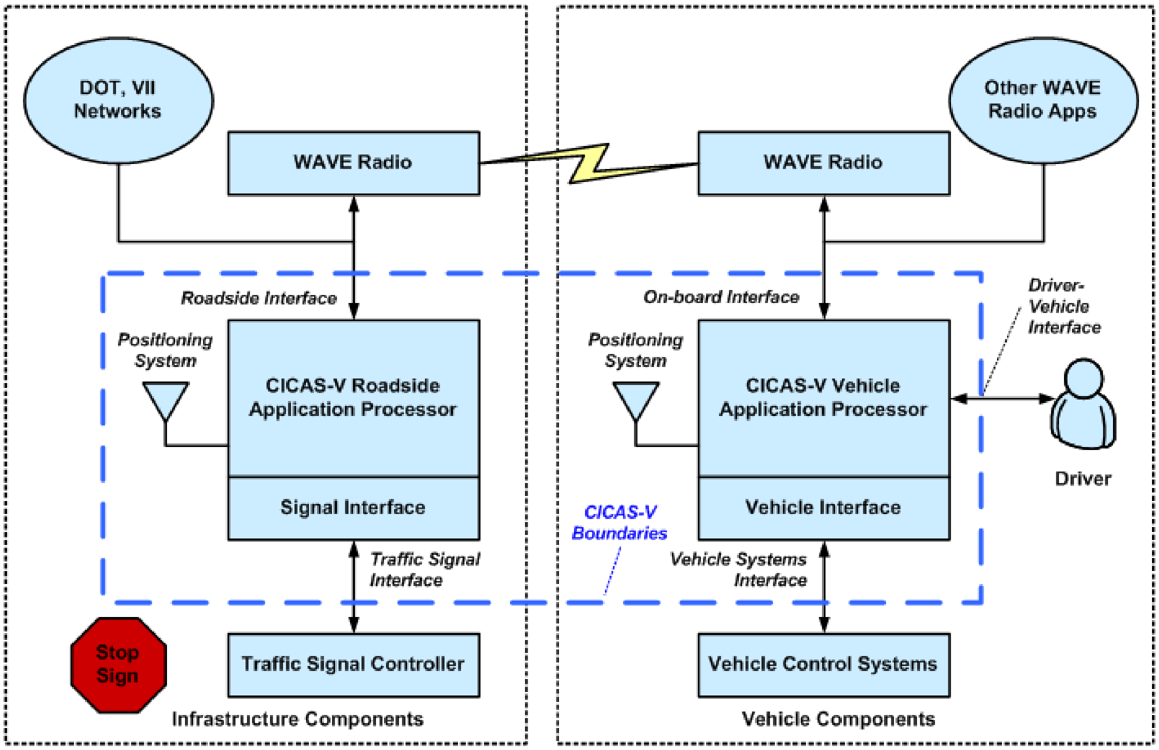

Figure 2 - CICAS-V System Components

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.

3.3.1 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 infrastructure deployed, all CICAS-V functions are performed within the vehicle.

3.3.1.1 General Infrastructure Component Capabilities

For each CICAS-V intersection with an infrastructure component, the CICAS-V roadside application processor broadcasts Wireless Access in Vehicle Environments (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)[2]

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

2. A positioning correction message
3. Geospatial information messages
4. Road surface information and other weather-related data, if available

The content of these messages has not been finalized. The following briefly describes the 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.

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[3] 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

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[3] 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.

distance is an important parameter for the warning calculation. The lane numbering scheme has to correspond to the traffic signal phase and timing 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 could 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.

3.3.1.2 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.

3.3.2 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 3.4 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 the CICAS-V system in the vehicle has not received the download of a GID for a Stop Controlled intersection, the CICAS-V system will not determine if a warning should be issued or not.

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.

3.4 Modes of Operation

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 the following sections.

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 3 shows the relationship between the modes of operation, the states relevant to driver notifications and warnings, and the desired behavior of the system.

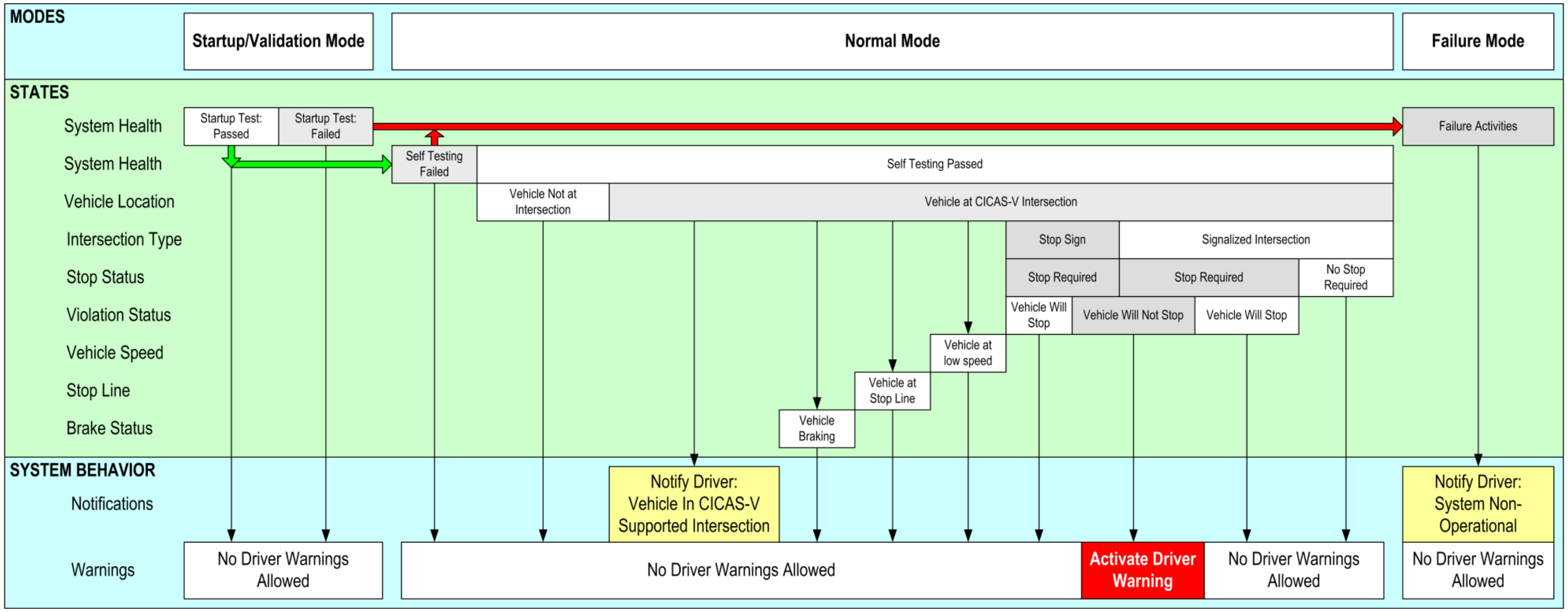

Figure 3 - CICAS-V Mode-State-Behavior Diagram

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 1 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 1 - CICAS-V Scenario Table

Scenario Data Types			**Requirement from CICAS-V ConOps**
Startup/ Validation	Coverage		• 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.
	Positioning		
	Geospatial Information		
	Phase and Timing		
Normal Operation	Intersection Types	Stop Sign	• 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).
		Flashing Red Light	
		Flashing Yellow Light	
		Traffic Signal	
	Traffic Signal Types	Fixed Signal Timing	
		Actuated Signal	
		Emergency Preemption	
		Advanced Signal Controller	
	Intersection Conditions	Right Turn Lane	
		Left Turn Lane	
		Positioning Services	
		Reduced Visibility	
		Speed Limit	
		Road Conditions	
	Driver-Vehicle Interface	Alert of Approaching Intersection	
		Warning of Probable Red Light/Stop Sign Violation	
System Failures	Geospatial Database Errors		• 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.
	GID Errors		
	Communication Errors		
	Vehicle Equipment		
Maintenance	Network Interface		• The RSE must be able to communicate with the backend center for security validation and software updates.
	Local Interface		

3.4.1 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, Wireless Access in Vehicle Environments (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 system 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 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.

3.4.2 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.

3.4.2.1 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 and 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 Driver-Vehicle Interface (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.

3.4.2.2 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.

3.4.2.3 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 4 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.

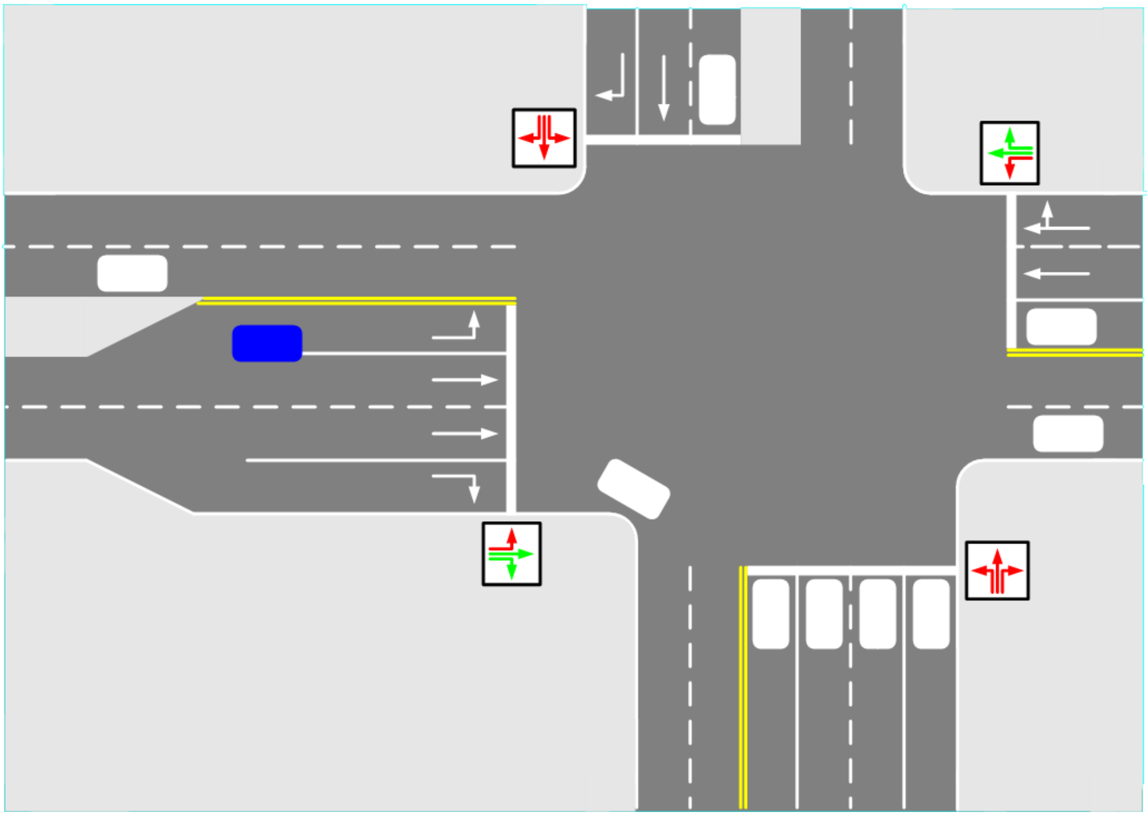

Figure 4 - Vehicle Entering a Dedicated Left Turn Lane

3.4.2.4 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 may be inactive for this intersection
2. The vehicle's CICAS-V processes may only consider the signals for the through-lanes

3. The vehicle’s CICAS-V processes may 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.

3.4.2.5 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).

3.4.2.6 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.

3.4.3 System Error and Failure Scenarios

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

3.4.3.1 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.

3.4.3.2 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.

3.4.3.3 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 a CICAS-V equipped intersection, then the vehicle's CICAS-V processes will be inactive for that intersection. 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 System 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 3.4.2.4.

3.4.4 Maintenance Scenarios

Conditions: *The CICAS-V Intersection is "in service" and a diagnostic self-test is set to trigger at an interval as recommended in the CICAS-V Intersection Maintenance Handbook. 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.

4 Information View

The Information View serves the following stakeholders:

- CICAS-V System Designers
- CICAS-V Stakeholders
- System Designers for systems interfacing with CICAS-V

The Information View addresses the following:

- Data flows between CICAS-V components and external systems
- Data schemas for the information associated with the data flows

The Information View provides the system developers and developers of other interfacing systems with an overview of the data schemas and data flows for the CICAS-V system. This information will be used by CICAS-V system designers to

- design the data structures and interface components for the system;
- prepare Interface Specifications if necessary to coordinate interface design between multiple design efforts; and
- assist with Standards development for the required Message Sets and Data Dictionaries.

The view also provides the CICAS-V stakeholders a way to review and validate the data and data flow requirements for the system.

4.1 Data Flows

Figure 5 shows the data flows between CICAS-V system components and external systems. Each of these data flows will be associated with one or more message sets. The data elements for the information in these data flows will in turn establish the context for the data structures that will be required to support the CICAS-V system components.

Messages within vehicles (between the CICAS-V processor and the driver and vehicle interfaces) may vary, based on the design of the vehicle. These differences should be transparent to the implementation of CICAS-V, providing that the necessary functionality and information are present.

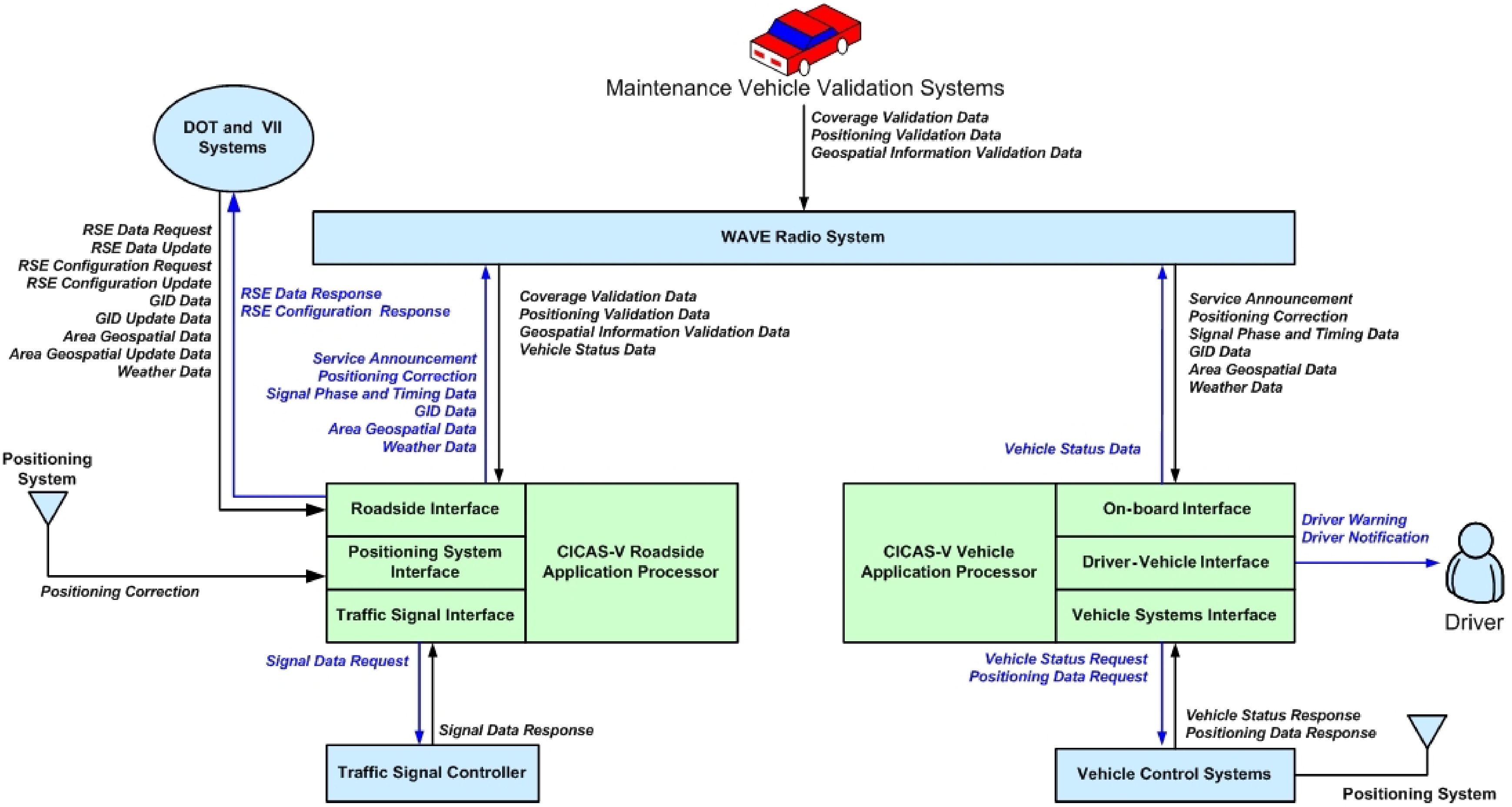

Figure 5 - CICAS-V Data Flows

The data flows shown in Figure 5 will be implemented using standard message sets for the ITS industry wherever possible. In some cases, new standards or new message sets will be required. The relationships between the identified data flows and the message sets are shown in Table 2.

Table 2 - 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 (SPaT) 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

* Some of the standards and message sets identified above are in draft stages and this architecture assumes that the final version of the standards and message sets will provide the necessary capabilities for this project.

** The NTCIP 1202 does not currently support all of the required data. A new standard may be required, both to add the necessary data elements, data frames, and messages, but also to define a new protocol that will be fast enough to meet the requirements for the CICAS-V system.

4.2 Data Schemas

The following data schemas and elements are preliminary. Additional data elements may be required to accommodate the final design. The final design may require re-normalization or de-normalization of the tables and data elements included in this section. Where feasible, the tables and data elements are based on recommended data structures from the Traffic Management Data Dictionary. Figure 6 shows the high-level organization of data within the CICAS-V system and indicates the primary direction of flow for each type of information.

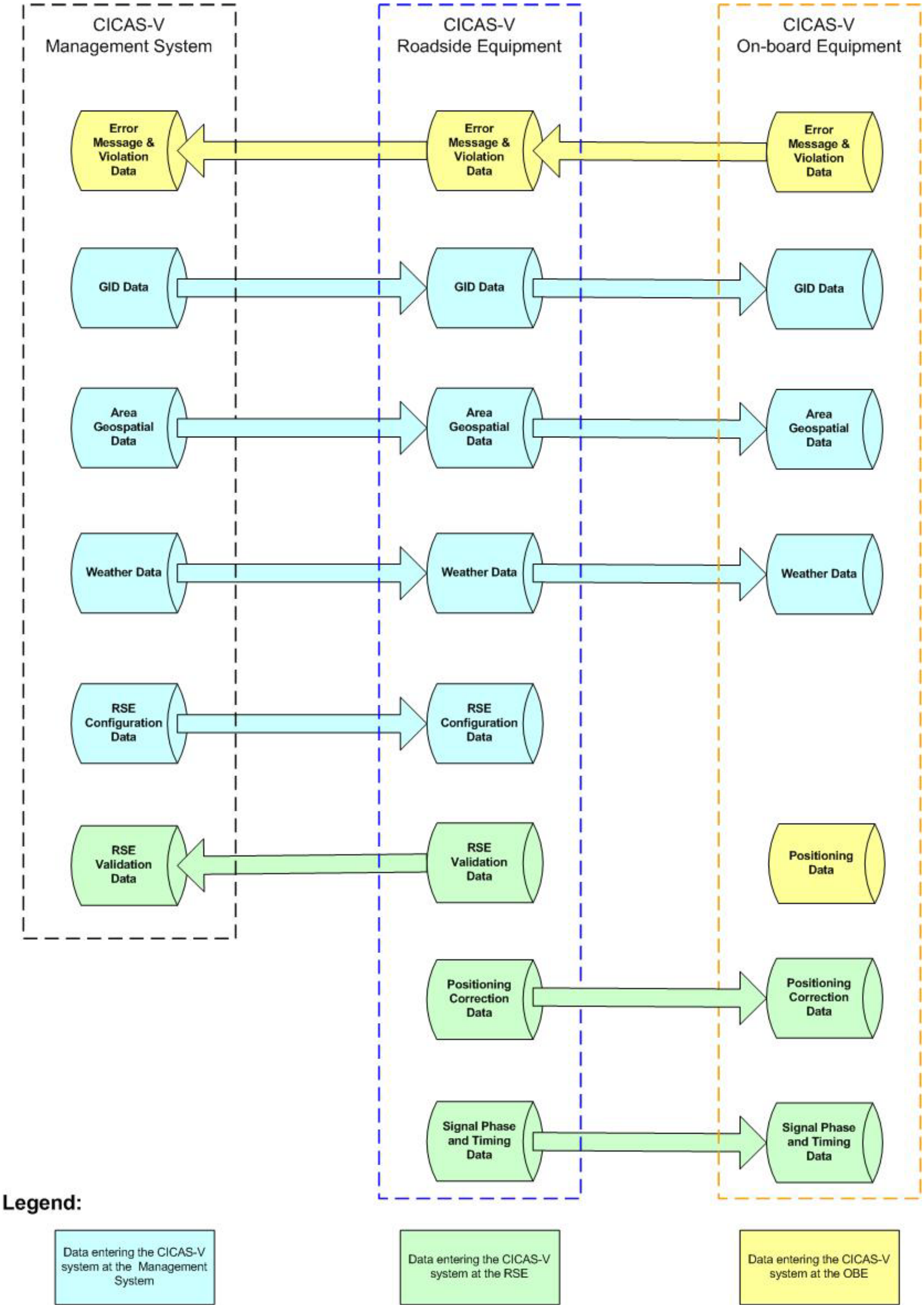

Figure 6 - CICAS-V Data Locations

The final design may require additional data elements and data structures, and some aspects of the RSE and OBE data structures may vary between system providers. The data structures in this architecture description represent the current understanding of the minimum data requirements. Figure 7 shows an Entity Relationship Diagram for the CICAS-V data structures.

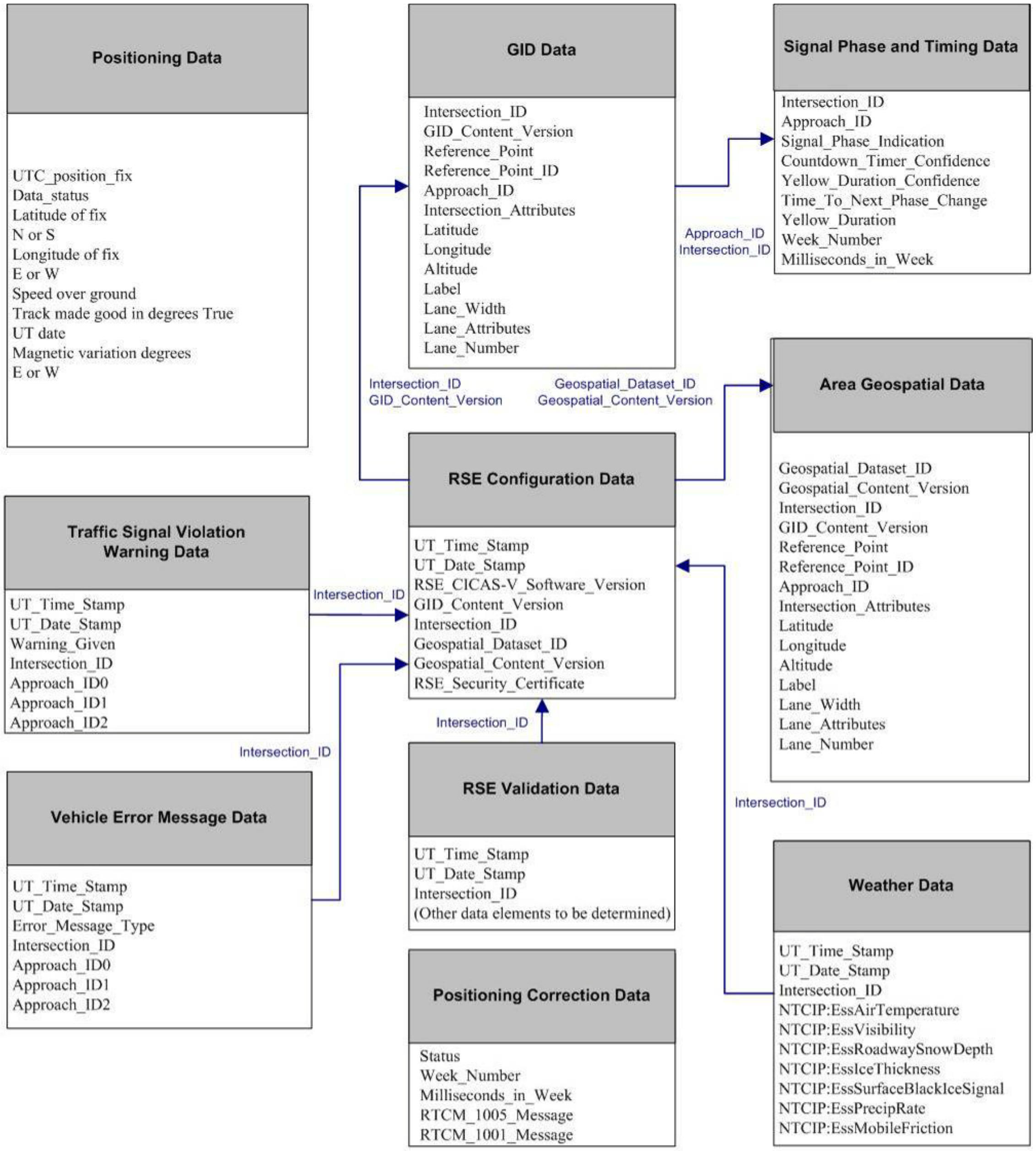

Figure 7 - CICAS-V Entity Relationship Diagram

This section lists 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. Data elements and data frames listed in these requirements are specified in several ITS standards included in the Appendix C list of references.

The following tables represent the preliminary understanding of the data elements that may be required for each data structure. The tables and data elements may require modification to meet the requirements of the final design.

Table 3 shows the preliminary list of data elements associated with the positioning system data.

Table 3 - 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 4 shows the preliminary list of data elements associated with the global positioning correction data.

Table 4 - 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 5 shows the preliminary list of data elements associated with the intersection signal state, phase, and timing.

Table 5 - 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 6 shows the preliminary list of data elements associated with the GID.

Table 6 - 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 7 shows the preliminary list of data elements associated with the Area Geospatial Data. In contrast to the GID data shown in Table 6, the Area Geospatial Data contain the GIDs for several, primarily stop controlled intersections in one data set. This data is optional.

Table 7 - 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 8 shows the preliminary list of data elements associated with the Traffic Signal Violation Warning Data. This data is optional.

Table 8 - 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

The traffic signal violation warning alert data flows from the OBE to the RSE. This data indicates that a warning has been given to a vehicle's driver. The Intersection ID must be set to the Intersection ID (from GID or SPaT) of the applicable intersection.

If the vehicle was on a lone approach, its Approach ID is stored in Approach ID0 and subsequent Approach IDs are set to zero. If multiple approaches are involved, up to two additional Approach IDs may be used. The approaches should be ordered from highest to lowest probability for the location of the vehicle at the time the warning was issued.

Table 9 shows the preliminary list of data elements associated with the Vehicle Error Message Data. This data is optional.

Table 9 - 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

If implemented, this information would be used to collect data about CICAS-V error conditions within vehicles or associated with roadside infrastructure encountered during travel for the purpose of determining the correct functioning of the overall CICAS-V.

Table 10 shows the preliminary list of data elements associated with the Weather Data. This data is optional.

Table 10 - 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 11 shows the preliminary list of data elements associated with the RSE Configuration Data.

Table 11 - 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 12 shows the preliminary list of data elements associated with the RSE Validation Data.

Table 12 - 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	

5 Decomposition View

The Decomposition View serves the following stakeholders:

- CICAS-V System Designers
- CICAS-V System Test Engineers
- System Designers for systems interfacing with CICAS-V

The Decomposition View addresses:

- decomposing the system into modules
- assigning unique identification names to the modules
- allocating system functionality to the modules
- associating the high-level requirements to the appropriate modules

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. Test engineers will use this view to prepare the System Test Plan and the System Test Procedures for each module. System designers will use this view to design each module so that it performs the required functions.

The functional decompositions are illustrated by block diagrams as shown in Figure 8.

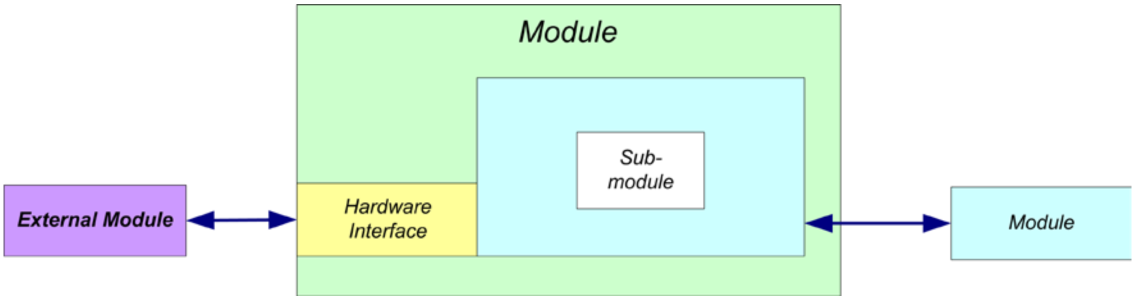

Figure 8 - Legend for Decomposition Diagrams

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, to reuse existing code from other sources, or to optimize how the coding will be performed.

5.1 OBE Functional Decomposition

As shown in Figure 9, 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

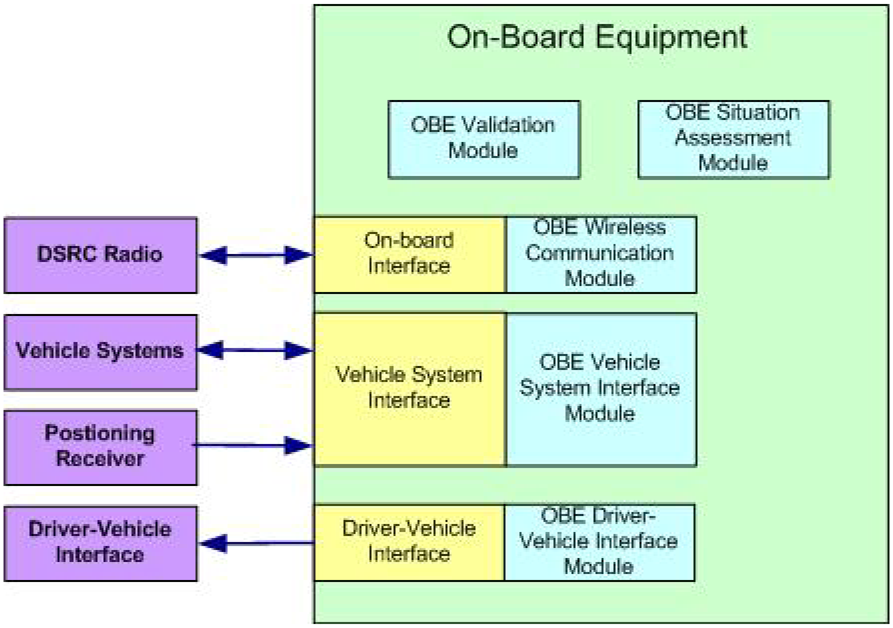

Figure 9 - OBE Functional Modules Overview

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

5.1.1 OBE Vehicle System Interface Module

The OBE Vehicle System Interface Module, shown in Figure 10, will be responsible for wired vehicle communication between the OBE and all other physical devices.

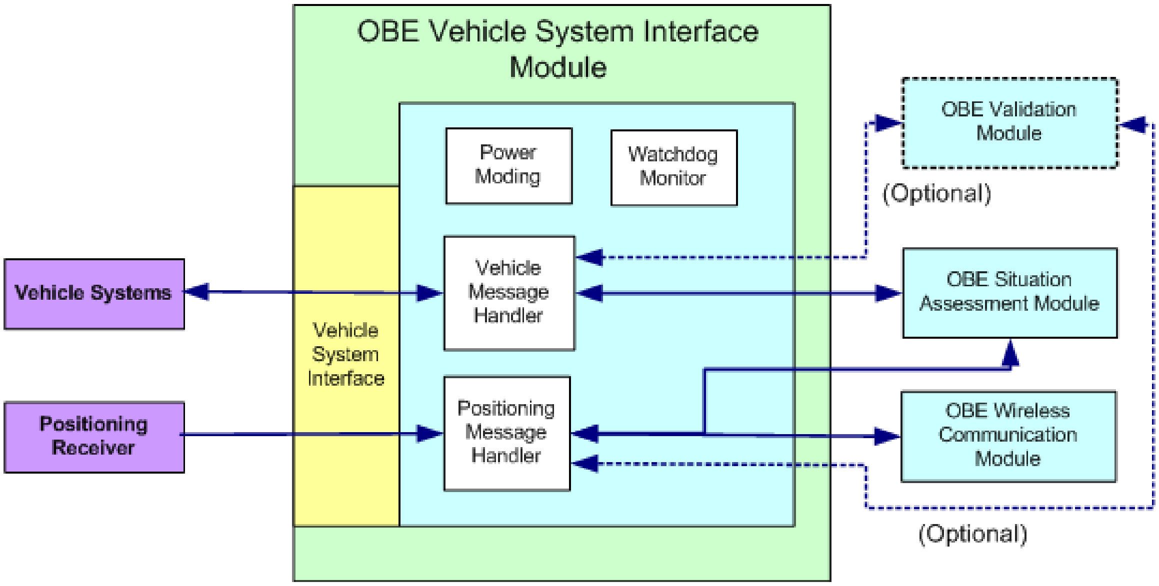

Figure 10 - OBE Vehicle System Interface Module

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. 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”. Final transition occurs in this mode. The OBE will be capable of ignoring multiple, sporadically timed changes of IGN state while in “Shutdown” mode.

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 the following:

- Determining the cause of the abnormal operation by testing the individual modules for correct operation
- Restart of the OBE system and its drivers
- 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 system receiver could interface directly with the Vehicle System Interface Module or be integrated within the Vehicle System Interface Module.

5.1.2 OBE Wireless Communication Module

The OBE Wireless Communication Module, shown in Figure 11, 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.

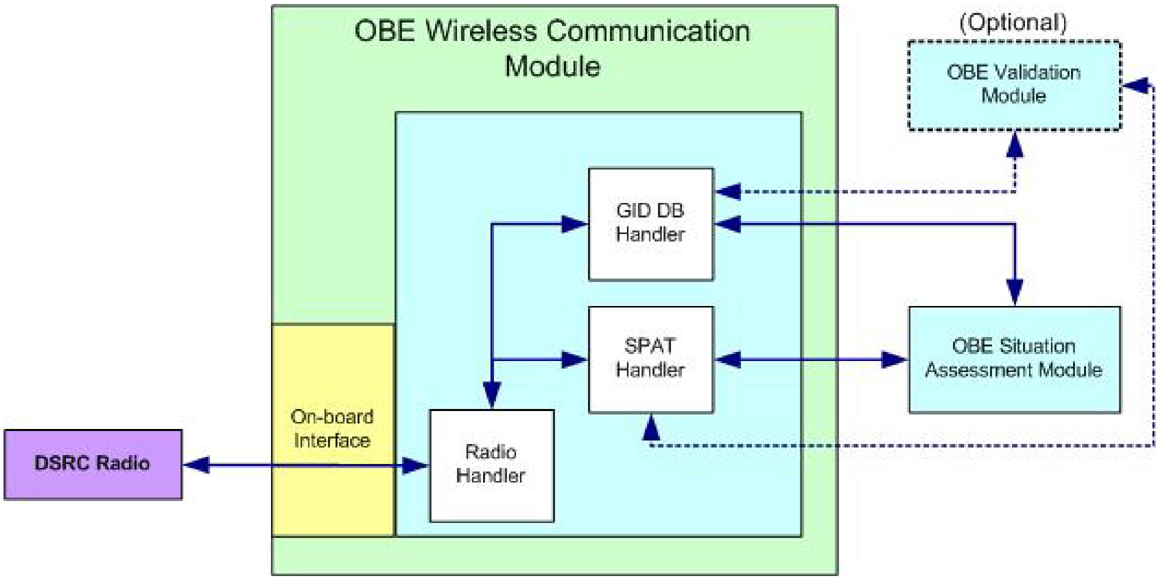

Figure 11 - OBE Wireless Communication Module

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 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 sends the message to the on-board interface for delivery to the DSRC radio.

5.1.3 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 12. It will determine the actual location of the vehicle including

- the actual lane of travel;

- any nearby intersection that may be necessary to monitor;
- 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.

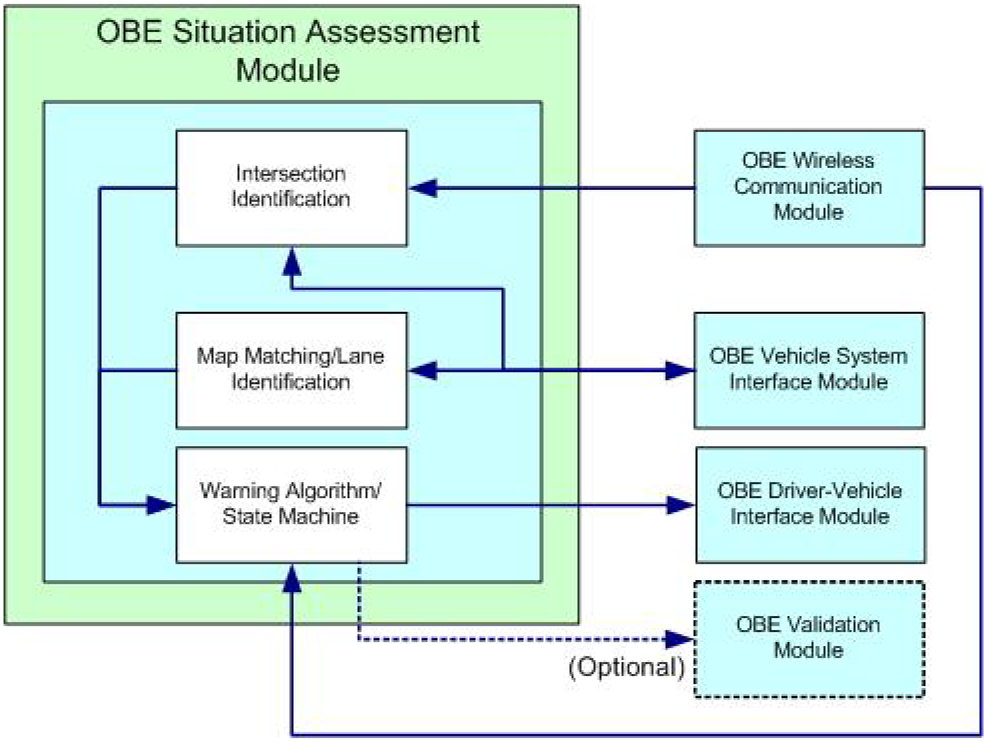

Figure 12 - OBE Situation Assessment Module

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.

5.1.4 OBE Driver-Vehicle Interface Module

The OBE Driver-Vehicle Interface Module, shown in Figure 13, will maintain the display and audio interfaces to the driver as needed during normal and alert operations.

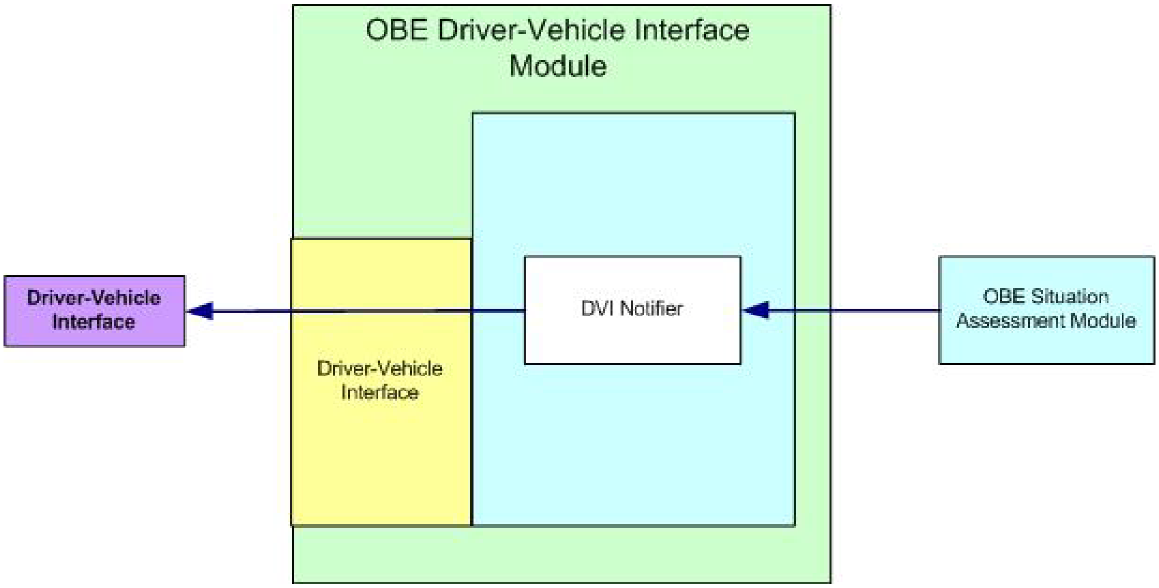

Figure 13 - OBE Driver-Vehicle Interface Module

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;
- 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.

5.1.5 OBE Validation Module

The OBE Validation Module, shown in Figure 14, will be used to evaluate the DSRC integrity and positioning availability and accuracy for the CICAS-V system applications at specific intersections.

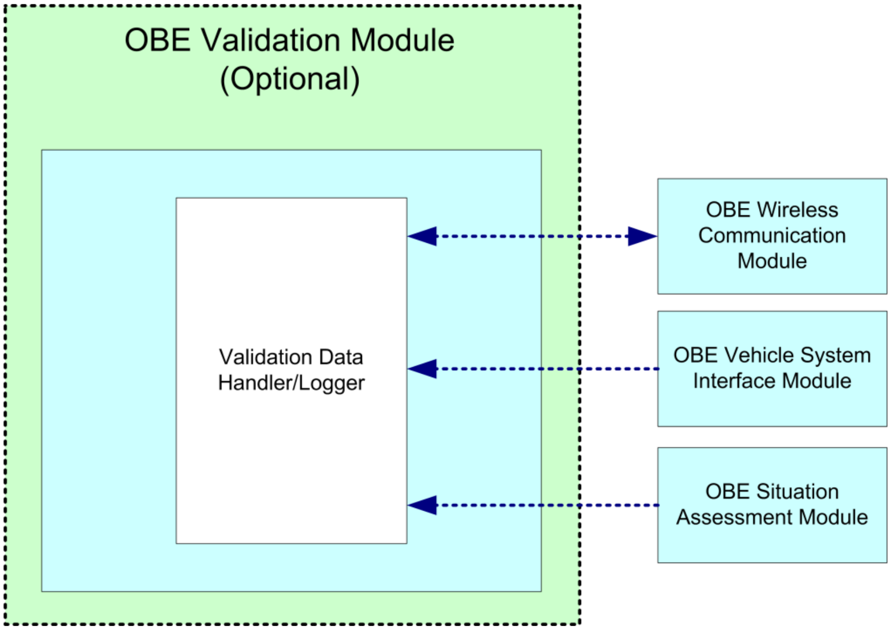

Figure 14 - OBE Validation Module

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.

5.2 RSE Functional Decomposition

As shown in Figure 15, the RSE is decomposed into the following functional modules:

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

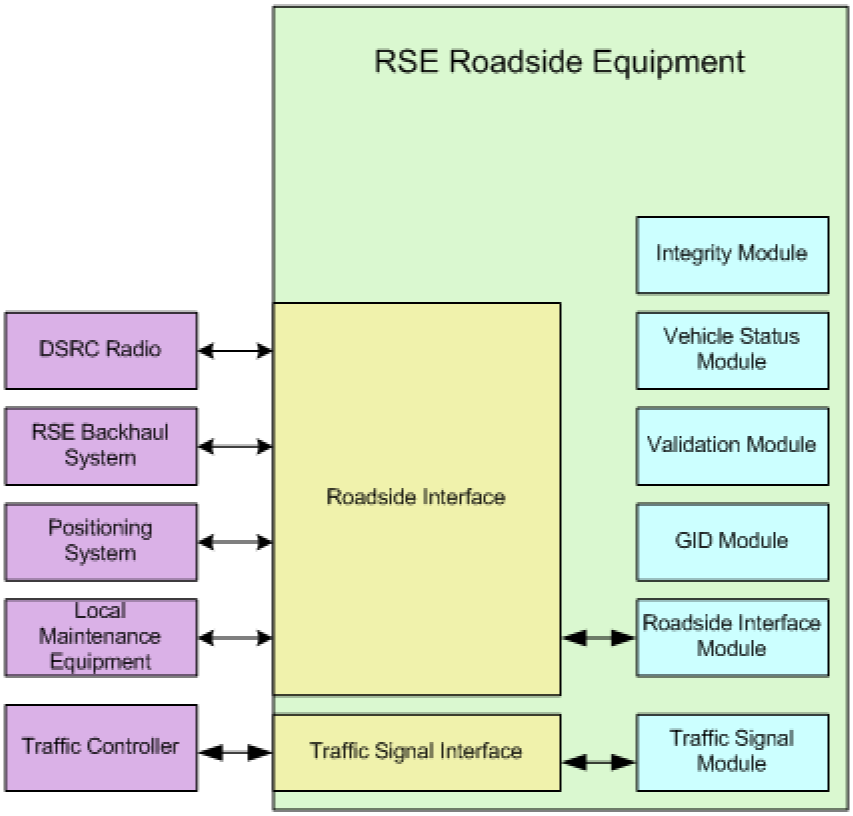

Figure 15 - RSE Functional Modules

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

5.2.1 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 16 shows a block diagram of the Integrity Module and the other modules with which it communicates.

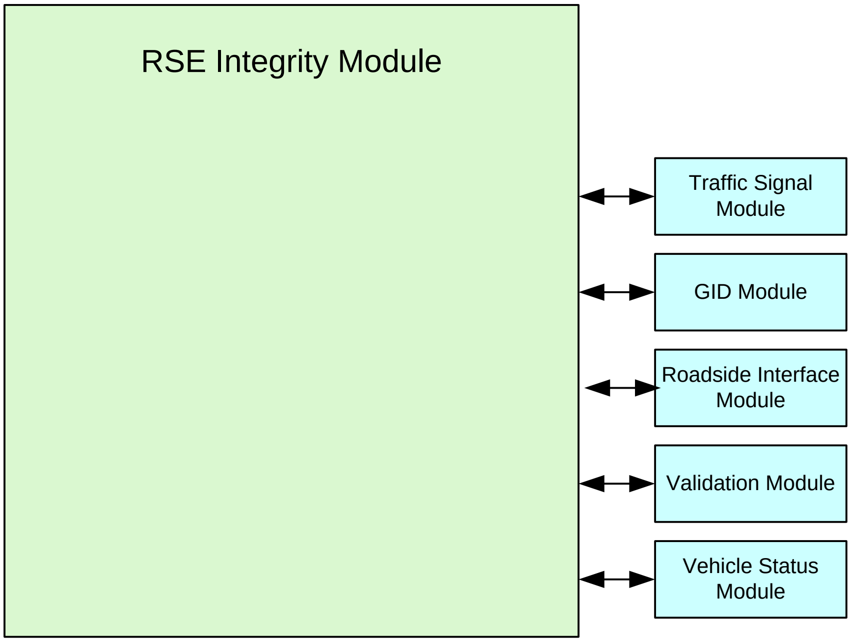

Figure 16 - RSE Integrity Module

5.2.2 RSE Roadside Interface Module

The Roadside Interface Module manages all communications with external devices except the traffic signal control equipment. Figure 17 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.

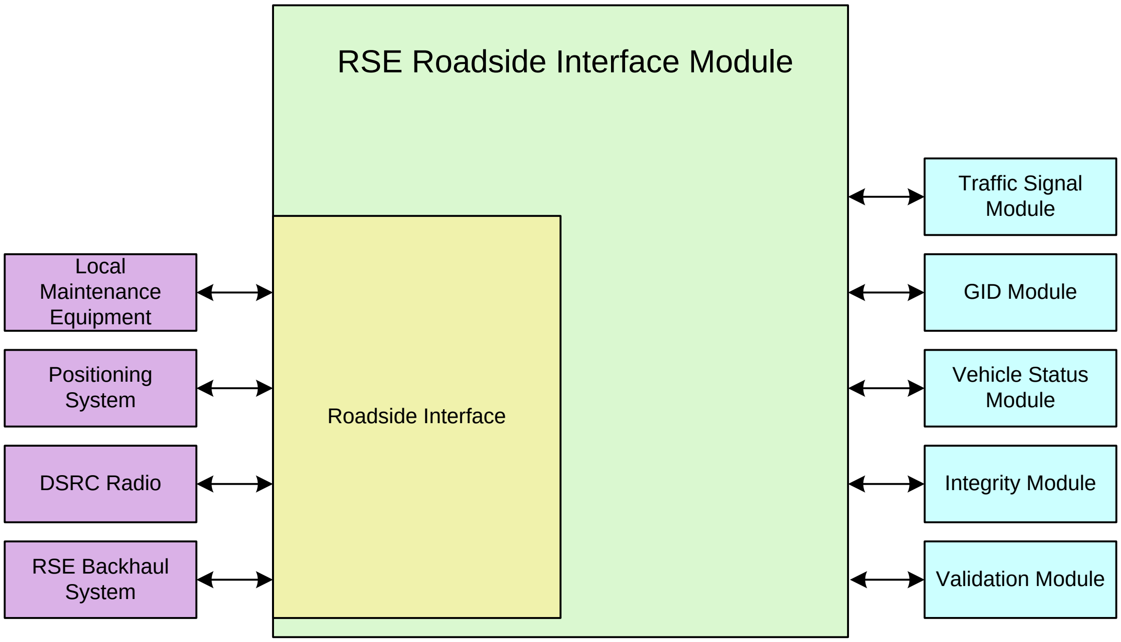

Figure 17 - RSE Roadside Interface Module

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 three 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
- Vehicle data update requests: when a vehicle identifies the need for and obtains an update of the area geospatial data.

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.

5.2.3 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 18 shows the block diagram for the Traffic Signal Processing Module.

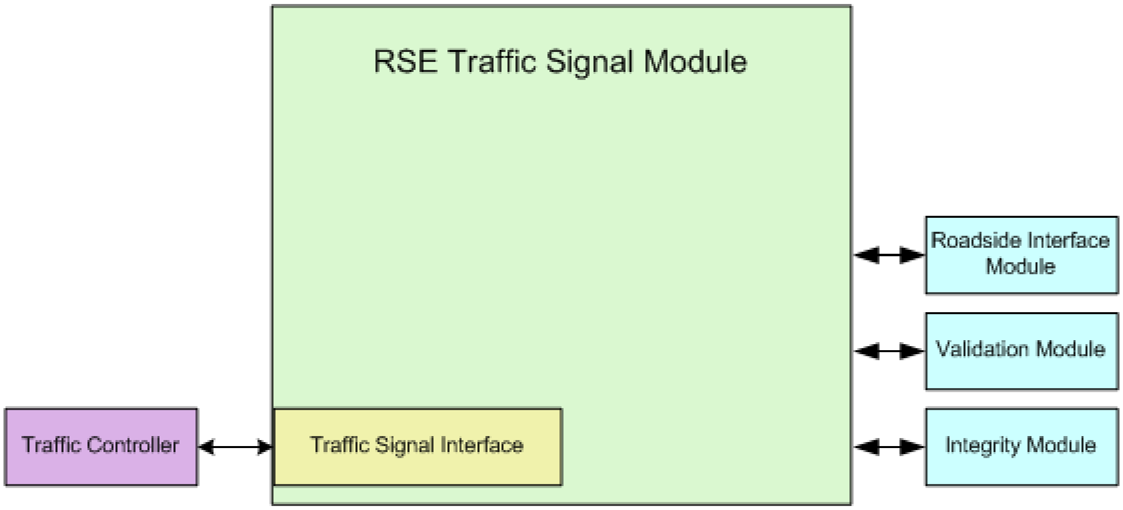

Figure 18 - RSE Traffic Signal Module

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.

5.2.4 RSE GID Module

The GID Module receives the current geometric intersection description data, stores it, and sends the data to other modules. Figure 19 shows the block diagram for the GID Module.

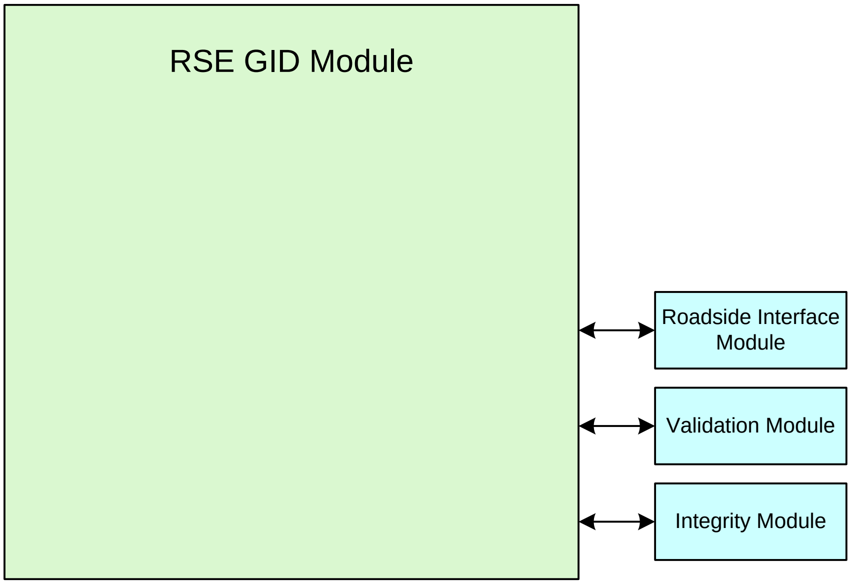

Figure 19 - RSE GID Module

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.

5.2.5 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 20 shows a block diagram for the module.

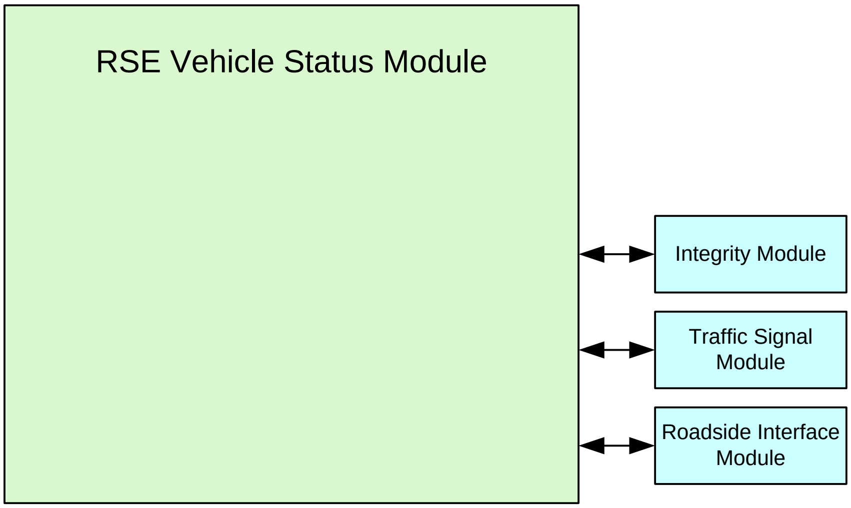

Figure 20 - RSE Vehicle Status Module

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 requesting module.

5.2.6 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 21 shows a block diagram of the Validation Module.

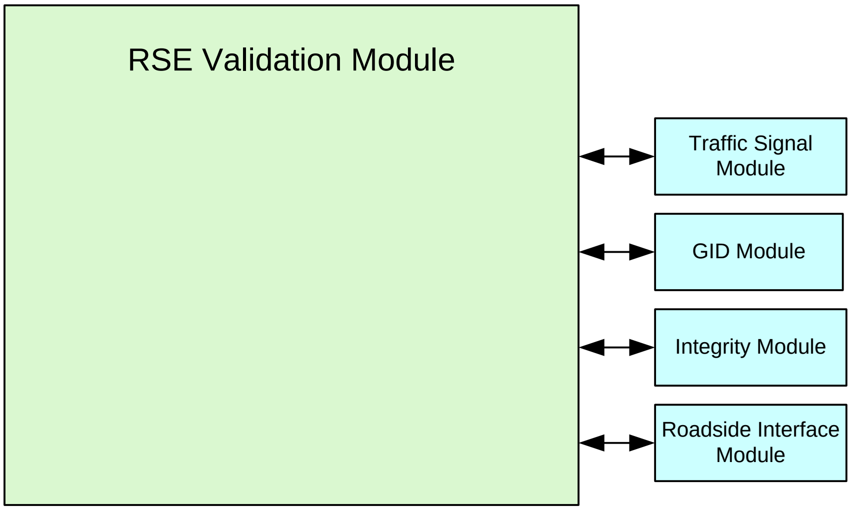

Figure 21 - RSE Validation Module

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 requestor.

6 Physical View

The Physical View serves the following stakeholders:

- CICAS-V System Designers
- CICAS-V Hardware Designers
- CICAS-V Test Engineers
- Network Designers
- Communication System Designers

The Physical View addresses

- identifying CICAS-V computer hardware components;
- identifying network components;
- identifying communication equipment components;
- establishing the physical and connective relationships between components;
- associating high-level hardware requirements with physical components;
- associating system modules with the physical components.

The Physical View provides an overview of the planning for the hardware, communications, and operational support for the system. Designers use this view to plan procurement and installation of the equipment required for the CICAS-V system. Test engineers use this view to prepare appropriate verification procedures for the equipment and construction associated with the equipment installation. Figure 22 shows the CICAS-V physical components and supporting infrastructure. No packaging restrictions are implied by the figure.

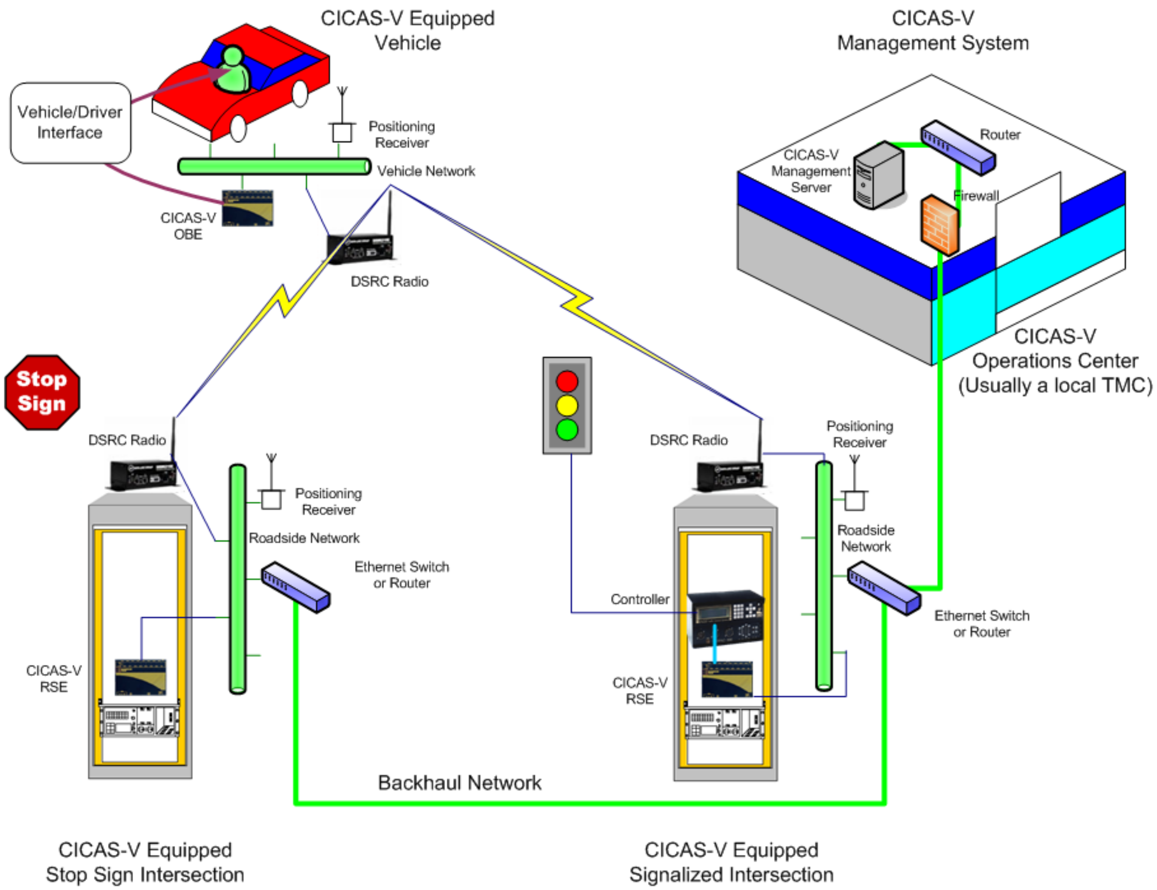

Figure 22 - CICAS-V Components and Supporting Infrastructure

The primary computer platforms for CICAS-V are the RSE computer and the OBE computer. Other platforms, such as the maintenance vehicles, CICAS-V Management System, and maintenance access workstation are not discussed in this architecture. The RSE and OBE are needed to prototype and test the system. The other platforms will enhance deployment and are included in the ConOps but are not essential at this stage.

The RSE and OBE computer platforms are not tightly specified. The intention is to allow a wide range of open platform solutions to develop, and to allow existing roadside platforms and in-vehicle computing platforms to be adapted to run the CICAS-V applications.

7 Technology View

The Technology View serves the following stakeholders:

- CICAS-V System Designers
- CICAS-V Hardware Designers
- CICAS-V Stakeholders
- System Designers for interfacing systems
- Network Designers
- Communication System Designers
- Federal Highway Administration

The Technology View addresses

- identifying technologies that will be used;
- identifying industry standards and specifications and how they will be implemented;
- identifying supporting technologies required for system operation.

The designers use this view to identify constraints imposed on the design by standards, specifications, and regulatory rules. Designers also use this view to identify design constraints imposed by the technologies selected for the system implementation. United States Department of Transportation (USDOT) A uses this view to verify that appropriate ITS standards are being used in compliance with USDOT regulations.

7.1 Technology Options

7.1.1 Roadside Communications Options

The roadside network interface for the RSE is currently assumed to be an Ethernet connection, with a 10/100BaseT interface. The local roadside networks will be interconnected by the VII backbone network, which will also connect to the operations center and the CICAS-V Management System server. The physical infrastructure for the VII network is transparent to the CICAS-V system.

There are currently three technology alternatives for the positioning system interface:

- Embed the positioning system(s) in the CICAS-V RSE components (no external interface required).
- Connect the positioning system(s) to the roadside network and use the roadside network for the positioning system physical interface (only network interface required). If the VII RSE is equipped with a positioning system that meets the design criteria for CICAS-V, the VII positioning system would be connected to the CICAS-V components through the roadside network.
- Connect the positioning system(s) to the RSE with TIA-232 or TIA-485 serial interface connections.

Two of these alternatives would eliminate the need for a separate physical interface for the positioning system and the Roadside Interface Module would only require network connections. Two network connections have been specified for the Roadside Interface Module components, one for local maintenance access and one for VII network connectivity.

The interface between the RSE and the Traffic Signal System equipment may be a TIA-232 or TIA-485 serial interface, or a 10BaseT Ethernet network connection. Even controllers that do not support network interfaces could be retrofitted with serial to Ethernet converters and connected to the roadside network. This approach would reduce the physical interfaces for the RSE to the two Ethernet ports.

7.1.2 Positioning System

At this stage of the design, there are several options available regarding the positioning systems that could be used for the CICAS-V system.

At the RSE, the design options include the following:

- Integrating a positioning system receiver, configured as a local base station, into the RSE components using an embedded receiver or a plug-in commercial grade receiver, which would eliminate the positioning interface as an external interface
- Connecting a positioning system receiver, configured to output local base station correction data, via TIA-232 serial interface
- Providing network position correction data via a roadside network. Global Positioning System (GPS) data from a local area GPS network could be used such that a cluster of regional intersections are covered by a single GPS station.

A similar set of open design decisions exist for the positioning systems on-board the vehicle. The type of positioning receiver is not fixed. The positioning system equipment could be built into the OBE components, or the OEM could decide to use a positioning system that is already part of the vehicle systems equipment. In this second instance, the positioning system interface would be part of the vehicle systems interface, and could be either serial or network connected.

The OBE components will use the best possible positioning data available for a given set of conditions. The OBE components will integrate the potential correction data with the GPS data delivered from the local positioning system receiver. Possible sources of correction data include:

- Wide Area Augmentation System (WAAS) (U.S. Federal Aviation Authority)
- National Differential Global Positioning System (NDGPS) (USDOT)
- Local or network GPS corrections delivered via DSRC roadside equipment (RSE, CICAS-V, Department of Transportation)

The OBE module will then select one source of corrections depending on the availability and accuracy requirements. 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.

The Map Matching and Lane Identification algorithms will map the location of the vehicle to the GID downloaded from the RSE. The OBE components will attempt to resolve location and lane of travel to highest possible accuracy given the limitations of a particular location and time.. Potential values for location accuracy might include:

- Lane Level
- Road Level
- No Match

7.1.3 Vehicle Systems Interface

The Vehicle Systems Interface is not simply a network connection. The Vehicle Systems Interface (as noted above) may include a serial interface for the positioning system, a vehicle network bus connection such as CAN, and a separate connection for power mode signaling. Alternatively, all of the interface messaging could be accommodated using the network interface.

The Vehicle Systems Interface will be responsible for conversion of any proprietary data formats required to communicate with OEM-specific components. This module will use Generic CAN Message information in the OBE Vehicle System Interface data store to translate OEM-specific information from the vehicle CAN network to a generic message format. This module represents an edge of the CICAS-V boundary. At this point, OBE has an interface to the vehicle CAN network.

Layers 1 and 2 of the International Standards Organization (ISO) model—the high-speed CAN physical layer—are described in the following standards:

- SAE J2284/3
- ISO 11898-2

Additional detail about the Single Wire CAN (SWC) physical layer may be found in the following standards:

- SAE J2411
- ISO 11898-1

The purposes of translating the CAN message from the OEM format to the generic format are:

- to protect the proprietary nature of the OEM's message set, and
- to allow the system to record consistent data regardless of the make/module of manufacture of the vehicle.

In order to protect the proprietary nature of the OEM messages, this module will be developed for each OEM independent of the other module designs. Additional vehicle features will be gathered from the Vehicle Feature Availability data that is also stored in the Vehicle System Interface data store.

7.1.3.1 CAN Vehicle Status Data

The OBE components will obtain vehicle status data through the CAN messages that are sent to the Vehicle Systems Interface. A minimum of three critical values must be available for the CICAS-V system to work:

- Vehicle speed

- Vehicle acceleration
- Vehicle brake position

Additional information may be available from the vehicle which could be used to improve the accuracy of the situational assessment algorithm:

- Vehicle turn signal setting
- Vehicle traction control
- Vehicle yaw rate
- Vehicle throttle position
- Electronic stability system status
- Brake torque
- Brake pressure

The Vehicle Systems Interface could also, if necessary, communicate using a system-specific message set. Possible communication could include

- System failure
- Memory full

7.1.3.2 OBE Vehicle System Interface Data Store

The customization of the Vehicle Systems Interface to each vehicle will require significant configuration information. This configuration information data store will consist of the following:

- Vehicle Feature Availability data – This data will include any specific information about features available on the vehicle that could be used by OBE. Possible specific information that could be included is Panic Brake Assist or Stability Control.
- Generic CAN Message data – This data will include translation information to convert values within OEM specific CAN message data to standardized engineering units.
- Vehicle CAN Message data – This data will include additional OEM specific CAN message translation information that is not common among OEMs.
- Current Vehicle Status data – This data will include vehicle status information required for the situation assessment. Each status record will include timestamp information.
- Interface Message Packaging data – This data will define the format in which the interface messages are packaged and transmitted.

7.1.4 OBE Driver-Vehicle Interface Module

The OBE Driver-Vehicle Interface Module will maintain the visual display, haptic, and audio interfaces to the driver as needed during normal and alert operations. Depending on the OEM design decisions for the Driver-Vehicle Interface, this interface could also require a significant set of configuration data.

The Driver-Vehicle Interface will likely require sub-components to deal with each type of driver interface and warning device.

If a video interface is selected that requires initialization upon power up (e.g., to create initial graphics) the Driver-Vehicle Interface Module will need to be responsible for the startup, initialization, and monitoring of the process. The Video Driver would be responsible for maintaining the DVI video display after the initial boot up. This module will be responsible for accepting the Driver Warning and Driver Notification messages and translating them to the proper format for the Driver-Vehicle Interface.

If the CICAS-V driver warning human-machine interface (HMI) is an illuminated icon, the interface module will need to conduct a bulb test during vehicle start.

An Audio Support driver would be needed to provide the necessary software or hardware required to drive the DVI audio portion. The input to this module could be a WAV or MP3 file. Based on the message sent to the DVI, the appropriate file would be played. This would require that an appropriate driver be available to process those formats. The output could also be an AC97 driver.

7.1.5 Maintenance Vehicle Validation Equipment

The ConOps discusses the need for a system Validation Mode for assessing each intersection before it goes into operation. The process would involve evaluation of information sent from maintenance vehicles as they pass through the intersection. The functionality for this Validation Mode would not need to be part of the basic CICAS-V OBE components. Design choices include:

- build the functions into the OBE and include a way to turn on the functionality in maintenance vehicles
- build a separate OBE design for maintenance vehicles that includes the functionality
- build a separate device which has only the required functionality to perform the Validation Mode tasks

Since some of the required functionality may be dependent on direct connectivity to the DSRC radios, the first of the above alternatives may not be feasible.

7.1.5.1 DSRC Signal Quality Evaluation Module

The DSRC Signal Quality Evaluation Module will monitor and report on the DSRC radio performance, such as received signal strength, signal to noise ratio, and bit and frame errors. When required for Validation messages, the module parameters could include the specific geographical location of poor signal reception and bit errors.

7.1.5.2 Position Quality Evaluation Module

The Position Quality Evaluation Module will monitor the availability and certainty of the positioning data. When required for Validation Messages, the module can report:

- geographical locations of poor signal availability, and
- geographical locations of high uncertainty positioning data.

7.1.6 Traffic Signal Controller Interface

The expected interface with the traffic controller is through a serial TIA-232 interface. It is possible that some traffic control equipment will offer a network interface such as 10/100BaseT Ethernet.

7.2 Standards and Specifications

Implementation of the CICAS-V system will be dependent on a large body of standards that can be found among the references listed in Appendix C.

8 National ITS Architecture View

The National ITS Architecture View serves the following stakeholders:

- CICAS-V System Designers
- Regional ITS Architecture Coordinators
- Federal Highway Administration

The National ITS Architecture View addresses

- relating the CICAS-V physical architecture to the physical architecture described in the National ITS Architecture;
- identifying the ITS Market Packages associated with the CICAS-V system;
- relating the CICAS-V logical architecture to the logical architecture described in the National ITS Architecture.

This view provides the US Department of Transportation, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National ITS Architecture and how the system might relate to the Regional ITS Architectures where it is deployed. This includes the system's relationship to the standard Market Packages and to the National ITS Physical and Logical Architectures.

The FHWA in January 2001 issued Part 940 of Title 23 of the Code of Federal Regulations (23 CFR 940), its final rule on conformance of ITS systems and projects to the National ITS Architecture and associated standards. This architecture view allocates the components of the CICAS-V system according to the structure and views of the National ITS Architecture.

System functions in the National ITS Architecture are described in three representations: market packages, a physical architecture (in terms of subsystems, terminators, and equipment packages), and a logical architecture (in terms of processes and the data flows between them). A complete description of these representations and their associated object classes can be found in the referenced National ITS Architecture documentation. The description of the National ITS Architecture herein is limited to those aspects of the architecture that are specifically related to the CICAS-V system.

8.1 Physical Architecture

The *Physical Architecture* is comprised of transportation, communications, and institutional layers. The transportation layer includes the various transportation-related processing centers, distributed roadside equipment, vehicle equipment, and other equipment used by travelers to access ITS services. The communication layer provides for the transfer of information between the transportation layer elements. The institutional layer introduces the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the Architecture.

Within the physical architecture, *subsystems* are used to describe collections of specific processing functions related to real-world transportation systems. *Terminators* are real-world users of, and objects associated with, the transportation systems. In the physical architecture, terminators interact with the subsystems, but are "outside the scope of" the transportation system itself. Terminators can be sources of information or consumers of information.

The Transportation and Communication Layers together are the *Architecture Framework* that coordinates overall system operation by defining what each major transportation system element does and how they interact to provide user services. Figure 23 shows a high-level view of the Architecture Framework. The shaded areas of the figure indicate the elements corresponding to the CICAS-V system.

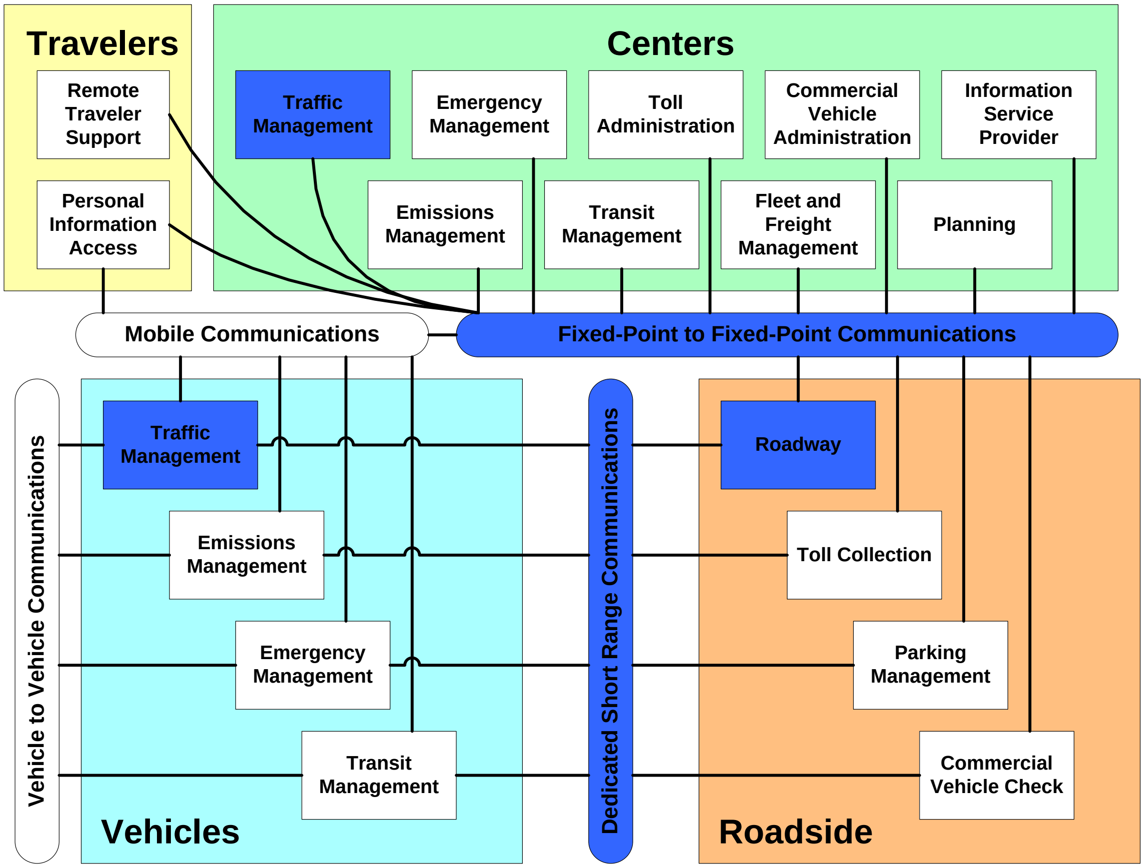

Figure 23 - Architecture Framework

Figure 24 shows the portions of the National ITS Physical Architecture that correspond to the CICAS-V system. The CICAS-V in this picture is overlaid on the VII Proof of Concept, which includes other data flows not associated with CICAS-V. Legend

☐ Element is Part of CICAS-V

☐ Element is Part of CICAS-V but Deferred

🟦 Element is External to CICAS-V

Figure 25 shows the corresponding CICAS-V Physical Architecture for the deployment.

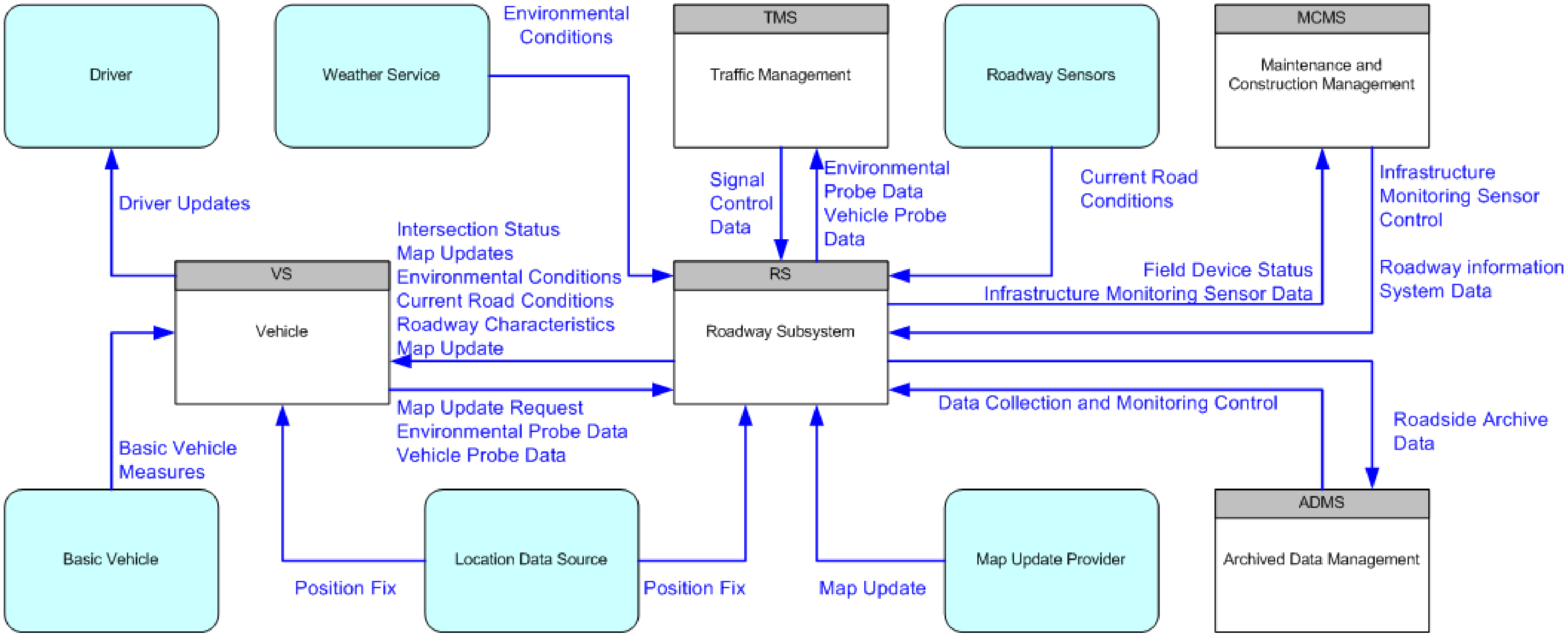

Figure 24 - CICAS-V Components of National ITS Physical Architecture

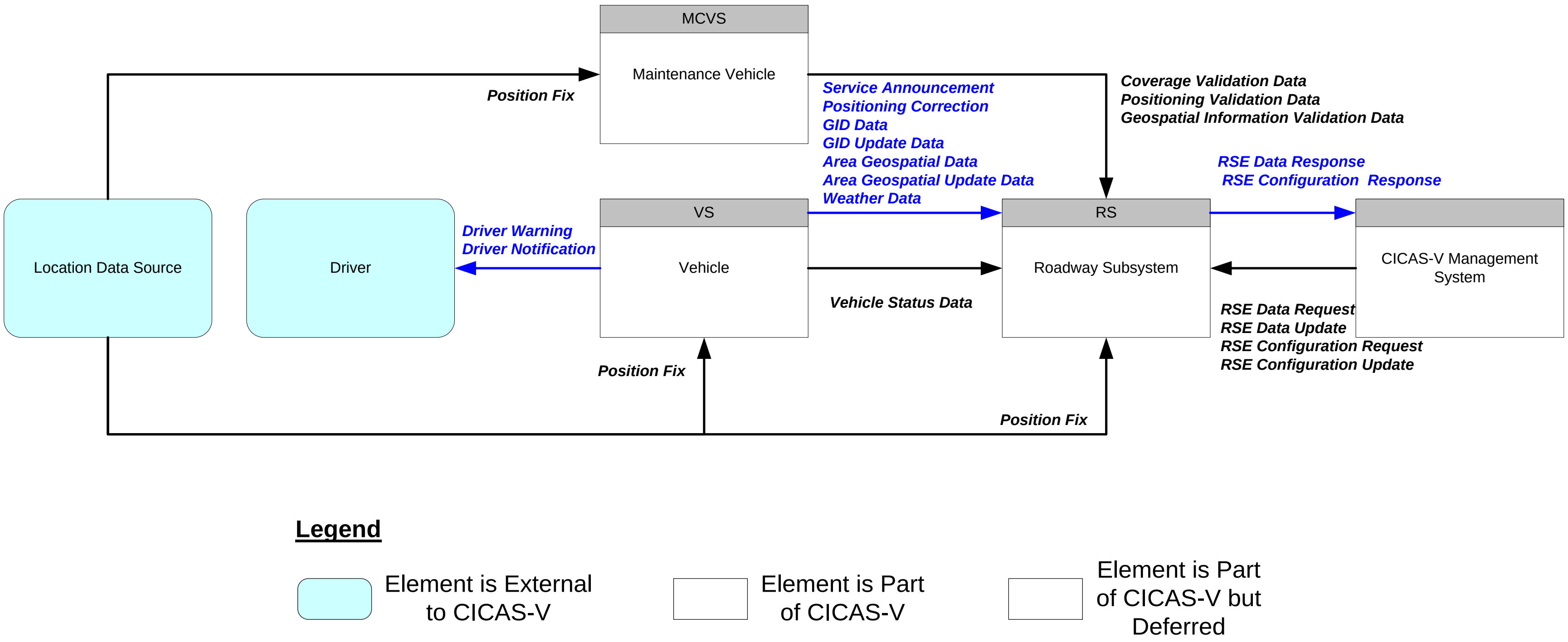

Figure 25 - CICAS-V Physical Architecture

8.2 Market Packages

Market packages represent functional groupings within the Physical Architecture that correspond to specific services. Market packages are collections of functions (the "package") that can be used together to meet a related group of operational needs (the "market"). A market package does not necessarily correspond to a specific product or system. Version 5.0 of the National ITS Architecture describes eighty-five market packages to represent the breadth of capabilities in the overall architecture. Table 13 illustrates the distribution of CICAS-V components in the context of these market packages.

Table 13 - Market Packages Relating to CICAS-V

Market Package	Market Package Name
AVSS05	Intersection Safety Warning
ATIS09	In Vehicle Signing
ATMS03	Surface Street Control

8.2.1 Intersection Safety Warning

The National ITS Architecture provides the following description of the Intersection Safety Warning market package:

> "This market package will determine the probability of a collision in an equipped intersection (either highway-highway or highway-rail) and provide timely warnings to drivers in response to hazardous conditions. Monitors in the roadway infrastructure assess vehicle locations and speeds near an intersection. Using this information, a warning is determined and communicated to the approaching vehicle using a short range communication system. Information can be provided to the driver through the market package ATIS09—In Vehicle Signing."

CICAS-V meets the intent of this market package by warning the driver of potential controlled intersection violations. The CICAS-V implementation varies from this description in several ways:

- CICAS-V will be implemented at arterial and highway intersections.
- CICAS-V has not been described in the context of highway-rail intersections.
- CICAS-V will use vehicle equipment to monitor vehicle locations and speeds near intersections, not roadway infrastructure components.
- CICAS-V will communicate with roadway infrastructure using a short range communication system, but the driver warning will be generated by vehicle components, not roadway components.

8.2.2 In-Vehicle Signing

The National ITS Architecture provides the following description of the In-Vehicle Signing market package:

> "This market package supports distribution of traffic and travel advisory information to drivers through in-vehicle devices. It includes short range communications between roadside equipment and the vehicle and wireline

> connections to the Traffic Management Subsystem for coordination and control. This market package also informs the driver of both highway-highway and highway-rail intersection status."

As noted in the previous market package description, this market package may be used to support the Intersection Safety Warning functions of CICAS-V. The CICAS-V implementation varies from this description in the following ways:

- CICAS-V uses short range communications between roadside equipment and the vehicle and wireline connections to the Traffic Management Subsystem, but not in the ways described by this market package.
- CICAS-V uses wireline connections to the Traffic Management System to manage the CICAS-V system, not to provide coordination or control.
- CICAS-V will inform the vehicle, not the driver, of intersection status.

8.2.3 Surface Street Control

The National ITS Architecture provides the following description of the Surface Street Control market package:

> "This market package provides the central control and monitoring equipment, communication links, and the signal control equipment that support local surface street control and/or arterial traffic management. A range of traffic signal control systems are represented by this market package ranging from static pre-timed control systems to fully traffic responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. Additionally, general advisory and traffic control information can be provided to the driver while en-route."

The CICAS-V implementation varies from this description in the following ways:

- CICAS-V interfaces with the signal control equipment to obtain traffic control information, but does not obtain general advisory information other than weather data.
- CICAS-V obtains traffic control information and provides it to the vehicle, not the driver.

8.3 Logical Architecture

The Logical Architecture provides a functional requirements process model for ITS systems. Data Flow Diagrams (DFDs) and DFD descriptions are used to identify the processes and information associated with the functional requirements process model.

Within the ITS Logical Architecture volume of the National ITS architecture, DFD: 1 *Manage Traffic* is the level one diagram for the Traffic Management functions. This functionality includes

- DFD: 1.2 *Provide Device Control.* DFD: 1.2 covers the processes that provide the mechanism through which traffic management strategies can be implemented. This in turn includes the functionality of

  - DFD: 1.2.7 *Provide Roadside Control Facilities.* DFD: 1.2.7 covers the processes that distribute the data implementing traffic management strategies to roadside equipment used for traffic management. The processes include:
    - DFD: 1.2.7.1 *Process Indicator Output Data For Roads.*
    - DFD: 1.2.7.2 *Monitor Roadside Equipment Operation for Faults.*
    - DFD: 1.2.7.6 *Provide Intersection Collision Avoidance Data*.
    - DFD: 1.2.7.8 *Provide Device Interface to Other Roadway Devices.*

DFD: 3 *Provide Vehicle Monitoring and Control* is the level one diagram for the vehicle ITS systems. This functionality is responsible for providing facilities for the automatic control of vehicles. This functionality includes:

- DFD: 3.1 *Monitor Vehicle Status.* DFD: 3.1 covers the processes that monitor vehicle operation, driver performance and data provided from the roadway on which the vehicle is operating. This data is used to generate messages for output to the driver and may also provide input to the vehicle control facilities for automatic action. This functionality is provided through three processes:
  - DFD: 3.1.1 *Produce Collision and Crash Avoidance Data*
  - DFD: 3.1.2 *Carry-out Safety Analysis*
  - DFD: 3.1.3 *Process Vehicle On-board Data*

DFD: 6 *Provide Driver and Traveler Services* is the level one diagram for the Driver Interface services in the vehicle. This functionality includes:

- DFD: 6.2 *Provide Information Services*. DFD: 6.2 describes the facility that provides advisory and broadcast information to drivers and travelers aboard transit vehicles. This includes:
  - DFD: 6.2.5 *Provide Driver Information Interface*

Figure 26 shows a simplified version of the above DFDs, showing only the functions and data flows associated with the CICAS-V system.

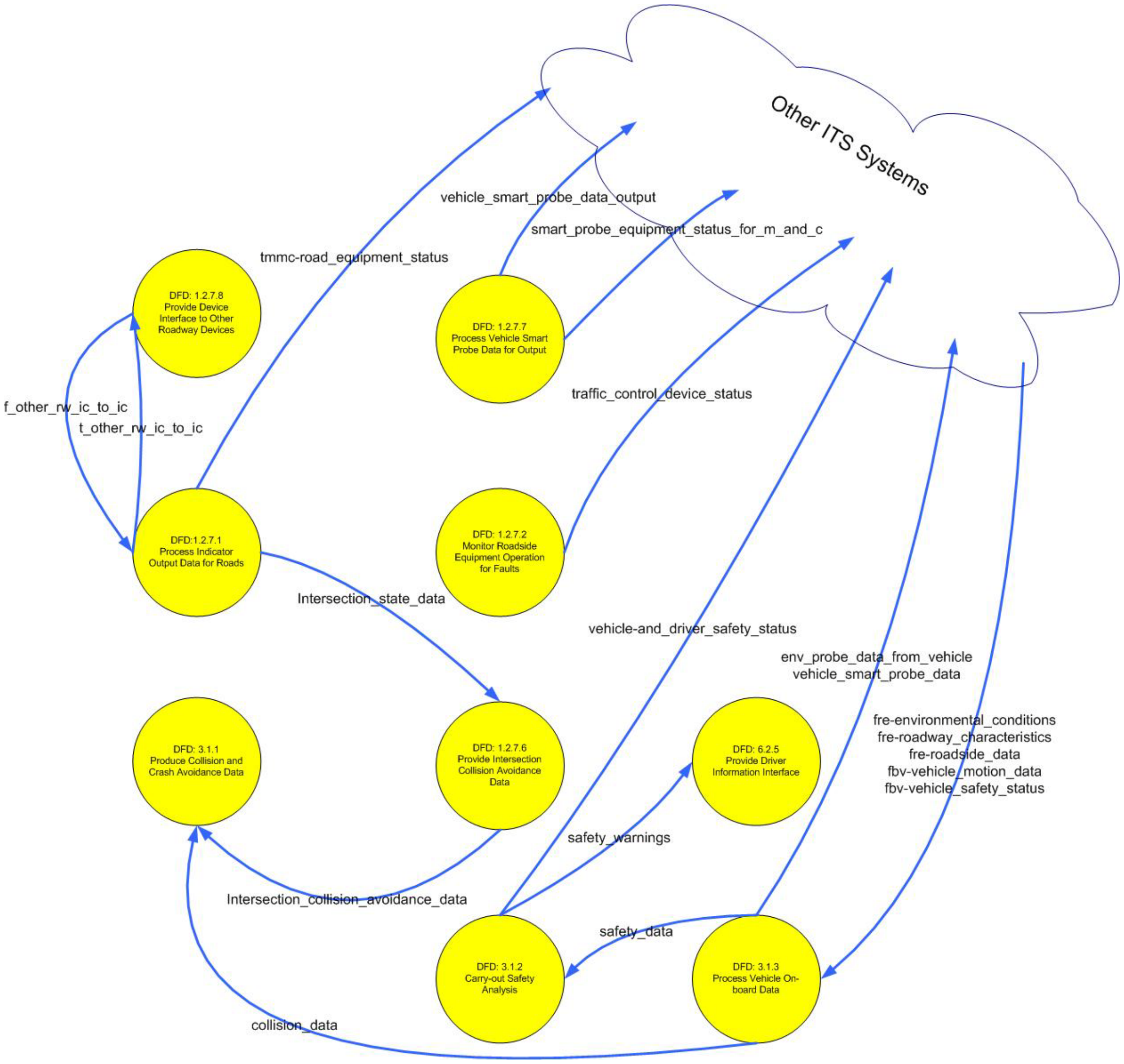

Figure 26 - DFD for the CICAS-V System as Depicted by National ITS Architecture

The architecture flows in the Physical Architecture Dictionary corresponding to CICAS-V data flows include the following:

- Basic Vehicle Measures – Information provided to on-board ITS equipment from the vehicle platform indicating current vehicle status
- Data Collection and Monitoring Control – Information used to configure and control data collection and monitoring systems
- Driver Updates – Information displayed or otherwise conveyed by the vehicle to the driver
- Environmental Conditions – Current road conditions that are measured by environmental sensors
- Intersection Status – Status of intersection congestion, approaching vehicles, etc.

- Maintenance and construction center personnel inputs – Maintenance and construction related information, including device configuration, entered by maintenance and construction center personnel
- Maintenance and construction vehicle location data – The current location and related status (speed, direction, etc.) of the maintenance vehicle
- Map update request – Request for a map update which could include a new underlying map or map layer
- Map updates – Map updates which could include a new underlying static or real-time map or map layer update
- On-board safety data – Safety data measured by on-board sensors. Includes information about the vehicle, vehicle components, cargo and driver
- On-board safety request – Request for on-board vehicle safety data by the roadside equipment
- Position Fix – Information which provides a traveler's or vehicle's geographical position
- Road network conditions – Current and forecasted traffic information, road and weather conditions, traffic incident information, and other road network status
- Road weather information – Road conditions and weather information that are made available by road maintenance operations to other transportation system operators
- Signal control status – Status of surface street signal controls
- Vehicle location – Location of a vehicle calculated on-board the vehicle

Appendix A: List of Acronyms

ANSI	American National Standards Institute
ATIS	Advanced Traveler Information System
C2C	Center to Center
CAMP	Crash Avoidance Metrics Partnership
CAN	Controller Area Network. Wired network system common in newer model vehicles.
CICAS	Cooperative Intersection Collision Avoidance System
CICAS-V	Cooperative Intersection Collision Avoidance System for Violations
ConOps	Concept of Operations
DFD	Data Flow Diagrams
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
ESS	Environmental Sensor Stations
ETMCC	External Traffic Management Center Communication
FHWA	Federal Highway Administration
FOT	Field Operational Test
GID	Geometric Intersection Description
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human-Machine Interface
ID	Identification or Identifier
IEEE	Institute of Electrical and Electronics Engineers
IGN	Ignition
ISO	International Standards Organization
ITS	Intelligent Transportation Systems
LRMS	Location Referencing Message Specification
MS/ETMCC	Message Sets for External Traffic Management Center Communications
NDGPS	Nationwide Differential Global Positioning System
NHTSA	National Highway Traffic Safety Administration
NMEA	National Marine Electronics Association, Inc.
NTCIP	National Transportation Communications for ITS Protocol
OBE	On-board Equipment
OEM	Original Equipment Manufacturer

POC	Proof of Concept
RSE	Roadside Equipment
RTCM	Radio Technical Commission for Maritime Services
SAE	SAE International, an organization formerly known as Society for Automotive Engineers
SPaT	Signal Phase and Timing
SWC	Single Wire CAN
TCIP	Transit Communications Interface Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TIA	Telecommunications Industry Association
TMDD	Traffic Management Data Dictionary
USDOT	United States Department of Transportation
UTC	Coordinated Universal Time
UUID	Universal Unique Identifier
VAN	Vehicle Area Network
VII	Vehicle Infrastructure Integration
VSC2	Vehicle Safety Communications 2
WAAS	Wide Area Augmentation System
WAV/MP3	Audio file formats
WAVE	Wireless Access in Vehicular Environments
WSA	WAVE Service Announcement

Appendix B: Glossary of Terms

10/100BaseT: 10/100BaseT Ethernet (also known as IEEE802.3) is the *de facto* standard for local area networks.

Conflict (also called a Traffic Conflict): An event involving at least two road users, in which the action of one user causes the other users to make an evasive maneuver to avoid a crash (Parker and Zegeer, 1989). Conflicts which take place at an intersection are relevant to CICAS-V and are referred to as Traffic Signal Conflicts or Stop Sign Conflicts, depending on the intersection type.

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.

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 and provides a highly accurate time source given a suitable GPS receiver. The network of satellites is owned by the US Department of Defense. It uses an intermediate circular orbit satellite constellation of at least 24 satellites.

Ignition Wire: Signal wire that provides status of vehicle. High (battery voltage) indicates the vehicle is in the “ON” position, Low (0 VDC) indicates the vehicle is in the OFF or ACCESSORY mode.

Intersection: For CICAS-V, an intersection is a junction of two or more public roads where at least one approach to the intersection is controlled by either a stop sign or a traffic signal.

Light Vehicles: The term “light vehicles” refers to passenger vehicles sold or operated legally within the U.S., including sedans, light trucks, and vans.

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.

TCP/IP: Transmission Control Protocol/Internet Protocol is a set of communications protocols which implement a protocol stack on which a network may run.

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

WAV/MP3: Audio file formats used to store sound information. WAV file format is used for storing uncompressed sound data. MP3 is a codec used with a WAV file to encode and compress the data.

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 Integration Initiative and Intelligent Transportation Systems 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.

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U.S. Department of Transportation
ITS Joint Program Office-HOIT
1200 New Jersey Avenue, SE
Washington, DC 20590

Toll-Free "Help Line" 866-367-7487
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