Vehicle-to-Infrastructure (V2I) Safety Applications

Performance Requirements, Vol. 7, Stop Sign Gap Assist (SSGA)

www.its.dot.gov/index.htm
Final Report — August 2015
FHWA-JPO-16-254

U.S. Department of Transportation

Produced by Battelle Memorial Institute under DTFH61-12-D-00040
U.S. Department of Transportation
Federal Highway Administration Office of Safety Research and Development

Notice

Source: Bottom left cover image courtesy of the University of Minnesota Center for Transportation Studies; all other cover images purchased from iStockphoto LP.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-16-254		

4. Title and Subtitle	5. Report Date
Vehicle-to-Infrastructure (V2I) Safety Applications Performance Requirements, Vol. 7, Stop Sign Gap Assist	August 2015
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Denny Stephens, Jeremy Schroeder, Rachel Klein	1000025516-0301-7

9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
Battelle Memorial Institute 505 King Avenue Columbus, OH 43201	11. Contract or Grant No. DTFH61-12-D-00040

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation FHWA Office of Safety Research and Development Turner-Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Government Technical Monitor; Gregory Davis, FHWA Office of Safety Research and Development

16. Abstract

This document is the seventh of a seven volume report that describe the Performance Requirements for the connected vehicle vehicle-to-infrastructure (V2I) safety applications developed for the U.S. Department of Transportation (U.S. DOT). This volume describes the Performance Requirements for the infrastructure and vehicle components of the Stop Sign Gap Assist V2I Safety Application. This application is designed to assist drivers on a minor road safely traverse or enter a major road, when only the minor road has posted stop signs. The applications provides approaching cross-traffic information to support driver decisions. The safety applications described here integrate roadside and in-vehicle advisories, alerts and warnings to make the driver aware of hazards in time to take action to prevent a potential crash. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the messages are consistent and coordinated, to best capture the attention of the driver and to avoid conflicting or confusing driver messaging.

17. Key Words	18. Distribution Statement
Connected vehicles, Vehicle-to-Infrastructure, V2I, V2I Safety Applications, Stop Sign Gap Assist, SSGA	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	82	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

Table of Contents

Table of Contents ..... **i**
Chapter 1 Scope **1**
1.1 DOCUMENT IDENTIFICATION 1
1.2 DOCUMENT OVERVIEW 2
Chapter 2 Referenced Documents **3**
Chapter 3 Performance Requirements **6**
3.1 INTRODUCTION AND OVERVIEW 6
3.1.1 Organization of this Chapter 6
3.1.2 Structure and Format of the Performance Requirements 7
3.1.2.1 Performance Requirements Identifier Structure 8
3.1.2.2 Verification Methods 9
3.2 V2I SYSTEM FUNCTIONAL ARCHITECTURE 9
3.2.1 System Components and Interfaces 11
3.2.1.1 Driver 11
3.2.1.2 Infrastructure Systems Components 11
3.2.1.3 Vehicle System Components 12
3.2.1.4 V2I/I2V Wireless Data Interface 13
3.2.1.5 Infrastructure System Interfaces 13
3.2.1.6 Vehicle System Interfaces 14
3.3 STOP SIGN GAP ASSIST (SSGA) APPLICATION PERFORMANCE REQUIREMENTS 14
3.3.1 SSGA Application Introduction and Overview 14
3.3.1.1 Application Purpose 14
3.3.1.2 Safety Impacts of Application 15
3.3.1.3 Summary of Improvements 15
3.3.1.4 How the Application Works 15
3.3.1.5 Application Assumptions 28
3.3.1.6 Application Swim Lane & Sequence Diagrams 29
3.3.1.7 Messages Exchanged and Used by the Application 31
3.3.2 SSGA Infrastructure Application Component Requirements 34
3.3.2 SSGA Vehicle Application Component Requirements 48
APPENDIX A. SSGA Application Message Candidate Data Elements **A-1**
APPENDIX B. Acronyms and Abbreviations **B-1**
APPENDIX C. Terms and Definitions **C-1**

List of Tables

Table 3-1. Definition of SSGA Terms 24
Table 3-2. Summary of SSGA Infrastructure and Vehicle Displays 26
Table 3-3. Summary of Messages used by SSGA Application Components 32
Table 3-4. SSGA Infrastructure Application Component Performance Requirements 35
Table 3-5. SSGA Vehicle Application Component Performance Requirements 49

Table A-1. Explanation of Candidate Data Table Headers A-2
Table A-2. Description of Candidate Data Elements for the SSGA Infrastructure Data Systems Message A-3
Table A-3. Description of Candidate Data Elements for the SSGA Roadside Signage Message Data Description A-6
Table A-4. Description of Candidate Data Elements for the SSGA Infrastructure Map Message and SSGA Wireless Map Message A-7
Table A-5. Description of Candidate Data Elements for the SSGA I2V Wireless Message Data Description A-11
Table A-6. Description of Candidate Data Elements for the SSGA Vehicle Systems Message Data Descriptions A-15
Table A-7. Description of Candidate Data Elements for the SSGA Driver Warning Message Data Description A-17

List of Figures

Figure 3-1. Functional Architecture for Connected Vehicle V2I Safety Applications 10
Figure 3-2. Illustration of SSGA Roadside and In-Vehicle Signage for Subject Vehicle(s) on the Minor Road 17
Figure 3-3. Illustration of SSGA Roadside and In-Vehicle Advisory, Alert, and Warning Messages Issued to Subject Vehicle at Stop Sign based on Location of Approaching Remote Vehicle(s) from the Left on the Intersecting Major Road 18
Figure 3-4. Illustration of SSGA Roadside and In-Vehicle Advisory, Alert, and Warning Messages Issued to Subject Vehicle at Stop Sign based on Location of Approaching Remote Vehicle(s) from the Right on the Intersecting Major Road 19
Figure 3-5. Examples of Signage used for Road Closures and Diversion Routes 20
Figure 3-6. Examples of Dynamic Signage for Minor Road Vehicles at Stop-Controlled Intersections in Minnesota (left) and Iowa (right) 20
Figure 3-7. Illustration of roadside and In-vehicle signage, both generic (DII) and vehicle-specific (DVI), to the subject vehicle waiting at the stop-controlled intersection, as a function of the speed and distance from intersection of remote vehicles approaching from the left and right 23
Figure 3-8. Swim-lane Process Diagram for the SSGA Application 30

Chapter 1 Scope

1.1 Document Identification

This document is the seventh of a seven volume report that describes the performance requirements for six connected vehicle vehicle-to-infrastructure (V2I) safety applications developed for the U.S. Department of Transportation (U.S. DOT). This volume describes the Performance Requirements for the infrastructure and vehicle components of the Stop Sign Gap Assist V2I safety application. This application is designed to assist drivers on a minor road safely traverse or enter a major road, when only the minor road has posted stop signs. The applications provides approaching cross-traffic information to support driver decisions. The application first provides an advisory message to minor road drivers as they approach a stop sign controlled intersection, then support stopped drivers in identifying unsafe gaps in cross-traffic at major road intersections by providing applicable advisory, alert, and warning messages.

The seven volumes comprising this V2I Safety Applications Performance Requirements report are:

- Vol. 1, V2I Safety Application Overview and Common Requirements
- Vol. 2, Curve Speed Warning (CSW)
- Vol. 3, Red Light Violation Warning (RLVW)
- Vol. 4, Reduced Speed Zone Warning with Lane Closure (RSZW/LC)
- Vol. 5, Spot Weather Information Warning – Reduced Speed (SWIW-RS)
- Vol. 6, Spot Weather Information Warning – Diversion (SWIW-D)
- Vol. 7, Stop Sign Gap Assist (SSGA).

This volume transforms the Concept of Operations (ConOps) and System Requirements previously developed for the SSGA application into a set of performance requirements, which specify how the application integrates roadside and in-vehicle advisories, alerts and warnings to make the driver aware of hazards in time to take action to prevent a potential crash. Performance requirements are provided for both infrastructure and vehicle application components of the application to ensure that infrastructure and vehicle messages presented to drivers are consistent and coordinated, to best capture the attention of the driver, and avoid conflicts or confusion.

1.2 Document Overview

The objective of this V2I Safety Application Performance Requirements volume is to provide integrated requirements for the infrastructure and vehicle components of one of a series of V2I safety applications, their wireless messaging and their driver messaging that ensure coordinated and consistent delivery of safety hazard advisories, alerts and warnings to drivers. This volume describes the V2I System of Systems within which the application is expected to function.

The SSGA safety application described here captures relevant data from roadside infrastructure sensors and in-vehicle sensors and processes them to determine if there is a potential crash hazard. If a hazard is detected, the application issues integrated roadside and in-vehicle advisories, alerts and warnings to make the driver aware of the hazards in time to take action to prevent the crash.

The application described here has both an infrastructure-based component and a vehicle-based component, which may be developed by different stakeholders. Infrastructure-based components are expected to be developed by state and local agencies responsible for building and maintaining the roadway infrastructure and their contractors. Vehicle-based components are expected to be developed by vehicle manufacturers, their tier one suppliers, and aftermarket system suppliers. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the data exchange between the two components is synchronized and consistent and that they deliver messages to the driver that are harmonized to best capture the attention of the driver and that avoid confusing the driver.

This document has been written with the assumption that the reader possesses a general knowledge associated with connected vehicles and the associated infrastructure surrounding connected vehicles.

The intended audience of this document includes infrastructure and vehicle application developers, wireless equipment systems manufacturers, intelligent transportation systems (ITS) developers, state and local departments of transportation, and U.S. DOT Connected Vehicle Program Managers.

The remainder of this volume consists of the following sections and content:

Section 2 (Applicable Documents) describes the external documentation utilized and referenced throughout this document.

Section 3 (Requirements) provides the background and requirements for the SSGA application.

Appendices:

A. SSGA Application Message Candidate Data Elements
B. Acronyms and Abbreviations
C. Terms and Definitions

Chapter 2 Referenced Documents

The following sections include documents that are either cited herein or were reviewed for the development of this document. Documents from U.S. DOT are presented first, followed by documents from other government and non-government organizations.

U.S. Department of Transportation

- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-058. (2012).
- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-059. (2012).
- Analysis of Fatal Crashes Due to Signal and Stop Sign Violations. Campbell, B.N., J.D. Smith, and W.G. Najm. (September 2004). U.S. DOT Volpe National Transportation Systems Center report to NHTSA, DOT HS 809 779, available at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2004/FARS%20Violation%20DOT%20HS%20809%20779.pdf.
- Driver Vehicle Interface (DVI) Design Assistance for Advanced Technology Applications, Campbell, J. L., Brown, J. L., et al, National Highway Traffic Safety Administration, (in press). (Battelle Final Report to Virginia Tech Transportation Institute and National Highway Traffic Safety Administration).
- Highway Functional Classification: Concepts, Criteria and Procedures, Federal Highway Administration, FHWA-PL-13-026, 2013 Edition.
- Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 edition, Federal Highway Administration. http://mutcd.fhwa.dot.gov/.
- Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-060. (2013).
- Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-061. (2013).

American Association of State Highway and Transportation Officials (AASHTO)

- The Green Book. A Policy on Geometric Design of Highways and Streets, 6th edition. 2011.

Enterprise Pooled Funds Study

- Design and Evaluation Guidance for Intersection Conflict Warning Systems (ICWS). Crowson, G. and Jackels, J. (Dec 2011). ENTERPRISE Pooled Fund Study, FHWA Office of Safety. http://www.enterprise.prog.org/Projects/2010_Present/developingconsistencyIWS/Design_and_Eval_Guidance/Guidance%20for%20ICWS%20Version%201-122011.pdf.
- System Requirements for Intersection Conflict Warning Systems (ICWS). Crowson, G. and Jackels, J. (May 2013). ENTERPRISE Pooled Fund Study. http://www.enterprise.prog.org/Projects/2010_Present/icwssyseng/ICWS%20System%20Requirements%20FINAL%20051713.pdf.
- Concept of Operations for Intersection Conflict Warning Systems (ICWS). Crowson, G. and Jackels, J. (Nov 2012). ENTERPRISE Pooled Fund Study. http://www.enterprise.prog.org/Projects/2010_Present/icwssyseng/ICWS%20Concept%20of%20Operations%20FINAL%20110812.pdf.

International Organization for Standardization (ISO)

- ISO 9141-2. Road vehicles – Diagnostic systems – Part 2: CARB requirements for interchange of digital information (1994).
- ISO 11898, Road vehicles – Controller area network (CAN) – Part 6: High-speed medium access unit with selective wake-up functionality.
- ISO 14230-4, Road vehicles – Diagnostic systems – Keyword Protocol 2000 – Part 4 Requirements for emission-related systems.
- ISO 15765, Road vehicles – Diagnostic communication over Controller Area Network (DoCAN) – Part 4: Requirements for emissions-related systems.

Institute of Transportation Engineers (ITE) Standards

- ITE ATC Transportation Controller (ATC) v5.2b.
- ITE Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications.

National Marine Electronics Association

- NMEA 0183 Interface Standard.

National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) Standards

- NTCIP 1103 Transportation Management Protocols.
- NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.
- NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.
- NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS).

Radio Technical Commission for Maritime Services

- RTCM 10403.2, Differential GNSS (Global Navigation Satellite Systems) Services – Version 3.

Society of Automotive Engineers (SAE) Standards

- SAE J1211. Handbook for Robustness Validation of Automotive Electrical/Electronic Modules.
- SAE J1850 VPW, J1850 PWM. Class B Data Communications Network Interface (June 2006).
- SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary.
- SAE J2178 Class B Data Communication Network Messages-Detailed Header Formats and Physical Address Assignments.

Transportation Research Board (TRB)

- National Cooperative Highway Research Program (NCHRP) Report 600. Human Factors Guidelines for Road Systems, 2nd edition. (2012).

University of Minnesota

- Cooperative Intersection Collision Avoidance System – Stop Sign Assist (CICAS-SSA) Concept of Operations, Version 1.0 (2008)
- Determination of the Alert and Warning Timing for the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Using Macroscopic and Microscopic Data: CICAS-SSA, Report #1 (2010)
- The Design of a Minimal Sensor Configuration for a Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA, Report #2 (2010)
- Macroscopic Review of Driver Gap Acceptance and Rejection Behavior at Rural Thru-Stop Intersections in the US – Data Collection Results in Eight States: CICAS-SSA, Report #3 (2010)
- Sign Comprehension, Considering Rotation and Location, using Random Gap Simulation for a Cooperative Intersection Collision Avoidance System – Stop Sign Assist: CICAS-SSA, Report #4 (2010)
- Validation Study – On-Road Evaluation of the Cooperative Intersection Collision Avoidance System – Stop Sign Assist Sign: CICAS-SSA, Report #5 (2010)
- Infrastructure consortium proposal for intersection decision support, Volume 3: The Minnesota program. Donath, M., and Shankwitz, C. (2001). Minneapolis, MN: Center for Transportation Studies.

Chapter 3 Performance Requirements

3.1 Introduction and Overview

This section of the document enumerates the Performance Requirements for the Stop Sign Gap Assist (SSGA) Application. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the advisories are consistent and coordinated.

3.1.1 Organization of this Chapter

The chapter begins by describing the V2I System, including its functional architecture, components and interfaces. This is followed application performance requirements first for the infrastructure application component, followed by the vehicle application component. This chapter is organized under the following headings.

- 3.1 Introduction and Overview
  - 3.1.1 Organization of this Chapter
  - 3.1.2 Structure and Format of the Performance Requirements
    - 3.1.2.1 Performance Requirements Identifier Structure
    - 3.1.2.2 Verification Methods
- 3.2 V2I System Functional Architecture
  - 3.2.1 System Components and Interfaces
    - 3.2.1.1 Driver
    - 3.2.1.2 Infrastructure Systems Components
    - 3.2.1.3 Vehicle System Components
    - 3.2.1.4 V2I/I2V Wireless Data Interface
    - 3.2.1.5 Infrastructure System Interfaces
    - 3.2.1.6 Vehicle System Interfaces
- 3.3 Stop Sign Gap Assist (SSGA) Application Performance Requirements
  - 3.3.1 SSGA Application Introduction and Overview
    - 3.3.1.1 Application Purpose
    - 3.3.1.2 Safety Impacts of the Application
    - 3.3.1.3 Summary of Improvements
    - 3.3.1.4 How the Application Works
    - 3.3.1.5 Application Assumptions
    - 3.3.1.6 Application Swim Lane & Sequence Diagrams
    - 3.3.1.7 Messages Exchanged and Used by the Application
  - 3.3.2 SSGA Infrastructure Application Component Requirements
  - 3.3.3 SSGA Vehicle Application Component Requirements

In developing the performance requirements contained here, the authors developed a framework for coordinating the delivery of roadside and in-vehicle messages to drivers. The framework that sets the stage for subsequent requirements is described in the application introduction and overview and in its assumptions. This is followed by Application Swim Lane and Sequence Diagrams that illustrate the flow of data, data processing and decision trees for hazard assessment and for decisions in whether to issue advisories, alerts and/or warnings to drivers.

As illustrated in the V2I System of Systems description below, the V2I application is implemented in a framework of multiple existing and legacy systems that capture data, process it and issue messages to drivers and other systems. The application description includes a description of the messages that are exchanged between systems that make up the V2I System of Systems.

Following explanation of the rationale and underlying frameworks, requirements are presented, first for the infrastructure application components and then for the vehicle application components. Appendix A provides Application Message Data Tables, which suggest data elements that may be needed by the application to perform its required functions.

The authors of these requirements expect that questions will arise during the design and implementation of this application. The rationales, frameworks, and requirements presented here are expected to evolve. Understanding that different components will be developed by different agencies, the purpose here is to provide an underlying structure for discussion between these agencies to support coordination and refinement of the requirements that are necessary to successfully develop and implement the application to achieve its safety objectives.

3.1.2 Structure and Format of the Performance Requirements

Each requirement in the following tables includes the following elements:

- **Unique Identifier** of the form **[A.B.CC.DD]**, described in more detail below.
- **Requirement Title** describes the topic of the requirement. **Requirement Titles** are presented in bold face type for readability.
- **Requirement Statement** provides the specific requirement which is subject to verification and validation, and represents the description of design, development, behavior, operation, performance, etc. of the application. **Requirement Statements** are presented in bold type face to distinguish them from supporting text including the *Requirements Elaboration.*
- *Requirements Elaboration* provides supporting text for the **Requirement Statement** that aids in understanding, interpretation and application of the **Requirement Statement** where needed. *Requirements Elaboration* text is presented in italics type face to distinguish it from the **Requirements Statement**. *Requirements Elaboration* is not necessarily subject to verification and validation, but may be useful in establishing methods and acceptance criteria for verification and validation.
- Verification Method describes how the performance requirements will be verified, whether by Inspection (I), Demonstration (D), Test (T) or Analysis (A). Each of these is described in more detail below.

3.1.2.1 Performance Requirements Identifier Structure

Performance requirements for this V2I application is organized and numbered by the application, the component, and requirement category. For consistency and accessibility the requirements are uniquely identified by a four element number of the format [A.B.CC.DD] where A designates the application, B designates the application component, CC designates the application category, and DD is the unique requirement number within the category. The [A] designators for each application are

- [1.B.CC.DD] Common Application Requirements
- [2.B.CC.DD] CSW Application Requirements
- [3.B.CC.DD] RLVW Application Requirements
- [4.B.CC.DD] RSZW/LC Application Requirements
- [5.B.CC.DD] SWIW-RS Application Requirements
- [6.B.CC.DD] SWIW-D Application Requirements
- [7.B.CC.DD] SSGA Application Requirements

The [B] designators for the application components are

- [A.1.CC.DD] Infrastructure Application Component Requirements
- [A.2.CC.DD] Vehicle Application Component Requirements
- [A.3.CC.DD] Infrastructure Application Platform Requirements[1]

The [CC] designator for the application categories are

- [A.B.01.DD] Interfaces and Interface Specifications
- [A.B.02.DD] Functional Requirements
- [A.B.03.DD] Data Input Requirements
- [A.B.04.DD] Data Output Requirements

Common Application requirements include the following additional categories:

- [A.B.05.DD] Computation and Communication Performance Requirements
- [A.B.06.DD] Operational Performance Requirements
- [A.B.07.DD] Supportability Requirements
- [A.B.08.DD] Security Requirements
- [A.B.09.DD] Human Factors, Health and Safety Requirements
- [A.B.10.DD] Installation and Setup Requirements
- [A.B.12.DD] Operation, Maintenance and Diagnostic Requirements
- [A.B.12.DD] Documentation Requirements
- [A.B.13.DD] Staffing and Training Requirements
- [A.B.14.DD] Physical and Environmental Performance Requirements

[1] While outside the system of interest, candidate performance requirements are provided in Volume 1 for the Infrastructure Application Platform for reference.

3.1.2.2 Verification Methods

The verification method describes how the performance requirements will be verified in order to ascertain that the system of interest conforms to the requirements in this specification. The four potential methods of verification include the following.

Analysis is a verification method that utilizes established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements are met.

Demonstration is a verification method that generally denotes the actual operation, adjustment, or re-configuration of items to provide evidence that the designed functions were accomplished under specific scenarios.

Inspection is a verification method that consists of investigation, without the use of special laboratory appliances or procedures, of items to determine conformance to those specified requirements. Examination is generally nondestructive and typically includes the use of sight, hearing, smell, touch; and/or simple physical manipulation of the system when it is safe to do so. Inspection can also be applied to the project work products. For instance, verifying that software is developed using a certain programming language would be verified by inspection.

Testing is a verification method that generally denotes the determination of properties by instrumentation and measurement. This method includes functional operation, and involves the application of established scientific principles and procedures.

3.2 V2I System Functional Architecture

Figure 3-1 illustrates the V2I System of Systems Functional Architecture upon which the Performance Requirements are based. The figure illustrates a number of key elements concerning the architecture of the V2I safety application described in this volume. First, the V2I safety application has two core components, an Infrastructure Application Component residing and operating on an Infrastructure Application (Computing) Platform and a Vehicle Application Component residing on a Vehicle Application (Computing) Platform. Both components are necessary to achieve the safety application objectives of integrating and processing infrastructure and vehicle data and delivering coordinated messages to the driver. These two application components share data and information by exchanging messages through wireless data interface(s).

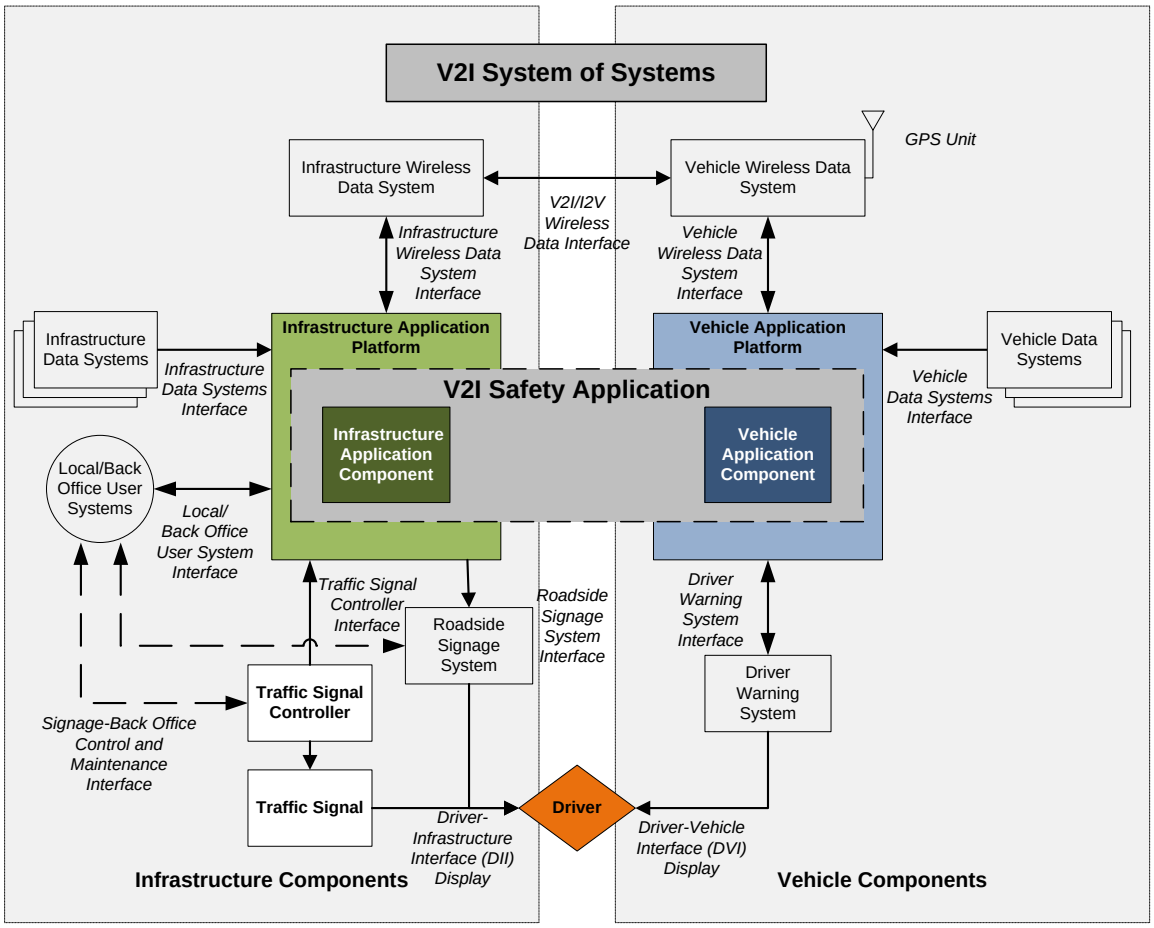
Each of the application components resides and operates on a computing platform that provides the necessary hardware and software data interfaces needed to exchange data with other systems. Each computing platform has an interface for wireless data systems that support with wireless exchange of data between the Infrastructure and Vehicle Application Components. From a requirements standpoint, the Application Components are independent from the form of wireless communication, it is expected that the primary form of communication between the two will be Dedicated Short Range Communication (DSRC).

The Infrastructure Application Platform also provides interfaces for data exchange with Infrastructure Data Systems, Local or Back Office User Systems and user interfaces, Traffic Signal Controllers and Roadside Signage Systems. The Vehicle Application Platform also provides interfaces for capture of data from vehicle systems and a driver warning system with a Driver-Vehicle Interface display.

The infrastructure application component issues messages through dynamic message signs that are visible to and applicable to all approaching vehicles and drivers. The vehicle application component issues messages through a driver warning interface that may be vehicle specific or may be the same as that displayed by dynamic message and static roadside signs. This V2I Safety Application is expected to coordinate and synchronize the display of roadside and in-vehicle messages to the driver.

Vehicle-specific messages for drivers may be equally or more cautious than roadside signs, but must never be less cautious. Vehicle-specific message must never conflict with roadside messages. For example, the vehicle application component in a truck carrying an unusual load with a high center of gravity and high rollover potential may recommend a lower vehicle-specific safe speed in a curve than the infrastructure application component recommends for all vehicles. However, the vehicle application component in a sports car under good road surface conditions must not recommend a higher safe speed in a curve than does the infrastructure signage.

An important concern and rationale for developing these Performance Requirements is that the vehicle and infrastructure components of the applications are likely to be developed and implemented by different entities. Infrastructure components may be developed by public state and local agency infrastructure owners and contractors and vehicle components may be developed by private vehicle manufacturers and suppliers.



Source: Battelle

Figure 3-1. Functional Architecture for Connected Vehicle V2I Safety Applications

3.2.1 System Components and Interfaces

As illustrated in Figure 3-1 there many components which make up the System-of-Interest (SOI) and supporting components. These components include:

- System-Of-Interest Components
  - Infrastructure Application Component
  - Vehicle Application Component
- Supporting Components
  - Infrastructure Application Platform
  - Infrastructure Wireless Data Systems (with GPS)
  - Infrastructure Data Systems
  - Roadside Signage System
  - Traffic Signal Controller
  - Traffic Signal
  - Local/Back Office User Systems
  - Vehicle Application Platform
  - Vehicle Wireless Data Systems (with GPS)
  - Vehicle Data Systems
  - Driver Warning System
  - Driver
- Interfaces
  - V2I/I2V Wireless Data Interface
  - Infrastructure Wireless Data Systems Interface
  - Vehicle Wireless Data Systems Interface
  - Infrastructure Data Systems Interface
  - Vehicle Data Systems Interface
  - Roadside Signage System Interface
  - Driver Warning System Interface
  - Local/Back Office User Systems Interface
  - Traffic Signal Controller Interface

The function of each of these components and interfaces is described below.

3.2.1.1 Driver

The Driver is the consumer of information delivered by the safety application. Static roadside signage and dynamic Roadside Signage Systems and in-vehicle Driver Warning Systems convey information to drivers such as advisories, alerts, and warnings to make the driver aware of hazards in time to take action to prevent a potential crash.

3.2.1.2 Infrastructure Systems Components

Infrastructure Application Component is the infrastructure component of the V2I safety application. It obtains data from the Vehicle Application Component through the Infrastructure Wireless Data Systems, Infrastructure Data Systems, Traffic Signal Controller and Local/Back Office User Systems, processes the data and issues appropriate message to drivers through Infrastructure Wireless Data

Systems and Roadside Signage Systems. The application also issues messages containing relevant data to the Vehicle Application Component through the Infrastructure Wireless Data Systems.

Infrastructure Application Platform is the computational platform which hosts the Infrastructure Application Component and provides the necessary hardware and software interfaces enabling communication with Infrastructure Wireless Data Systems, Infrastructure Data Systems, Roadside Signage System, Traffic Signal Controller, and Local/Back Office User Systems.

Roadside Signage System receives messages from the Infrastructure Application Component and delivers dynamic advisories and alerts to all approaching vehicles from the roadside.

Infrastructure Wireless Data System receives messages from the Infrastructure Application Component through the Infrastructure Application Platform, formats and processes the messages and issues the message via wireless communications to vehicles within wireless communication range. The System also performs the inverse, receiving wireless messages from nearby vehicles, formatting and processing the message and issuing the message to the Infrastructure Application Component through the Infrastructure Application Platform. The system also obtains universal time, coordinated (UTC) time.

Local/Back Office User System provides a technical user interface for the installation, configuration, maintenance, diagnostics, and management of the Infrastructure Application Component. The system may be a computer that is attached locally and temporarily to perform these functions or the system may connect remotely via dedicated lines or the Internet to perform these functions. The system may provide a function for upload or download of configuration and data files to the Infrastructure Application Platform. The system may also provide a connection to obtain GPS differential correction data.

Infrastructure Data Systems provide infrastructure data and information to the Infrastructure Application Component through the Infrastructure Application Platform. Examples of relevant data include weather information, road surface condition data, visibility data, and infrastructure-based vehicle detection and speed data.

Traffic Signal Controller is the external component that provide traffic signal phase and timing data required by some V2I Safety Applications through the Infrastructure Application Platform.

Traffic Signal is the traditional “driver display” component of the Traffic Signal Controller.

3.2.1.3 Vehicle System Components

Vehicle Application Component is the vehicle component of the V2I safety application. It obtains data from the Infrastructure Application Component through Vehicle Wireless Data Systems, Vehicle Data Systems, processes the data and issues appropriate messages to drivers through the Driver Warning System and Driver Vehicle Interface.

Vehicle Application Platform is the computational platform which hosts the Vehicle Application Component and provides the necessary hardware and software interfaces enabling communication with Vehicle Wireless Data Systems, Vehicle Data Systems, and the Driver Warning System.

Driver Warning System is the component which collects and arbitrates messages, advisories, alerts and warnings and delivers them to the driver. These alerts may be visual, aural, haptic, or some other means that captures the driver’s attention and conveys the relevant information. When multiple safety applications are hosted on the Vehicle Applications Platform, the Driver Warning System will prioritize and arbitrate alerts and warnings from the multiple safety applications. Note: The placement of the

Driver Warning System shown in Figure 3-1 is intended to show representative functionality and is not meant to restrict implementation.

Vehicle Wireless Data System receives messages from the Vehicle Application Component through the Vehicle Application Platform, formats and processes the messages and issues the message via wireless communications to Infrastructure Wireless Data Systems within wireless communication range. This system also performs the inverse, receiving wireless messages from nearby infrastructure, formatting and processing the message and issuing the message to the Vehicle Application Component through the Vehicle Application Platform. This system also obtains GPS location and time. It may include a processor for GPS differential correction.

Vehicle Data Systems represent systems contained within the vehicle that provide vehicle-related information to the Vehicle Application Component. Information provided may come from a positioning system, vehicle data bus, sensors, actuators on the vehicle, or stability systems. Specific interfaces to the original equipment manufacturers' (OEM) vehicle systems are dependent on specific information required to support the safety application.

3.2.1.4 V2I/I2V Wireless Data Interface

V2I/I2V Wireless Data Interface is the wireless communications interface that communicates relevant data between the Infrastructure and Vehicle Application Components through their respective Wireless Data Systems and Application Platforms.

3.2.1.5 Infrastructure System Interfaces

Infrastructure Wireless Data System Interface is the interface between the Infrastructure Application Platform and the Infrastructure Wireless Data Systems Component. This interface is used by the Infrastructure Applications Platform and the Infrastructure Applications Components to send and receive data to nearby vehicles via the V2I/I2V Wireless Data Interface.

Infrastructure Data Systems Interface is the interface between the Infrastructure Application Platform and Infrastructure Data Systems. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to capture data from infrastructure sensor systems such as weather information, road surface condition data, visibility data, and infrastructure-based vehicle detection and speed data.

Roadside Signage System Interface is the interface between the Infrastructure Applications Platform and the Roadside Signage System. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to send advisory and alert messages to local dynamic message signs at the roadside for display to all approaching vehicles.

Local/Back Office User System Interface supports IP communication with a computer that is attached locally or remotely via dedicated lines or the Internet to perform upload and download of data files as well as installation, configuration, maintenance, diagnostics, and management of the Infrastructure Application Component.

Traffic Signal Controller Interface is the interface between the Infrastructure Applications Platform and the local Traffic Signal Controller. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to capture traffic signal phase and timing data required by some V2I Safety Applications.

3.2.1.6 Vehicle System Interfaces

Vehicle Wireless Data System Interface is the interface between the Vehicle Application Platform and the Vehicle Wireless Data Systems component. This interface is used by the Vehicle Applications Platform and the Vehicle Applications Components to send and receive data to nearby infrastructure via the V2I/I2V Wireless Data Interface.

Vehicle Data Systems Interface is the interface between the Vehicle Application Platform and Vehicle Data Systems. The interface is used by Vehicle Applications Platform and Vehicle Applications Components to capture data from vehicle systems such as a positioning system, vehicle data bus, sensors, actuators on the vehicle, or stability systems.

Driver Warning System Interface is the interface between the Vehicle Application Platform and Driver Warning System. The interface is used by Vehicle Applications Platform and Vehicle Applications Components to send messages, advisories, alerts and warnings to the Warning System for arbitration and delivery to the driver.

3.3 Stop Sign Gap Assist (SSGA) Application Performance Requirements

3.3.1 SSGA Application Introduction and Overview

Stop Sign Gap Assist – Application designed to assist drivers on a minor road avoid crashes by providing approaching cross-traffic information to support driver decisions in safely traversing stop-sign controlled intersections. The application will first provide an advisory message to minor road drivers as they approach a stop sign controlled intersection, then support stopped drivers in identifying unsafe gaps in cross-traffic at major road intersections by providing applicable advisory, alert, and warning messages. The application integrates data from infrastructure- and vehicle-based sensors, most importantly from the major road vehicle detection system that detects the presence, distance, and speed of each vehicle within its coverage zone.

3.3.1.1 Application Purpose

The goal of the SSGA application is to improve roadway safety at non-signalized intersections where only the minor road has posted stop signs. This will be achieved through the integration of both vehicle-based and infrastructure-based technologies, including both onboard and roadside signage warning systems. The application will help drivers on a minor road stopped at an intersection understand the state of activities associated with that intersection by providing alerts and warnings of unsafe gaps on the major road. In this way, the SSGA safety application will help drivers maneuver through cross traffic, reducing the number of conflicts and crashes. The application coordinates roadside messages for all vehicles with in-vehicle, vehicle-specific advisories to notify drivers in time for them to react.

3.3.1.2 Safety Impacts of Application

There will be several impacts on drivers in the deployment of V2I safety applications:

- ***Real-Time Messaging:*** The greatest impact is that drivers will receive real-time advisories and alerts while stopped at an intersection based on current distance and speed of intersecting major road vehicles from the intersection, as well as current driving conditions and current weather and roadway conditions.
- ***Reduction in Right Angle Crashes:*** The SSGA application should result in fewer right angle crashes at stop-controlled intersections that result from a minor road driver accepting a gap (i.e., entering the intersection) that should have been rejected due to the proximity of approaching remote vehicles resulting in inadequate time to clear the intersection.
- ***Effective Messaging (Format and Timing):*** The safety application is designed to provide drivers with a combination of haptic, visual, and/or audio messages in an effective format that does not distract or overwhelm. These messages are designed to be presented to drivers in a timeframe that provides adequate reaction time to reduce speed and safely traverse an adverse weather zone.

3.3.1.3 Summary of Improvements

- ***Reduces number of right-angle incidents due to drivers of subject vehicles not rejecting an unsafe gap distance:*** SSGA aids drivers of subject vehicles by providing warnings about unsafe gaps. The application will provide messages that indicate it is unsafe to turn onto or cross the intersection, thereby reducing the potential for a crash-imminent scenario caused by a subject vehicle proceeding when the gap is unsafe.
- ***Increases driver awareness of approaching remote vehicles on major roadway:*** In the current state, the subject driver must identify approaching remote vehicles, independently assess their speed and distance to the intersection, and determine whether or not it is safe to turn onto or cross the major road. SSGA aids the subject driver by alerting or warning a driver on the minor road when it is unsafe to proceed through the stop-controlled intersection. The system detects vehicles on the major, intersecting roadway and issues a warning when there is an insufficient gap for safe passage through an intersection. The application is functional for all varieties of intersections: divided or undivided roadways, skewed intersections, etc.
- ***Immediate benefits for all drivers at stop-controlled intersections:*** This application incorporates a dynamic DVI for onboard warnings and driver-infrastructure interface (DII) with automated signage. The automated DII signs will provide alerts and warnings of unsafe gaps to drivers of both equipped and non-equipped vehicles. In this way, the application can provide immediate benefits for all drivers at stop-controlled intersections.

3.3.1.4 How the Application Works

The objective of SSGA V2I Application is to deliver coordinated infrastructure- and vehicle-based advisory, alert, and warning messages to subject vehicles on a minor road at a stop-controlled intersection. The application first provides a “stop ahead” advisory message to subject vehicles on a minor road approaching the stop-controlled intersection. At the intersection, SSGA Alert and Warning

messages indicate unsafe gaps based on approaching remote vehicle speed and distance from the intersection.

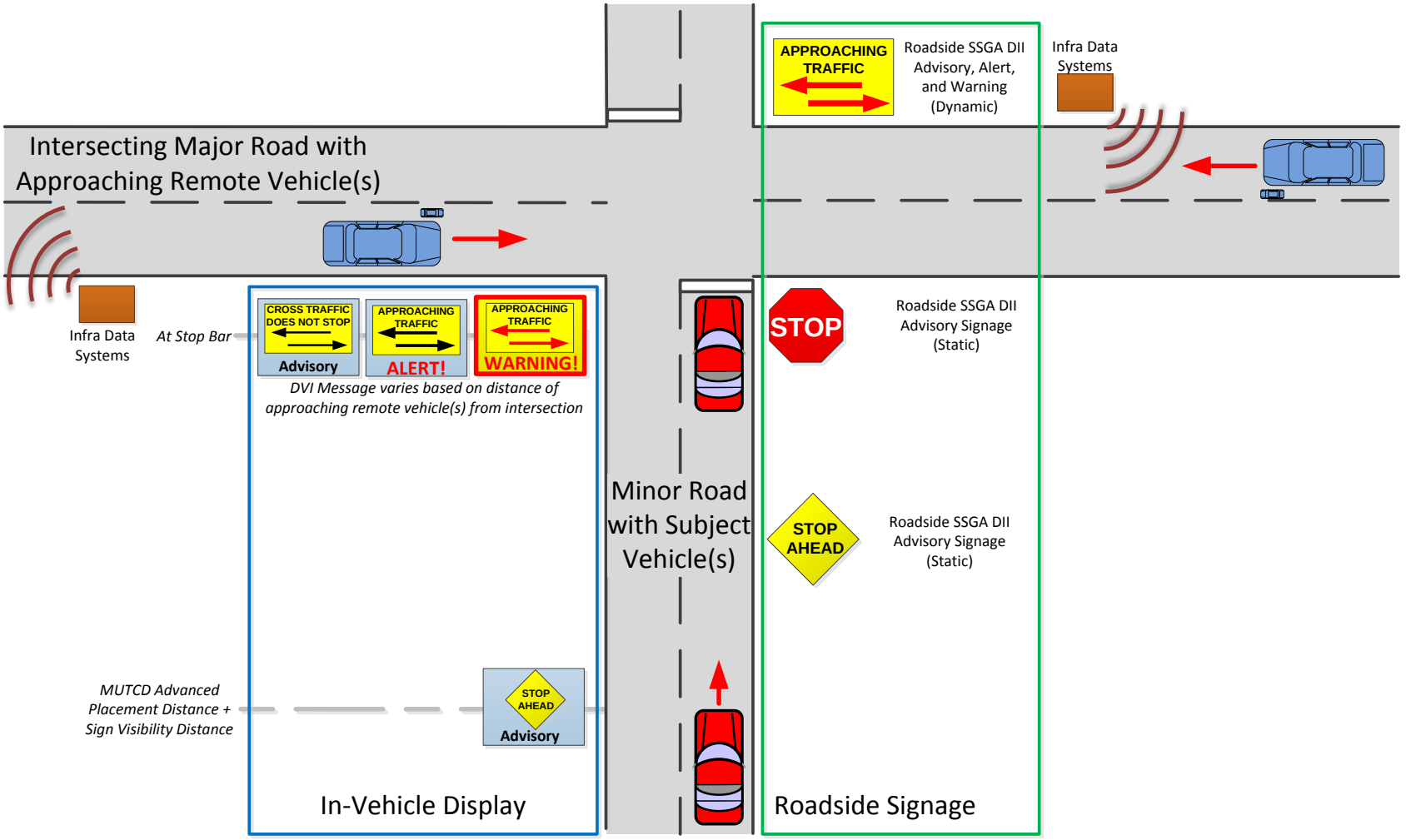
Figure 3-2 below illustrates the key concepts and integration of roadway and in-vehicle signage for a minor road subject vehicle that is approaching and stopped at a stop-controlled intersection. That is, the subject vehicle first receives a coordinated "stop ahead" advisory message while approaching the stop-controlled intersection from the DII static signage. The location of this signage in advance of the intersection is defined by the MUTCD advanced placement distances for warning signs in Table 2C-4.

Once the subject vehicle has proceeded to the stop bar, the dynamic DII signage transmits coordinated advisory, alert, and warning messages regarding approaching remote vehicles for each direction on the intersecting major road while at the stop bar. The box on the right in Figure 3-2 illustrates the roadside signage and DII messages displayed to the driver as the subject vehicle approaches and is stopped at the stop-controlled intersection.

Figure 3-3 and Figure 3-4 show the key concepts and integration of roadway and in-vehicle signage that a minor road subject vehicle receives while stopped at the stop bar, that are based on the speed and distance of remote vehicle(s) on the intersecting roadway that are approaching the stop-controlled intersection from the left and right, respectively. Each figure shows message graphics for which no remote vehicles are detected to be approaching from the opposite direction. These messages might incorporate MUTCD signs, such as those presented in Figure 3-5. The box above the roadway illustrates roadside signage or DII displayed to the driver at the stop bar seeking to turn onto or cross the intersecting roadway, which in this graphic is assumed to be a dynamic message sign (DMS). This sign could also be a static sign with dynamic elements, such as flashing beacons, although this might restrict the issuance of direction-specific messages and distance thresholds for both alerts and warnings. Two examples of existing deployments are shown in Figure 3-6. The design for this roadside sign at the intersection merits further research for human factors considerations to maximize driver understanding and the presentation of useful information.

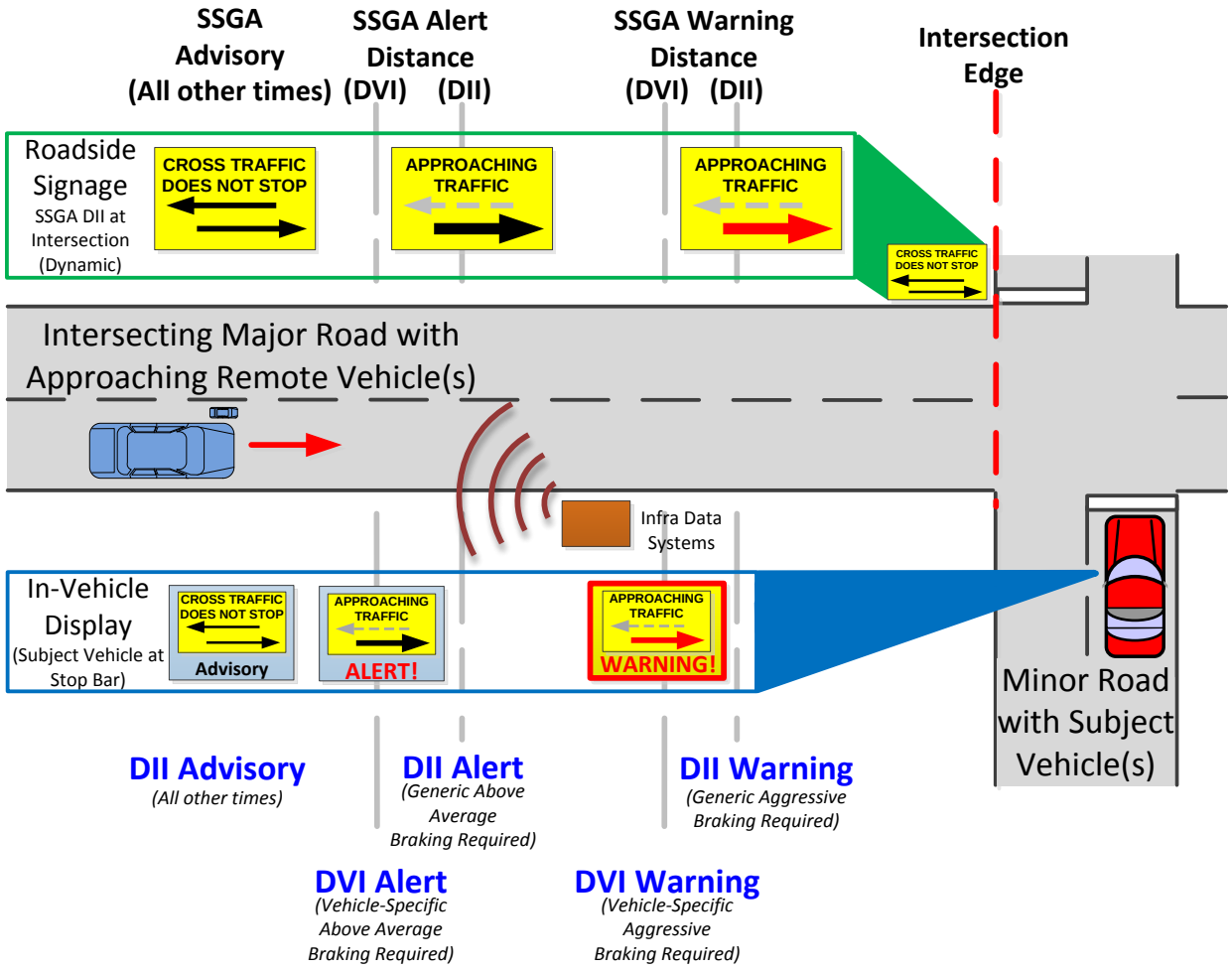
The SSGA Infrastructure Application component delivers roadside advisory, alert, and warning messages to the driver, based upon infrastructure-based sensor systems placed on the major roadway that detect the speed and location of approaching remote vehicles. As implied by the separate illustrations presented in Figure 3-3 and Figure 3-4, the message delivered regarding approaching remote vehicles is independent for each direction. For example, a remote vehicle approaching from the right may merit an SSGA Warning message and a different remote vehicle approaching from the left may merit an SSGA Alert message, in which case two distinct elements would be shown to indicate a warning and alert, respectively for each direction. If an alert or warning message is valid for only one direction, the appropriate message would be displayed for that direction and it is expected that the other direction would be de-emphasized. Only if no alert or warning is merited for either direction would a "Cross Safely" advisory be displayed. The design and appropriate gap distances for displaying Advisory, Alert, and Warning message merits further research to maximize driver understanding and better understand gap rejection behavior, accordingly.

The DII Alert Distance and DII Warning Distance represent a marginally acceptable gap distance for most drivers and an unacceptable gap distance for most drivers, respectively, for the generic subject vehicle. These distances are conditional based upon available weather or road surface conditions data from local road-weather information system (RWIS) and other infrastructure. Infrastructure-based signage and messaging is generic, intended for display to all drivers. While intended for all drivers, DII messages may be targeted for specific vehicle classes, such as commercial trucks, and include appropriate language to identify target vehicles.



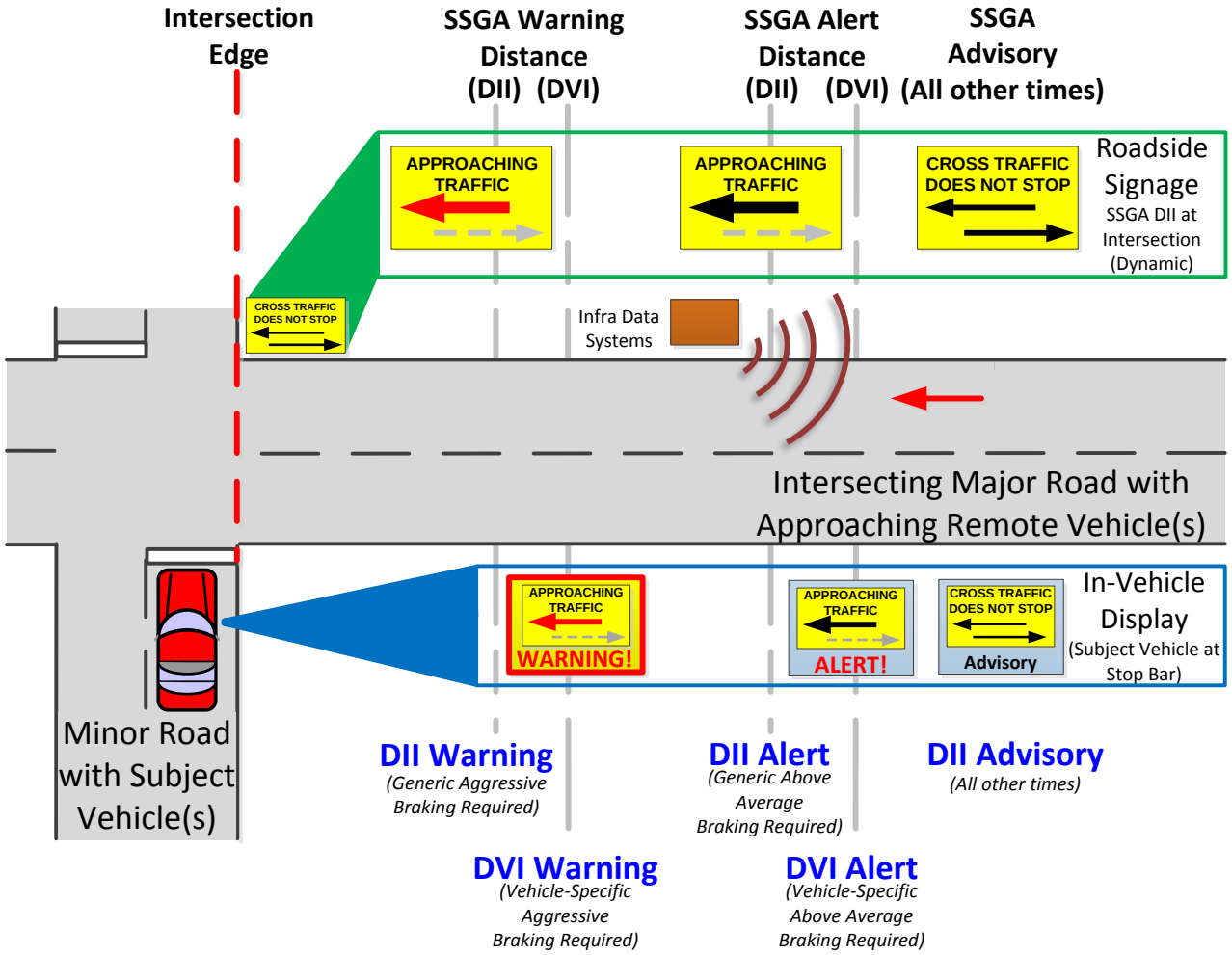
Source: Battelle

Figure 3-2. Illustration of SSGA Roadside and In-Vehicle Signage for Subject Vehicle(s) on the Minor Road



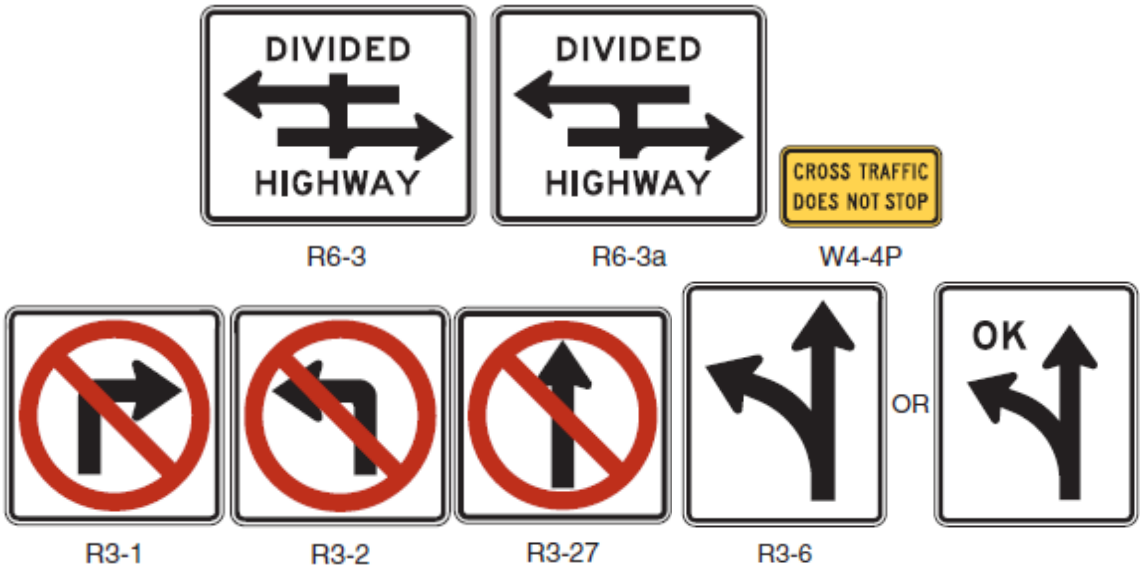
Source: Battelle

Figure 3-3. Illustration of SSGA Roadside and In-Vehicle Advisory, Alert, and Warning Messages Issued to Subject Vehicle at Stop Sign based on Location of Approaching Remote Vehicle(s) from the Left on the Intersecting Major Road



Source: Battelle

Figure 3-4. Illustration of SSGA Roadside and In-Vehicle Advisory, Alert, and Warning Messages Issued to Subject Vehicle at Stop Sign based on Location of Approaching Remote Vehicle(s) from the Right on the Intersecting Major Road



Source: MUTCD 2009 Ed.

Figure 3-5. Examples of Signage used for Road Closures and Diversion Routes

Source: University of Minnesota

Source: thegazette.com

Figure 3-6. Examples of Dynamic Signage for Minor Road Vehicles at Stop-Controlled Intersections in Minnesota (left) and Iowa (right)

The boxes to the left of the vehicle and road in the Figure 3-2, and below the road in Figure 3-3 and Figure 3-4 illustrate the coordinated in-vehicle SSGA signage. These illustrations assume the vehicle includes a graphical Driver Vehicle Interface (DVI) display. As shown in Figure 3-2, as the subject vehicle approaches the stop-controlled intersection on the minor road, the SSGA Vehicle Application Component receives a wireless message from the infrastructure containing infrastructure-based sensor data and roadside signage messages. At approximately the same time that a driver would observe the roadside static "Stop Ahead" DII advisory sign, the DVI displays a SSGA "Stop Ahead" Advisory, notifying the driver of the subject vehicle that he/she is approaching a stop-controlled intersection. (The distance at which the SSGA "Stop Ahead" Advisory is displayed in the vehicle in advance of the stop-controlled intersection is the MUTCD "Sign Visibility Distance" plus the MUTCD advanced placement distance for warning signs in Table 2C-4).

As the vehicle approaches the stop-controlled intersection and slows to stop at the stop bar, the SSGA Vehicle Application Component receives a wireless message from the infrastructure containing infrastructure-based sensor data including the position and speed of approaching remote vehicles on the major road, and collects applicable dynamics and stability data from the vehicle. The SSGA Vehicle Application Component computes the subject vehicle-specific SSGA DVI Alert and Warning Distance between approaching remote vehicles and the intersection that are needed to safely turn onto or cross the major road, using both infrastructure-based sensor data and vehicle-based sensor data. These distances may be above or below the infrastructure-based SSGA DII Alert and Warning Distances. For example, a heavy vehicle or an older driver may require a greater vehicle-specific safe gap distance than the generic safe gap distance computed by the infrastructure for the Alert and Warning Distances. In contrast, a sports car under good road surface conditions may not require as great of a gap distance. However, only the greater of the (generic) SSGA DII Alert and Warning Distances or the (vehicle specific) SSGA DVI Alert and Warning Distances, respectively, are used as the basis for in-vehicle alerts. The SSGA DVI Alert and Warning Distances may also be conditional, based upon infrastructure weather or road surface conditions where data are available, as well as subject vehicle operating conditions and whether or not the subject vehicle is turning. Figure 3-3 and Figure 3-4 present an example of the relationship between the DII Alert and Warning Distances and the DVI Alert and Warning Distances for remote vehicles approaching from the left and right, respectively. These figures illustrate that the DVI Alert and Warning Distances, if used by the application, would be a greater distance than the respective DII Alert and Warning Distances.

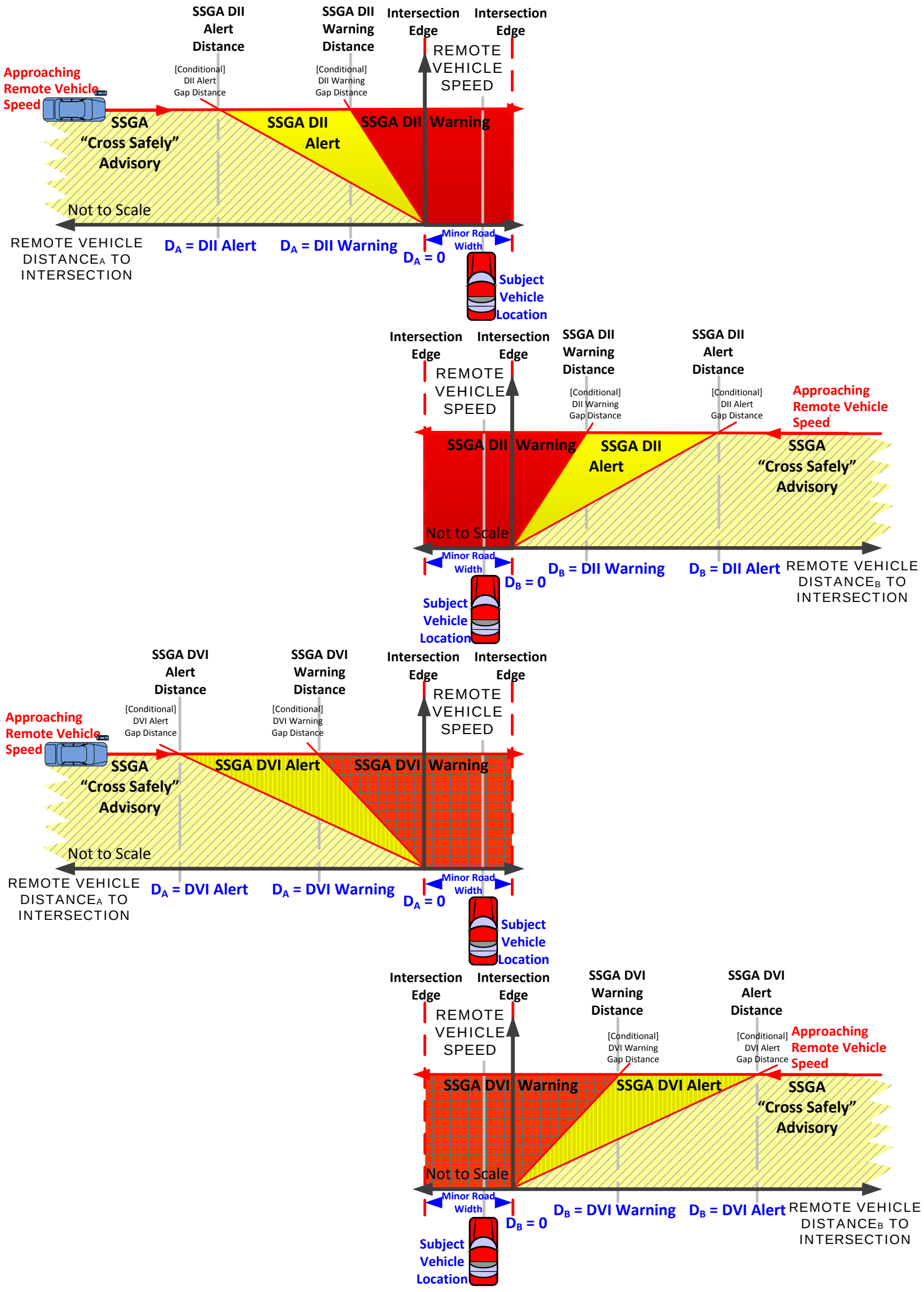
As described above, at approximately the same time that a driver would come to a complete stop at the intersection, the DVI displays the applicable SSGA Alert, Warning, or "Cross Safely" Advisory message based on the speed and distance of the approaching remote vehicles on the major roadway to the intersection. (The appropriate SSGA Alert, Warning, or "Cross Safely" Advisory message is displayed in the vehicle when the vehicle is proximate to the stop bar). The DVI continues to display the appropriate SSGA Alert, Warning, or "Cross Safely" Advisory continuously until the vehicle has exited the intersection after turning onto or crossing the major road.

Figure 3-7 illustrates advisories, alert, and warning displayed to and within the subject vehicle as a function of the remote vehicle direction, speed, and distance from the intersection. The top illustration in the figure shows the DII Alert and Warning distance for a vehicle approaching from the left. The second illustration in the figure shows the DII Alert and Warning distance for a vehicle approaching from the right. The third illustration in the figure shows the DVI Alert and Warning distance for a vehicle approaching from the left. The bottom illustration in the figure shows the DVI Alert and Warning distance for a vehicle approaching from the right. These four illustrations show how the DII Alert Distance, DVI Alert Distance, DII Warning Distance, and DVI Warning Distance are all functions of the position and speed of approaching remote vehicles on the intersecting major road. The SSGA DII Alert Distance and the SSGA DVI Alert Distance are marginally acceptable gap distances for most

drivers in a generic worst-case vehicle or most drivers in the specific subject vehicle, respectively, to safely enter or cross the roadway. The SSGA DII Warning Distance and the SSGA DVI Warning Distance are *minimum* acceptable gap distances for most drivers in a generic worst-case vehicle or most drivers in the specific subject vehicle, respectively, to safely enter or cross the roadway. That is, subject vehicles should wait for remote vehicles closer than the Warning Distance to pass before turning onto or crossing the major roadway in order to prevent a crash-imminent scenario.

The DII Alert and Warning Distances (for generic worst-case vehicles) are supplied to the vehicle application component by the infrastructure. The vehicle-specific potentially unsafe gap distances are computed by the vehicle. They are conditional based upon vehicle operating characteristics, infrastructure weather, or road surface conditions where data are available.

Table 3-1 provides a definition of the terms used here for the SSGA advisories, alert, and warning. Table 3-2 provides a tabular summary of the DII and DVI display criteria, display signage, and their location on the minor roadway.



Source: Battelle

Figure 3-7. Illustration of roadside and In-vehicle signage, both generic (DII) and vehicle-specific (DVI), to the subject vehicle waiting at the stop-controlled intersection, as a function of the speed and distance from intersection of remote vehicles approaching from the left and right

Table 3-1. Definition of SSGA Terms

SSGA DII "Stop Ahead" Advisory	Informative signage indicating the presence of a stop-controlled intersection ahead on the minor road.
SSGA DII "Cross Safely" Advisory	Informative signage indicating that no approaching remote vehicle has been detected on the intersecting major road that would present an unsafe gap or imminent crash risk.
SSGA DII Alert	Dynamic roadside signage indicating that the speed and distance of approaching remote vehicles are marginally acceptable for most drivers in a generic worst-case subject vehicle to safely enter or cross the roadway.
SSGA DII Alert Distance	Generic, infrastructure-based recommendation for gap distance of approaching remote vehicle(s) on major roadway to intersection at which to display SSGA DII Alert. Marginally acceptable gap distance for most drivers in a generic worst-case subject vehicle to safely enter or cross the roadway. Dependent upon approaching remote vehicle speed and position, and current environmental conditions.
SSGA DVI Alert	In-vehicle display indicating that the speed and distance of approaching remote vehicles are marginally acceptable for most drivers in the specific subject vehicle to safely enter or cross the roadway.
SSGA DVI Alert Distance	Vehicle-specific recommendation for gap distance of approaching remote vehicle(s) on major roadway to intersection at which to display SSGA DVI Alert. Marginally acceptable gap distance for most drivers in the specific subject vehicle to safely enter or cross the roadway. Dependent upon approaching remote vehicle speed and position, subject vehicle operating characteristics, and current environmental conditions.
SSGA DII Warning	Dynamic roadside signage indicating that the speed and distance of approaching remote vehicles are unacceptable for most drivers in a generic worst-case subject vehicle to safely enter or cross the roadway in order to prevent a crash-imminent scenario.
SSGA DII Warning Distance	Generic, infrastructure-based recommendation for gap distance of approaching remote vehicle(s) on major roadway to intersection at which to display SSGA DII Warning. *Minimum* acceptable gap distance for most drivers in a generic worst-case vehicle to safely enter or cross the roadway. That is, subject vehicles should wait for remote vehicles closer than the Warning Distance to pass before turning onto or crossing the major roadway in order to prevent a crash-imminent scenario. Dependent upon approaching remote vehicle speed and position, whether or not the subject vehicle is turning, and current environmental conditions.
SSGA DVI Warning	In-vehicle display indicating that the speed and distance of approaching remote vehicles are unacceptable for most drivers in the specific subject vehicle to safely enter or cross the roadway in order to prevent a crash-imminent scenario.
SSGA DVI Warning Distance	Vehicle specific recommendation for gap distance of approaching remote vehicle(s) on major roadway to intersection at which to display SSGA DVI Warning. *Minimum* acceptable gap distance for most drivers in the specific subject vehicle, to safely enter or cross the roadway. That is, subject vehicles should wait for remote vehicles closer than the Warning Distance to pass before turning onto or crossing the major roadway in order to prevent a crash-imminent scenario. Dependent upon approaching remote vehicle speed and position, subject vehicle operating characteristics, whether or not the subject vehicle is turning, and current environmental conditions.
Prohibitive Reference Frame	SSGA messages indicate when it is not safe for the minor road vehicle to enter the intersection (i.e., message do not indicate that it is safe). This lessens liability issues

	as compared to indicating to a driver when it is "safe" to go; "unsafe" is much easier to quantify than is safe.
Gap	The headway in the major road traffic stream of approaching remote vehicles, which is evaluated by a minor road subject vehicle driver to turn onto or cross the major road. For the SSGA application, this is expressed in units of distance (i.e., space gap). This generally refers to the distance between nearest approaching remote vehicle(s) and the intersection.
Minor Road	The lesser roadway (e.g., in terms of traffic volume, road classification, etc.) at an intersection. For the SSGA application, this road is defined as that which has stop signs at a stop-controlled intersection, i.e., for one or two directions. Any vehicle traveling on this roadway (i.e., a subject vehicle) must stop at the intersection and yield to any vehicles approaching on the major road (i.e., remote vehicles).
Major Road	Roadway of higher precedence (e.g., in terms of traffic volume, road classification, etc.) at an intersection. For the SSGA application, this road carries remote vehicles that are not required to stop at the stop-controlled intersection.
Subject Vehicle	Vehicle approaching or at a stop-controlled intersection on the minor road that receives SSGA application messages.
Remote Vehicle	Vehicle approaching a stop-controlled intersection on the major road, which does not have to stop. Vehicle does not receive SSGA application messages.

Source: Battelle

Table 3-2. Summary of SSGA Infrastructure and Vehicle Displays

	Driver Infrastructure Interface			Driver Vehicle Interface		
	Display Criterion	**Display Signage**	**Location**	**Display Criterion**	**Display Signage***	**Location**
Stage 1 "Stop Ahead" Advisory	Approaching a stop-controlled intersection. Displayed as static "Stop Ahead" roadside signage prior to stop-controlled intersection.	All vehicle Advisory of stop-controlled intersection ahead.	MUTCD Advanced Placement Distance	Received SSGA I2V Wireless Message	All vehicle Advisory of stop-controlled intersection ahead.	MUTCD Advanced Placement Distance + Sign Visibility Distance
Stage 1 "Cross Safely" Advisory	No approaching remote vehicles are detected on the intersecting major road that present an unsafe gap.	All vehicle Advisory to turn onto or cross major road with care.	Subject vehicle at intersection stop bar.	Received SSGA I2V Wireless Message	All vehicle Advisory to turn onto or cross major road with care.	Subject vehicle at intersection stop bar.
Stage 2a Infrastructure Alert	Infrastructure detected approaching remote vehicle with position and speed less than the SSGA DII Alert Distance to the intersection.	All vehicle Alert that remote vehicle is approaching on intersecting major road.	Subject vehicle at intersection stop bar.	Received SSGA I2V Wireless Message indicating infrastructure detected approaching remote vehicle with position and speed less than the SSGA DII Alert Distance to the intersection.	All vehicle Alert that remote vehicle is approaching on intersecting major road.	Subject vehicle at intersection stop bar.
Stage 2b Vehicle Specific Alert	N/A	N/A	N/A	Approaching remote vehicle has a position and speed less than the SSGA DVI Alert Distance to the intersection.	Vehicle-specific Alert that remote vehicle is approaching on intersecting major road.	Subject vehicle at intersection stop bar.

Table 3-2. Summary of SSGA Infrastructure and Vehicle Displays (Continued)

	Driver Infrastructure Interface			Driver Vehicle Interface		
	Display Criterion	**Display Signage**	**Location**	**Display Criterion**	**Display Signage***	**Location**
Stage 3a Infrastructure Warning	Infrastructure detected approaching remote vehicle with position and speed less than the SSGA DII Warning Distance to the intersection.	All vehicle Warning that it is unsafe for the subject vehicle to turn onto or cross the major road due to a remote vehicle that is imminently approaching on the intersecting major road.	Subject vehicle at intersection stop bar.	Received SSGA I2V Wireless Message indicating infrastructure detected approaching remote vehicle with position and speed below the SSGA DII Warning Distance to the intersection and a worst case subject vehicle must not turn onto or cross the major road in order to avoid a crash.	All vehicle Warning that it is unsafe for the subject vehicle to turn onto or cross the major road due to a remote vehicle that is imminently approaching on the intersecting major road.	Subject vehicle at intersection stop bar.
Stage 3b Vehicle Specific Warning	N/A	N/A	N/A	Approaching remote vehicle has a position and speed less than the SSGA DVI Warning Distance to the intersection.	Vehicle-specific Warning that it is unsafe for the subject vehicle to turn onto or cross the major road due to a remote vehicle that is imminently approaching on the intersecting major road.	Subject vehicle at intersection stop bar.

* If applicable, DVI displays Stage 3b Vehicle-specific Warning; otherwise if applicable DVI displays Stage 3a Infrastructure Warning; otherwise if applicable DVI displays Stage 2b Vehicle-specific Alert; otherwise if applicable DVI displays Stage 2a Infrastructure Alert; otherwise if applicable, DVI displays all vehicle Advisory (DII "Cross Safely" Advisory or DII "Stop Ahead" Advisory), as applicable.

Source: Battelle

3.3.1.5 Application Assumptions

Assumptions

- The subject vehicle is approaching or at a stop-controlled intersection equipped with a SSGA application.
- The SSGA application is intended for a variety of intersection types.
- The DVI issues alert and warning messages that are distinct for each direction of the major roadway and may differ depending upon the respective location(s) of approaching remote vehicle(s).
- Application has capabilities to detect presence and speed of multiple vehicles on the major road, and their distance from the intersection.
- The only driver and vehicle affected by the SSGA application is the subject vehicle stopped at the intersection with the intent to either enter or cross the major road traffic.
- The application does not consider other drivers or vehicle on the minor road.
- The DII is designed such that a driver on the minor road is aware if the application is inactive.
- A prohibitive reference frame (i.e., indicating to a driver when not safe to go) is used to lessen liability issues as compared to indicating to a driver when it is "safe" to go; "unsafe" is easier to quantify than is safe. As such, when no alert or warning is warranted, the SSGA application will continuously issue a "cross safely" advisory to indicate to minor road drivers the need to verify that it is safe to enter the intersection.
- The SSGA application might be used in conjunction with other connected vehicle applications.

Considerations

The SSGA system is intended to advise, alert, and warn only minor road vehicles about possible unsafe conditions for crossing the intersection. The system does not provide any message to major road drivers for a crash imminent scenario, e.g., when a minor road vehicle accepts an unsafe gap.

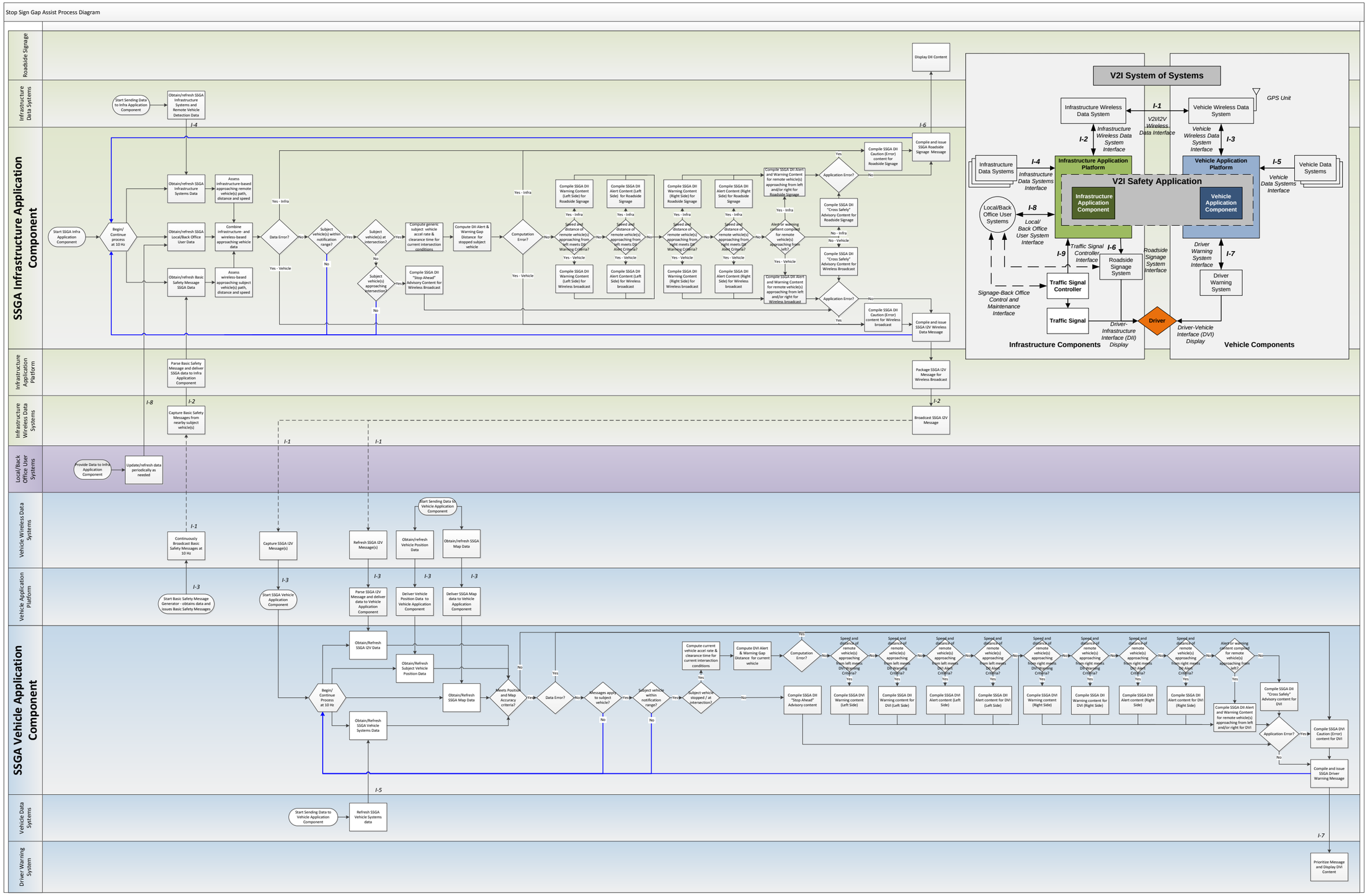
Further research is necessary to ascertain the appropriate display of SSGA advisory, alert, and warning messages. This is likely to include human factors research to ensure driver understanding of the signage and messages being presented. Otherwise, there exists a risk of presenting too much or too complex information for driver comprehension. Additionally, determining the appropriate gap distances of approaching remote vehicles at which to display alert and warning messages is important to closely mimic driver behavior to be credible and useful to drivers.

Consideration needs to be given to the timing for issuing of alert and warning messages that immediately follow another alert or warning message to give the driver sufficient time to react. Some smoothing between subsequent alert or warning messages to avoid abrupt transitions back and forth between alert and warning messages could make for a more useful and understood driver experience than a minimal (e.g., 0.5 second) display of a different message. For instance, after a remote vehicle has passed the intersection and the following remote vehicle distance may only merit an alert, continuing to display the warning message for 0.5 seconds until the approaching remote vehicle does merit the warning will be more intuitive and useful to the subject vehicle driver than a 0.5 second long alert message that would not allow sufficient time for the driver to react and safely cross or turn onto the major roadway.

3.3.1.6 Application Swim Lane & Sequence Diagrams

As the next step in the description of the SSGA Application, Figure 3-6 provides a swim-lane process diagram for the SSGA application illustrating the sequence of data flows and processing by the SSGA Infrastructure Application Component and the SSGA Vehicle Application Component. The figure includes the V2I Systems architecture diagram presented earlier for reference.

At a high level, the SSGA Infrastructure Application Component first issues a DII "Stop Ahead" Advisory as a SSGA I2V Wireless Message to vehicles approaching a stop-controlled intersection on a minor road. The SSGA Infrastructure Application Component continuously monitors the position and speed of major road remote vehicles, and obtains remaining infrastructure, local/back office, and vehicle data inputs. Based on available information, the SSGA Infrastructure Application Component determines the appropriate advisory, alert, or warning message for subject vehicles on the minor road based on the remote vehicle distance from the minor road intersection. The selected SSGA Roadside Signage Message is issued to the Roadside Signage System for display and a SSGA I2V Wireless Data Message is issued to the Infrastructure Wireless Data System for broadcast to nearby vehicles. Upon receipt of a SSGA I2V Wireless Data Message, the Vehicle Application Platform initiates the SSGA Vehicle Application Component. The SSGA Vehicle Application Component obtains I2V, position and map data inputs, determines if a driver advisory, alert, or warning is warranted and, if so, issues a SSGA DVI Advisory, Alert, or Warning Message to the Driver Warning System. These processes are performed at a rate of 10 Hz to update SSGA Roadside Signage Message and the SSGA Driver Advisory, Alert, and Warning Message to drivers of subject vehicles that are approaching or at the stop-controlled intersection on the minor road to assist them by identifying unsafe gaps. This diagram illustrates the concepts that are the basis for SSGA application requirements enumerated in section 3.8.2.



Source: Battelle

Figure 3-8. Swim-lane Process Diagram for the SSGA Application

3.3.1.7 Messages Exchanged and Used by the Application

For the purposes of these requirements, the data exchanged between system components, across system interfaces are encapsulated in ten messages summarized in Table 3-3 below. The table summarizes the message name, the source and recipient of the message, general description of the message content, location for description of data elements, and purpose of the message. In some cases such as the Basic Safety Message, the message is defined in an existing standard, such as SAE J2735. For further reference and background information, Appendix A suggests candidate data elements which may be included in these messages to support the SSGA safety application algorithms. Table A-1 provides an explanation of the headers in candidate data tables. As noted in Table 3-3, Table A-2 through Table A-7 describe the candidate data elements for each of the messages. This information is provided for guidance when implementing the performance requirements specified in this document.

Table 3-3. Summary of Messages used by SSGA Application Components

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
Infrastructure Component Messages					
SSGA Infrastructure Systems Message	External Vehicle Detection System, Infra Data System – Road Surface, Infra Data System – Local Weather	Infra Application Component	Detection of approaching vehicles and their speed, road surface conditions, local weather conditions	Table A-2 SSGA Infrastructure Systems Message Data Description	Used as input by SSGA Infrastructure Application Component to determine if a major road vehicle(s) is approaching the intersection. Road surface and weather data are forwarded to the Vehicle Application Component through the SSGA I2V Wireless Message.
SSGA Roadside Signage Message	Infra Application Component	Roadside Signage System	SSGA Roadside Signage message content	Table A-3 SSGA Roadside Signage Message Data Description	SSGA message content to be displayed on dynamic roadside signage.
SSGA Infrastructure Map Message	Local-Back Office Users Systems Interface	Infrastructure Map Message Handler	Detailed map of SSGA Intersection & signage	Table A-4 SSGA Map Message Data Description	Used as input by SSGA Vehicle Application Component to determine if subject vehicle and major road vehicles are approaching the intersection. May be uploaded through an externally generated data file.
V2I/I2V Messages					
Basic Safety Message	Vehicle Basic Safety Message Generator	Infrastructure Application Component	Vehicle location, speed and heading	SAE J2735 Basic Safety Message	Data used by Infrastructure Application Component to determine if vehicles are approaching on the minor road and the speed and distance of vehicle(s) approaching on the major road.
SSGA I2V Wireless Message	Infra Application Component	Vehicle Application Component	SSGA Approaching Vehicle Data, Operational Data, Road Surface Condition, Local Weather Data, SSGA Roadside Signage Data	Table A-5 SSGA I2V Wireless Message Data Description	Data used by vehicle application component to determine vehicle-specific SSGA Alert and Warning Distances, and content and timing for issuing DII and DVI advisories, alerts, and warnings.

Table 3-3. Summary of Messages used by SSGA Application Components (Continued)

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
SSGA Wireless Map Message	Infrastructure Map Message Handler	Vehicle Application Component	Detailed map of SSGA Intersection & signage	Table A-4 SSGA Map Message Data Description	Used as input by SSGA Vehicle Application Component to determine if subject vehicle and major road vehicles are approaching the intersection.
Wireless Position Correction Message	Infrastructure Position Correction Message Handler	Vehicle GPS Message Handler	Differential GPS Correction Data	SAE J2735 RTCM Corrections Message	Used as input by vehicle application component to determine if advisories, alerts and warnings are warranted.
Vehicle Component Messages					
GPS Position Message	Vehicle GPS Position Message Handler	Vehicle Application Component	Location, speed, heading of subject vehicle	SAE J2735 Full Position Vector	Used by the SSGA Vehicle Application Component to determine vehicle position, speed and heading and if and when to issue advisories, alerts, or warnings.
SSGA Vehicle Systems Message	Vehicle Data Systems	Vehicle Application Component	Vehicle Characteristics, Vehicle Functional Status, Vehicle Environmental Data	Table A-6 SSGA Vehicle Systems Message Data Description	Used as input by SSGA Vehicle Application Component to determine the vehicle-specific recommendations for proceeding through intersection.
SSGA Driver Warning Message	Vehicle Application Component	Driver Warning System	SSGA in-vehicle message content	Table A-7 SSGA Driver Warning Message Data Description	SSGA message content to be displayed on in-vehicle displays.

Source: Battelle

3.3.2 SSGA Infrastructure Application Component Requirements

Table 3-4 catalogs the performance requirements for the SSGA Infrastructure Application Component. These were developed based upon the integration strategy described in Section 3.3.1.4 above. It is expected that, as connected vehicle technology evolves and vehicle and infrastructure application component owners develop this and other V2I Safety Applications, the rationales, frameworks, and performance requirements presented here will evolve. Accordingly, before embarking upon design and development, application owners should update and refine the requirements to reflect current standards and policies. It is the responsibility of the designer to ensure that the resulting applications do not conflict with applicable published state and national regulations, policies, and guidelines.

Table 3-4. SSGA Infrastructure Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
7.01	**SSGA Infrastructure Application Component Requirements**			
7.01.01	**SSGA Infrastructure Application Component Interfaces and Interface Specifications**			
[7.01.01.01]	**SSGA Infrastructure Systems Message Interface**	**The SSGA Infrastructure Application Component shall obtain SSGA Infrastructure Systems Messages through the Infrastructure Data Systems Interface.**		D
[7.01.01.02]	**Basic Safety Message Interface**	**The SSGA Infrastructure Application Component shall obtain Basic Safety Messages through the Infrastructure Wireless Data Systems Interface.**		D
[7.01.01.03]	**SSGA Local/Back Office User Data Interface**	**The SSGA Infrastructure Application Component shall obtain SSGA Local/Back Office User Data through the Local/Back Office User Systems Interface.**		D
[7.01.01.04]	**SSGA I2V Wireless Message Interface**	**The SSGA Infrastructure Application Component shall issue SSGA I2V Wireless Messages through the Infrastructure Wireless Data Systems Interface.**		D
[7.01.01.05]	**SSGA Roadside Signage Message Interface**	**The SSGA Infrastructure Application Component shall issue SSGA Roadside Signage Messages through the Roadside Signage System Interface.**		D
7.01.02	**SSGA Infrastructure Application Component Functional Requirements**			
[7.01.02.01]	**Common Infrastructure Application Component Requirements**	**The SSGA Infrastructure Application Component shall adhere to Common Infrastructure Application Component Requirements.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.02]	**SSGA Infrastructure Systems Message Initiation**	**The SSGA Infrastructure Application Component shall obtain SSGA Infrastructure Systems Messages upon initiation of the component.**		D
[7.01.02.03]	**SSGA Infrastructure Systems Data – Vehicle Speed**	**The SSGA Infrastructure Application component shall obtain speed and distance of approaching vehicles from Infrastructure Data Systems before the vehicles are within the SSGA DII Advisory Distance of the intersection entrance.**	*The SSGA DII Advisory Distance is the distance from the beginning of the intersection defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.* *The SSGA Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D
[7.01.02.04]	**SSGA Infrastructure Systems Message Refresh Rate**	**The SSGA Infrastructure Application Component shall refresh SSGA Infrastructure Systems Messages at a configurable frequency.**	*Table (SSGA Infrastructure) SSGA Infrastructure Systems Data Description is referenced for guidance.*	D
[7.01.02.05]	**Basic Safety Message Initiation**	**The SSGA Infrastructure Application Component shall obtain Basic Safety Messages upon initiation of the component.**	*The SSGA Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.06]	**Basic Safety Message Vehicle Speed**	**The SSGA Infrastructure Application component shall obtain speed and distance of approaching vehicles from Basic Safety Messages before the vehicles are within the SSGA DII Advisory Distance of the intersection entrance.**	*The SSGA DII Advisory Distance is the distance from the beginning of the intersection defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.* *The SSGA Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D
[7.01.02.07]	**Basic Safety Message Refresh Rate**	**The SSGA Infrastructure Application Component shall refresh Basic Safety Messages at a configurable frequency.**		D
[7.01.02.08]	**SSGA Local/Back Office User Data Initiation**	**The SSGA Infrastructure Application Component shall obtain SSGA Local/Back Office User Data upon initiation of the component.**		D
[7.01.02.09]	**GPS Position Accuracy**	**GPS Position data used by the SSGA Vehicle Application Component shall be of at least Road Level Position Accuracy.**	*Road Level Position Accuracy is defined under Common Infrastructure Application Component Requirements.*	D
[7.01.02.10]	**SSGA Local/Back Office User Data Refresh Rate**	**The SSGA Infrastructure Application Component shall refresh SSGA Local/Back Office User Data at a configurable frequency.**	*Table (SSGA Local-Back Office) SSGA Local-Back Office User Systems Data Description is referenced for guidance.*	D
[7.01.02.11]	**Map Data Accuracy**	**Map data used by SSGA Vehicle Application Component shall be of at least Road Level Position Accuracy.**	*Road Level Position Accuracy is defined under Common Infrastructure Application Component Requirements.*	D
[7.01.02.12]	**Map Data Accuracy**	**Map data used by the SSGA Infrastructure Application Component shall be of at least Road**	*Road Level Position Accuracy is defined under Common Infrastructure Application Component*	D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
		Level Position Accuracy.	*Requirements.*	
[7.01.02.13]	**Approaching Subject Vehicle Characterization**	**The SSGA Infrastructure Application Component shall assess SSGA Infrastructure Data and Basic Safety Messages to determine if subject vehicle(s) on the minor road are approaching the intersection, and, if so, their distance from the stop bar.**		D
[7.01.02.14]	**Approaching Remote Vehicle Characterization**	**The SSGA Infrastructure Application Component shall assess SSGA Infrastructure Data and Basic Safety Messages to determine if remote vehicle(s) on the intersecting major road are approaching the intersection in either direction, and, if so, the direction, the distance and the approaching speed of each.**		D
[7.01.02.15]	**Compute [Conditional] SSGA Subject Vehicle Gap Acceptance Time**	**If the SSGA DII alerts and SSGA DII warnings are conditional (e.g. based upon weather or road conditions) the SSGA Infrastructure Application Component shall compute the Generic [Conditional] DII SSGA subject vehicle gap acceptance time for the approaching subject vehicle using current available SSGA Infrastructure Data.**		D
[7.01.02.16]	**Determine SSGA DII Subject Vehicle Gap Acceptance Time**	**If the SSGA DII alerts and SSGA DII warnings are not conditional, the SSGA Infrastructure Application Component shall determine the Generic SSGA DII Subject Vehicle Gap Acceptance Time based on real-time conditions as required by published guidelines and/or local policy.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.17]	**SSGA DII Subject Vehicle "Stop Ahead" Advisory Distance Definition**	**The SSGA DII Subject Vehicle "Stop Ahead" Advisory Distance shall be the distance on the minor road from the intersection stop bar as defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.**	*The DII Subject Vehicle "Stop Ahead" Advisory Distance is typically static, defined by the MUTCD Table 2C-4.*	D
[7.01.02.18]	**SSGA DII Subject Vehicle "Cross Safely" Advisory Distance Definition**	**The SSGA DII Subject Vehicle "Cross Safely" Advisory Distance shall be the distance at which no unsafe gap (in either direction) is determined.**		D
[7.01.02.19]	**SSGA DII Alert Gap Distance Definition**	**The SSGA DII Alert Gap Distance for the subject vehicle shall be the acceptable gap distance between a remote vehicle and the intersection based on the remote vehicle's approaching speed and the generic subject vehicle's gap acceptance time.**		D
[7.01.02.20]	**SSGA DII Warning Gap Distance Definition**	**The SSGA DII Warning Gap Distance for the subject vehicle shall be the minimum acceptable gap distance between a remote vehicle and the intersection based on the remote vehicle's approaching speed and the generic subject vehicle's gap acceptance time.**		D
[7.01.02.21]	**Determine SSGA DII Subject Vehicle "Stop Ahead" Advisory Distance**	**The SSGA Infrastructure Application Component shall determine the SSGA DII Subject Vehicle "Stop Ahead" Advisory Distance based upon MUTCD guidelines.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.22]	**Compute SSGA DII Alert and Warning Gap Distances**	**The SSGA Infrastructure Application Component shall compute the SSGA DII Alert Gap Distance(s) and DII Warning Gap Distance(s) for the generic subject vehicles using generic subject vehicle gap acceptance times for each side of the intersection in which a remote car is present, and the remote vehicle(s)' detected approaching speed(s).**		D
[7.01.02.23]	**SSGA DII Content General**	**SSGA DII content shall use a prohibitive frame, indicating that conditions may be unsafe.**		D
[7.01.02.24]	**SSGA DII Subject Vehicle "Stop Ahead" Advisory Criterion for Roadside Signage**	**If the subject vehicle is on the minor road approaching the intersection stop bar, the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing a current SSGA DII "Stop Ahead" Advisory to the Roadside Signage Interface.**		D
[7.01.02.25]	**SSGA DII Warning Criterion for Roadside Signage**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DII Warning Gap Distance then the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing a current SSGA DII Warning to the Roadside Signage System Interface.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.26]	**SSGA DII Alert Criterion for Roadside Signage**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DII Alert Gap Distance but greater than or equal to the SSGA DII Warning Gap Distance then the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing a current SSGA DII Alert to the Roadside Signage System Interface.**		D
[7.01.02.27]	**Criterion for Multiple SSGA DII Warning Messages on Roadside Signage**	**If the subject vehicle is at the intersection stop bar, and remote vehicles are approaching from both sides of the intersection at distances which require DII Alerts and/or DII Warnings then the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing both SSGA DII Alerts and/or Warnings to the Roadside Signage System Interface.**		D
[7.01.02.28]	**SSGA DII "Cross Safely" Advisory Criterion for Roadside Signage**	**If the subject vehicle is at the intersection stop bar, and the distance(s) of all approaching remote vehicle(s) are greater than or equal to the corresponding SSGA DII Alert Gap Distance(s) then the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing a current SSGA DII "Cross Safely" Advisory to the Roadside Signage System Interface.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.29]	**SSGA DII Subject Vehicle "Stop Ahead" Advisory Criterion for I2V Message**	**If the subject vehicle is on the minor road approaching the intersection stop bar, the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing a current SSGA DII "Stop Ahead" Advisory to the Infrastructure Wireless Data Systems Interface.**		D
[7.01.02.30]	**SSGA DII Warning Criterion for I2V Message**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DII Warning Gap Distance then the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing a current SSGA DII Warning to the Infrastructure Wireless Data Systems Interface.**		D
[7.01.02.31]	**SSGA DII Alert Criterion for I2V Message**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DII Alert Gap Distance but greater than or equal to the SSGA DII Warning Gap Distance then the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing a current SSGA DII Alert to the Infrastructure Wireless Data Systems Interface.**		D
[7.01.02.32]	**Criterion for Including Multiple Warnings Messages in I2V Message**	**If the subject vehicle is at the intersection stop bar, and remote vehicles are approaching from both sides of the intersection at distances which require DII Alerts and/or DII Warnings then the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing both SSGA DII Alerts and/or Warnings to the Infrastructure Wireless Data Systems Interface.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.33]	**SSGA DII "Cross Safely" Advisory Criterion for I2V Message**	**If the subject vehicle is at the intersection stop bar, and the distance(s) of all approaching remote vehicle(s) are greater than or equal to the corresponding SSGA DII Alert Gap Distance(s) then the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing a current SSGA DII "Cross Safely" Advisory to the Infrastructure Wireless Data Systems Interface.**		D
[7.01.02.34]	**SSGA Wireless Map Message**	**The SSGA Infrastructure Application Component shall compile and issue a SSGA Wireless Map Message containing SSGA Wireless Map Message Data described in Table (SSGA Wireless Map) SSGA Wireless Map Message Data Description to the Infrastructure Wireless Data Systems Interface.**		D
[7.01.02.35]	**SSGA Infrastructure Application Component Caution (Error) Message for Roadside Signage Criterion**	**In the event of an input data, computational or other recoverable SSGA Infrastructure Application Component error, preventing issuing of SSGA DII advisories, SSGA DII alerts, or SSGA DII warnings, the SSGA Infrastructure Application Component shall issue a SSGA Roadside Signage Message containing a SSGA DII Caution (Error) and an indication of SSGA Infrastructure Application Component Error to the Roadside Signage System Interface.**	*Caution message is displayed when denoting an error.*	D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.02.36]	**SSGA Infrastructure Application Component Caution (Error) Criterion for I2V Message**	**In the event of an input data, computational or other recoverable SSGA Infrastructure Application Component error, preventing issuing of SSGA DII advisories, SSGA DII alerts, or SSGA DII warnings, the SSGA Infrastructure Application Component shall issue a SSGA I2V Message containing a SSGA DII Caution (Error) and an indication of SSGA Infrastructure Application Component Error to the Infrastructure Wireless Data Systems Interface.**	*Caution message is displayed when denoting an error.*	D
7.01.03	**SSGA Infrastructure Application Component Data Input Requirements**			
[7.01.03.01]	**SSGA Infrastructure Systems Message Content**	**The SSGA Infrastructure Systems Message shall contain data required to perform the calculations specified under SSGA Infrastructure Application Functional Requirements.**	*Table (SSGA Infrastructure) SSGA Infrastructure Systems Message Data Description is referenced for guidance.*	D
[7.01.03.02]	**SSGA Infrastructure Systems Message Specification for Vehicle Speed Sensors**	**The SSGA Infrastructure Systems Message for capturing data from local Infrastructure-based Vehicle Speed Sensor Systems shall conform to NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS).**		D
[7.01.03.03]	**SSGA Infrastructure Systems Message Specification for Environmental Sensor Stations**	**The SSGA Infrastructure Systems Message for capturing data from local ESS Interface shall conform to NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.**		D
[7.01.03.04]	**Basic Safety Message Specification**	**The Basic Safety Message messages shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.03.05]	**SSGA Local/Back Office User Data Content**	**The SSGA Local/Back Office User Data shall contain data required to perform the calculations specified under SSGA Infrastructure Application Functional Requirements.**	*Table (SSGA Infrastructure) SSGA Infrastructure Systems Message Data Description is referenced for guidance.*	D
[7.01.03.06]	**SSGA Local/Back Office User Data Specifications**	**The SSGA Local/Back Office User Data and all Local/Back Office User System messages shall conform to Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications.**		D
[7.01.03.07]	**SSGA Local/Back Office User Data Content Text**	**The SSGA Local/Back Office User Data shall contain text used in SSGA DII Advisory and SSGA DII Alert roadway signage.**		D
[7.01.03.08]	**SSGA Local/Back Office User Data Content Prohibitive Frame**	**SSGA DII advisory and SSGA DII alert text shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and DII alert messages shall not indicate that conditions may be safe.*	D
[7.01.03.09]	**SSGA Local/Back Office User Data Content Graphics**	**The SSGA Local/Back Office User Data shall contain shapes and graphics used in SSGA DII Advisory and SSGA DII Alert roadway signage.**		D
7.01.04	**SSGA Infrastructure Application Component Data Output Requirements**			
[7.01.04.01]	**SSGA I2V Wireless Message Content**	**The SSGA I2V Wireless Message shall contain data required to perform the calculations specified under SSGA Vehicle Application Functional Requirements.**	*Table (SSGA Wireless) SSGA I2V Wireless Message Data Description is referenced for guidance.*	D
[7.01.04.02]	**SSGA I2V Wireless Message Specification**	**The SSGA I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary.**		D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.04.03]	**SSGA I2V Wireless Message Content Text**	**The SSGA I2V Wireless Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution (Error) text used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[7.01.04.04]	**SSGA I2V Wireless Message Prohibitive Frame**	**The SSGA I2V Wireless Message content (SSGA DII advisory, SSGA DII alert, and SSGA DII Caution (Error) messages) shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and alert messages shall not indicate that conditions may be safe.*	D
[7.01.04.05]	**SSGA I2V Wireless Message Graphics**	**The SSGA I2V Wireless Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution (Error) shapes and graphics used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[7.01.04.06]	**SSGA Roadside Signage Message Content**	**The SSGA Roadside Signage Message shall contain the content to be displayed on dynamic roadside signage.**	*The SSGA Roadside Signage Message shall contain one of three types of DII contents, a SSGA DII Advisory, a SSGA DII Alert, or a SSGA DII Caution.* *Table (SSGA Roadside) SSGA Roadside Signage Message Data Description is referenced for guidance.*	D
[7.01.04.07]	**SSGA Roadside Signage Message Specifications**	**The SSGA Roadside Signage Message shall conform to NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.**		D
[7.01.04.08]	**SSGA Roadside Signage Message Text**	**The SSGA Roadside Signage Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution text.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D

Table 3-4. SSGA Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.01.04.09]	**SSGA Roadside Signage Message Prohibitive Frame**	**The SSGA Roadside Signage Message (SSGA DII advisory and SSGA DII alert messages) shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and alert messages shall not indicate that conditions may be safe.*	D
[7.01.04.10]	**SSGA Roadside Signage Message Graphics**	**The SSGA Roadside Signage Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution shapes and graphics.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D

Source: Battelle

3.3.2 SSGA Vehicle Application Component Requirements

Table 3-5 catalogs the performance requirements for the SSGA Vehicle Application Component. These were developed based upon the integration strategy described in Section 3.3.1.4 above. It is expected that, as connected vehicle technology evolves and vehicle and infrastructure application component owners develop this and other V2I Safety Applications, the rationales, frameworks, and performance requirements presented here will evolve. Accordingly, before embarking upon design and development, application owners should update and refine the requirements to reflect current standards and policies. It is the responsibility of the designer to ensure that the resulting applications do not conflict with applicable published state and national regulations, policies, and guidelines.

Table 3-5. SSGA Vehicle Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
7.02	**SSGA Vehicle Application Component Requirements**			
7.02.01	**SSGA Vehicle Application Component Interfaces and Interface Specifications**			
[7.02.01.01]	**SSGA I2V Wireless Message Interface**	**The SSGA Vehicle Application Component shall obtain SSGA I2V Wireless Messages through the Vehicle Wireless Data Systems Interface.**		D
[7.02.01.02]	**SSGA Vehicle Data Interface**	**The SSGA Vehicle Application Component shall obtain SSGA Vehicle Data through the Vehicle Data Systems Interface.**		D
[7.02.01.03]	**SSGA Driver Message Interface**	**The SSGA Vehicle Application Component shall issue SSGA Driver Messages through the Driver Warning System Interface.**		D
7.02.02	**SSGA Vehicle Application Component Functional Requirements**			
[7.02.02.01]	**Common Vehicle Application Component Requirements**	**The SSGA Vehicle Application Component shall adhere to Common Vehicle Application Component Requirements.**		D
[7.02.02.02]	**SSGA Vehicle Application Component Initiation**	**The SSGA Vehicle Application Component shall be initiated upon receipt of an SSGA I2V Wireless Message by the Vehicle Wireless Data Systems.**		D
[7.02.02.03]	**SSGA I2V Wireless Message Initiation**	**The SSGA Vehicle Application Component shall obtain SSGA I2V Wireless Messages upon initiation of the component.**		D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.02.02.04]	**SSGA I2V Wireless Message Refresh Rate**	**The SSGA Vehicle Application Component shall refresh the SSGA I2V Wireless Message input at a configurable frequency.**		D
[7.02.02.05]	**SSGA Vehicle Data Initiation**	**The SSGA Vehicle Application Component shall obtain SSGA Vehicle Data upon initiation of the component.**		D
[7.02.02.06]	**Vehicle Data Systems Refresh Rate**	**The SSGA Vehicle Application Component shall refresh SSGA Vehicle Data at a configurable frequency.**		D
[7.02.02.07]	**SSGA Infrastructure Data**	**Upon receipt of a SSGA I2V Wireless Message, the SSGA Vehicle Application Component shall open the message and parse it for relevant SSGA data.**		D
[7.02.02.08]	**SSGA Positioning Accuracy Determination**	**The SSGA Vehicle Application Component shall determine if the received Position Data and the Map Data meet the position accuracy requirements for the received SSGA I2V Wireless Message.**		D
[7.02.02.09]	**SSGA Positioning Accuracy Assessment**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the SSGA I2V Wireless Message, the SSGA Vehicle Application Component shall refresh the Position Data and Map Data and continue processing.**	*The application should continue iteratively obtaining position and map data until SSGA application position accuracy requirements are satisfied for the SSGA I2V Wireless Message.*	D
[7.02.02.10]	**SSGA Positioning Accuracy Message – Advisory**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the received SSGA I2V Wireless Message, the SSGA Vehicle Application Component shall issue a SSGA Driver Message containing a SSGA DII Advisory to the Driver Warning System.**	*The SSGA Application issues only advisory messages if position and map accuracy are not sufficient to support alert and warning calculations.*	D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.02.02.11]	**SSGA I2V Message Applicability Determination**	**The SSGA Vehicle Application Component shall determine if the received SSGA I2V Wireless Message is applicable, based upon the subject vehicle's apparent path, the specified class of vehicles to which the message applies and other message criteria.**		D
[7.02.02.12]	**SSGA I2V Message Applicability Assessment**	**If the received SSGA I2V Wireless Message is not applicable, the SSGA Vehicle Application Component shall refresh the SSGA I2V Wireless Message and continue processing.**	*The application should continue iteratively obtaining SSGA I2V Wireless Messages until a message applicable to current vehicle conditions is received.*	D
[7.02.02.13]	**Compute Vehicle-Specific Gap Acceptance Time(s)**	**The SSGA Vehicle Application Component shall compute the Vehicle-Specific Gap Acceptance Time for each side of the intersection in which a remote car is present based upon available SSGA infrastructure and SSGA vehicle data and published industry or OEM guidelines.**		D
[7.02.02.14]	**Compute SSGA DVI Alert Gap and Warning Gap Distances**	**The SSGA Vehicle Application Component shall compute the SSGA DVI Alert Gap Distance(s) and the SSGA DVI Warning Gap Distance(s) corresponding to the vehicle-specific gap acceptance time for each side of the intersection in which a remote car is present, and the remote vehicle(s)'s detected approaching speed(s).**		D
[7.02.02.15]	**SSGA DVI "Stop Ahead" Advisory Criterion**	**If the subject vehicle is on the minor road approaching the intersection stop bar, the SSGA Vehicle Application Component shall issue a SSGA Roadside Signage Message containing a DII "Stop Ahead" Advisory to the Driver Warning System.**		D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.02.02.16]	**SSGA DVI Warning Criterion**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DVI Warning Gap Distance then the SSGA Vehicle Application Component shall issue an SSGA DVI Warning to the Driver Warning System.**		D
[7.02.02.17]	**SSGA DVI Alert Criterion**	**If the subject vehicle is at the intersection stop bar, and the distance of an approaching remote vehicle is less than the SSGA DVI Alert Gap Distance but greater than or equal to the SSGA DVI Warning Gap Distance then the SSGA Vehicle Application Component shall issue an SSGA DVI Alert to the Driver Warning System.**		D
[7.02.02.18]	**Criterion for Multiple SSGA DVI Warning Messages**	**If the subject vehicle is at the intersection stop bar, and remote vehicles are approaching from both sides of the intersection at distances which require DVI Alerts and/or DVI Warnings then the SSGA Vehicle Application Component shall issue a SSGA In-Vehicle Message containing both SSGA DVI Alerts and/or Warnings to the Driver Warning System.**		D
[7.02.02.19]	**SSGA DVI "Cross Safely" Advisory Criterion**	**If the subject vehicle is at the intersection stop bar, and the distance(s) of all approaching remote vehicle(s) are greater than or equal to the corresponding SSGA DVI Alert Gap Distance(s) then the SSGA Vehicle Application Component shall issue an In-Vehicle Message containing a current SSGA DII "Cross Safely" Advisory to the Driver Warning System.**		D
[7.02.02.20]	**SSGA Advisory, SSGA Alert and SSGA Warning**	**The SSGA Vehicle Application Component shall cease issuing SSGA DII advisory, SSGA DVI alert and SSGA**		D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
	Termination	**DVI warnings after the vehicle enters the major road or exists the intersection.**		
[7.02.02.21]	**SSGA DVI and SSGA DII Message Consistency**	**The SSGA Vehicle Application Component shall not issue a less cautious SSGA DVI advisory, DVI alert, or DVI warning than the SSGA Infrastructure Application components.**		D
[7.02.02.22]	**SSGA DVI Message Precedence**	**The SSGA Vehicle Application Component shall govern the message to be delivered to the Driver Warning System, based upon available SSGA infrastructure and SSGA vehicle data. The SSGA Vehicle Application shall use the greater of the generic SSGA DII Alert and Warning Distances or the vehicle-specific SSGA DVI Alert and Warning Distances, as the basis for in-vehicle alerts.**		D
[7.02.02.23]	**SSGA Caution (Error) Message Definition**	**The SSGA DVI Caution (Error) Message shall contain a blank or generic caution and an indication that the system is not operational.**		D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.02.02.24]	**SSGA Vehicle Application Component Error**	**In the event of an input data error, a computational error or other non-recoverable SSGA Vehicle Application Component Error preventing issuing of SSGA DVI advisories, SSGA DVI alerts, or SSGA DVI warnings, or position and map accuracy requirements not being met, the SSGA Vehicle Application Component shall issue a SSGA Driver Message containing a SSGA DVI Caution (Error) to the Driver Warning System.**		D
7.02.03	**SSGA Vehicle Application Component Data Input Requirements**			
[7.02.03.01]	**SSGA I2V Wireless Message Content**	**The SSGA I2V Wireless Message shall contain the data required to perform the calculations specified under SSGA Vehicle Application Functional Requirements**	*Table (SSGA Wireless) SSGA I2V Wireless Message Data Description is referenced for guidance.*	D
[7.02.03.02]	**SSGA I2V Wireless Message Specification**	**The SSGA I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary**		I
[7.02.03.03]	**SSGA I2V Wireless Message Content Text**	**The SSGA I2V Wireless Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution (Error) text used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[7.02.03.04]	**SSGA I2V Wireless Message Graphics**	**The SSGA I2V Wireless Message shall contain SSGA DII Advisory, SSGA DII Alert, and SSGA DII Caution (Error) shapes and graphics used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[7.02.03.05]	**SSGA Vehicle Systems Message Content**	**The SSGA Vehicle Systems Message shall contain data required to perform the calculations specified under SSGA Vehicle Application Functional Requirements.**	*Table (SSGA Vehicle) SSGA Vehicle Systems Message Data Description is referenced for guidance.*	D

Table 3-5. SSGA Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[7.02.03.06]	**Vehicle Data Systems Message Specifications**	**The SSGA Vehicle Systems Message shall conform to the standards and guidelines specified by the vehicle Original Equipment Manufacturer.**	*Specific interfaces to the OEM vehicle systems will be dependent on specific information required to support the safety application. Examples of vehicle data communication system specifications include: ISO 14230-4, ISO 9141-2, SAE J1850 VPW, SAE J1850 PWM, ISO 15765, ISO 11898, and SAE J2178*	D
7.02.04	**SSGA Vehicle Application Component Data Output Requirements**			
[7.02.04.01]	**SSGA Driver Message Content**	**The SSGA Driver Message shall contain the SSGA DII Advisory, SSGA DII Alert, SSGA DII Caution, SSGA DVI Alert, SSGA DVI Warning, or SSGA DVI Caution content to be displayed on the Driver Warning Interface.**	*Table (SSGA Driver) SSGA Driver Message Data Description is referenced for guidance.*	D
[7.02.04.02]	**SSGA Driver Message Specifications**	**The following is referenced for guidance pertaining to SSGA Driver Message Specifications: Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., Bacon, L. P., … Morgan, J. F. (in press). Driver Vehicle Interface (DVI) Design Assistance for Advanced Technology Applications. (Final report to Virginia Tech Transportation Institute and National Highway Traffic Safety Administration). Seattle, WA: Battelle.**		D

Source: Battelle

APPENDIX A. SSGA Application Message Candidate Data Elements

Appendix A suggests candidate data elements which may be included in these messages to support the SSGA safety application algorithms. Table A-1 provides an explanation of the headers in candidate data tables. As noted in Table 3-3, Table A-2 through Table A-7 describe the candidate data elements for each of the messages. This information is provided for guidance when implementing the performance requirements specified in this document.

Table A-1. Explanation of Candidate Data Table Headers

Data Element Descriptor	Explanation	Example
Data Item Description	Name of obtainable measure or item,	Posted speed limit, number of lanes
Application	V2I Safety Application that the data element pertains to	RLVW, SSGA
Type of Data	Identifies a general classification of the data element	Location data, speed data
Static/ Dynamic	Distinguishes the frequency by which the data element is subject to changes	Static, Dynamic
Need	Identifies whether the data element is critical to the application function, versus those that can enhance it	Required, optional
Input Source	Identifies the component that supplies the data element	Vehicle Application Component, infrastructure data system
Output Recipient	Identifies the component that receives the data element	Vehicle Application Component, infrastructure application component
Unit of Measure (English)	Metric used to quantify the data element, English system of measurement	Feet, °F
Valid Range (English)	Span of values from minimum to maximum that are acceptable inputs, English system of measurement	5-20, (-30)-120
Accuracy/ Tolerance (English)	Degree of variance between actual and measured value that will be acceptable, English system of measurement	+/-5, +/-0.01
Unit of Measure (Metric)"	Metric used to quantify the data element, international system of measurement	Meter, °C
Valid Range (Metric)	Span of values from minimum to maximum that are acceptable inputs, international system of measurement	5-20, (-30)-120
Accuracy/Tolerance(Metric)"	Degree of variance between actual and measured value that will be acceptable, international system of measurement	+/-5, +/-0.01
Refresh Rate	Frequency that the data element is updated with a new external value	10 Hz, Annually
References	Source documents that contain supporting information	MUTCD
Notes	Supplemental explanation	Determined by MUTCD or Local Policy

Source: Battelle.

Table A-2. Description of Candidate Data Elements for the SSGA Infrastructure Data Systems Message

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Approaching Vehicle Data (Required)															
Target (#)	SSGA	Approaching Vehicle	Dynamic	Required	External Vehicle Detection System	Infra Application Component	Integer	1-15	NA	Integer	1-15	NA	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range	SSGA	Approaching Vehicle	Dynamic	Required	External Vehicle Detection System	Infra Application Component	ft	1-5000	+/- 2	m	0.3-1524	+/-0.6	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range Rate	SSGA	Approaching Vehicle	Dynamic	Required	External Vehicle Detection System	Infra Application Component	ft/s	1-200	+/- 1	m/s	0.3-61	0.3	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Local Spot Weather Data (optional)															
Air Temperature	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		Temperature may be measured locally or estimated from nearby sensors
Temperature tolerance (if estimated)	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	°F	(-30)-120	+/-5	°C	(-35)-49	+/-9	5 min		Temperature may be measured locally or estimated from nearby sensors
Current precipitation condition	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	1 min		Precipitation may be measured locally or estimated from nearby sensors
Precipitation tolerance (if estimated)	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	5 min		Precipitation may be measured locally or estimated from nearby sensors
Visibility	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Visibility tolerance	SSGA	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		

Table A-2. Description of Candidate Data Elements for the SSGA Infrastructure Data Systems Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Wind Speed	SSGA	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	mph	0-100	+/- 5	km/h	0-160	+/-9	1 min		
Precipitation rate	SSGA	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in./hr	0-20	+/- 0.5	cm/hr	0-51	+/-1.3	1 min		
Precipitation accumulation	SSGA	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	1 min		
Water depth	SSGA	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Snow depth	SSGA	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Local Weather Data Applicable Road Map Segments	SSGA	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Local Weather Data Applicable Date and Time - Begin	SSGA	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Weather Data Applicable Date and Time - End	SSGA	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Road Surface Data (optional)															
Road surface temperature	SSGA	Road Surface Condition	Dynamic	One required from group	Infra Data System – Road Surface	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	SSGA	Road Surface Condition	Dynamic	One required from group	Infra Data System – Road Surface	Infra Application Component	n/a	-	-	n/a	-	-	5 min		

Table A-2. Description of Candidate Data Elements for the SSGA Infrastructure Data Systems Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Road surface friction coefficient	SSGA	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road Condition Data Applicable Road Map Segments	SSGA	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time - Begin	SSGA	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Road Condition Data Applicable Date and Time - End	SSGA	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		

Source: Battelle

Table A-3. Description of Candidate Data Elements for the SSGA Roadside Signage Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
DII MUTCD Sign Number	SSGA	SSGA Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage System	Integer	TBD	NA	Integer	TBD	NA	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DII Graphic	SSGA	SSGA Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage System	TBD	TBD	NA	TBD	TBD	NA	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DII Text	SSGA	SSGA Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage System	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	1 Hz		Max 3 Lines, 20 Characters each is typical for Roadside Dynamic Message Signs
DII Advisory Valid Time	SSGA	SSGA Roadside Signage Data	Dynamic	Required	Infra Application Component	Roadside Signage System	min	0.01-1440	+/- 0.01	min	0.01-1440	+/- 0.01	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications

Source: Battelle

Table A-4. Description of Candidate Data Elements for the SSGA Infrastructure Map Message and SSGA Wireless Map Message

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
SSGA Intersection Data															
Width of median	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	0.01-500	+/- 2	m	0.003-152	+/-0.6	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Number of lanes	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	n/a	1-10	+/- 0	n/a	1-10	+/- 0	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Number of left turn lanes	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	n/a	1-3	+/- 0	n/a	1-3	+/- 0	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Number of right turn lanes	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	n/a	1-2	+/- 0	n/a	1-2	+/- 0	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Width of intersection	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	10-500	+/- 2	m	3-152	+/-0.6	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Latitude of intersection corner 1	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Longitude of intersection corner 1	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Latitude of intersection corner 2	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Longitude of intersection corner 2	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.

Table A-4. Description of Candidate Data Elements for the SSGA Infrastructure Map Message and SSGA Wireless Map Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Latitude of intersection corner 3	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Longitude of intersection corner 3	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Latitude of intersection corner 4	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Longitude of intersection corner 4	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
SSGA Roadside Signage Data															
DII MUTCD Sign Number Options	SSGA	SSGA Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	Infra Application Component	Integer	NA	NA	Integer	NA	NA	1 Hz		Determined by MUTCD and Local Policy
DII Message Graphic Options	SSGA	SSGA Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 Hz		Determined by MUTCD and Local Policy
DII Message Text Options	SSGA	SSGA Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	Infra Application Component	Latin Alphabet	A-Z	NA	Latin Alphabet	A-Z	NA	1 Hz		Max 3 Lines, 20 Char each
Latitude of Sign 1	SSGA	SSGA Roadside Signage Data	Static	Optional, if Wireless Map provided	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Longitude of Sign 1	SSGA	SSGA Roadside Signage Data	Static	Optional, if Wireless Map provided	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.

Table A-4. Description of Candidate Data Elements for the SSGA Infrastructure Map Message and SSGA Wireless Map Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Latitude of Sign 2	SSGA	SSGA Roadside Signage Data	Static	Optional, if Wireless Map provided	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Longitude of Sign 2	SSGA	SSGA Roadside Signage Data	Static	Optional, if Wireless Map provided	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Latitude of Sign 3	SSGA	SSGA Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Longitude of Sign 3	SSGA	SSGA Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Latitude of Sign 4	SSGA	SSGA Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
Longitude of Sign 4	SSGA	SSGA Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction		Static Data may be loaded through an externally generated data file.
SSGA Intersection Data															
Offset of Stop Bar on Approach 1 from corner	SSGA	SSGA Intersection Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	0-100	+/- 2	m	0-30	+/- 0.6	Reconstruction, Repaving, or Restriping		
Offset of Stop Bar on Approach 2 from corner	SSGA	SSGA Intersection Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	ft	0-100	+/- 2	m	0-30	+/- 0.6	Reconstruction, Repaving, or Restriping		
Offset of Median Stop Bar on Approach 1 from corner	SSGA	SSGA Intersection Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	ft	0-100	+/- 2	m	0-30	+/- 0.6	Reconstruction, Repaving, or Restriping		

Table A-4. Description of Candidate Data Elements for the SSGA Infrastructure Map Message and SSGA Wireless Map Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Offset of Median Stop Bar on Approach 2 from corner	SSGA	SSGA Intersection Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	ft	0-100	+/- 2	m	0-30	+/- 0.6	Reconstruction, Repaving, or Restriping		

Source: Battelle

Table A-5. Description of Candidate Data Elements for the SSGA I2V Wireless Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
SSGA Operational Data															
SSGA Applicable Date and Time – Begin	SSGA	SSGA Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
SSGA Applicable Date and Time – End	SSGA	SSGA Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
SSGA Applicable Road Map Segments	SSGA	SSGA Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Data format is based upon segments in SSGA Road Map
Minor Road Approaching Vehicle Data (required)															
Target (#)	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	Integer	1-15	NA	Integer	1-15	NA	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft	1-5000	+/- 2	m	0.3-1524	+/-0.6	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range Rate	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft/s	1-200	+/- 1	m/s	0.3-61	0.3	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems

Table A-5. Description of Candidate Data Elements for the SSGA I2V Wireless Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Major Road Right Approaching Vehicle Data (required)															
Target (#)	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	Integer	1-15	NA	Integer	1-15	NA	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft	1-5000	+/- 2	m	0.3-1524	+/-0.6	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range Rate	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft/s	1-200	+/- 1	m/s	0.3-61	0.3	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Major Road Right Approaching Vehicle Data (required)															
Target (#)	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	Integer	1-15	NA	Integer	1-15	NA	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft	1-5000	+/- 2	m	0.3-1524	+/-0.6	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems

Table A-5. Description of Candidate Data Elements for the SSGA I2V Wireless Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Target (#) Range Rate	SSGA	Approaching Vehicle	Dynamic	Required	Infra Application Component	Vehicle Application Component	ft/s	1-200	+/- 1	m/s	0.3-61	0.3	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Local Spot Weather Data (Optional)															
Air Temperature	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		Temperature may be measured locally or estimated from nearby sensors
Temperature tolerance (if estimated)	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	°F	(-30)-120	+/-5	°C	(-35)-49	+/-9	5 min		Temperature may be measured locally or estimated from nearby sensors
Current precipitation condition	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	n/a	-	-	n/a	-	-	1 min		Precipitation may be measured locally or estimated from nearby sensors
Precipitation tolerance (if estimated)	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	n/a	-	-	n/a	-	-	5 min		Precipitation may be measured locally or estimated from nearby sensors
Visibility	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Visibility tolerance	SSGA	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Wind Speed	SSGA	Local Weather Data	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	mph	0-100	+/- 5	km/h	0-160	+/-9	1 min		
Precipitation rate	SSGA	Local Weather Data	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	in./hr	0-20	+/- 0.5	cm/hr	0-51	+/-1.3	1 min		
Precipitation accumulation	SSGA	Local Weather Data	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	1 min		

Table A-5. Description of Candidate Data Elements for the SSGA I2V Wireless Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Water depth	SSGA	Local Weather Data	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Snow depth	SSGA	Local Weather Data	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Local Weather Data Applicable Road Map Segments	SSGA	Local Weather Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Local Weather Data Applicable Date and Time – Begin	SSGA	Local Weather Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Weather Data Applicable Date and Time – End	SSGA	Local Weather Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Road Surface Data (optional)															
Road surface temperature	SSGA	Road Surface Condition	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	SSGA	Road Surface Condition	Dynamic	One required from group	Infra Application Component	Vehicle Application Component	n/a	-	-	n/a	-	-	5 min		
Road surface friction coefficient	SSGA	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road Condition Data Applicable Road Map Segments	SSGA	Road Surface Condition	Dynamic	Required	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time – Begin	SSGA	Road Surface Condition	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Road Condition Data Applicable Date and Time – End	SSGA	Road Surface Condition	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		

Source: Battelle

Table A-6. Description of Candidate Data Elements for the SSGA Vehicle Systems Message Data Descriptions

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Vehicle Characteristics															
Vehicle mass	SSGA	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	lb.	100-100000	+/- 25	kg	45-45360	+/- 11.3	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle length	SSGA	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft	0-200	+/- 2	m	0-61	+/-0.6	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle CG Height	SSGA	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	in	0-300	+/- 2	cm	0-7620	+/- 50.8	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Average Deceleration Rate	SSGA	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-32.2	+/- 1	m/s^2	0-9.81	+/- 0.304	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Maximum Deceleration Rate	SSGA	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-32.2	+/- 1	m/s^2	0-9.81	+/- 0.304	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle Functional Status															
Vehicle Speed Current	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	mph	0-120	+/- 2	km/h	0-194	+/-3.2	10 Hz		
Vehicle acceleration Current	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-50	+/- 2	m/s^2	0-15	+/-0.6	10 Hz		
Brake activation	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Steering wheel angle	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	degrees	(-70)-70	+/- 2	degrees	(-70)-70	+/- 2	10 Hz		
Vehicle traction	SSGA	Vehicle	Dynamic	Optional	Vehicle Data	Vehicle	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		

Table A-6. Description of Candidate Data Elements for the SSGA Vehicle Systems Message Data Descriptions (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
control activation		Functional Status			Systems	Application Component									
Antilock brake system activation	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Electronic stability control activation	SSGA	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Vehicle Environmental Data															
Temperature (Air)	SSGA	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 Hz		Potential for Ice
Rain Sensor Status	SSGA	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4	n/a	n/a	0,1,2,3,4	n/a	n/a	1 Hz		Potential for Slippery Roads/Low Visibility
Windshield Wiper Status	SSGA	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4	n/a	n/a	0,1,2,3,4	n/a	n/a	1 Hz		Potential for Slippery Roads/Low Visibility
Headlight Status	SSGA	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4	n/a	n/a	0,1,2,3,4	n/a	n/a	1 Hz		Potential for Low Visibility

Source: Battelle

Table A-7. Description of Candidate Data Elements for the SSGA Driver Warning Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
DVI MUTCD Sign Number	SSGA	SSGA Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	Integer	TBD	NA	Integer	TBD	NA	10 Hz		Determined by MUTCD, Local Policy, and Driver Warning System manufacturer specifications
DVI Graphic	SSGA	SSGA Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	TBD	TBD	NA	TBD	TBD	NA	10 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DVI Text	SSGA	SSGA Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	10 Hz		Determined by Roadside Signage System manufacturer specifications
DVI Message Valid Time	SSGA	SSGA Driver Warning Message Data	Dynamic	Required	Vehicle Application Component	Driver Warning System	min	0.01 to 1440	+/- 0.01	min	0.01 to 1440	+/- 0.01	10 Hz		Determined by Roadside Signage System manufacturer specifications
DVI Message Priority	SSGA	SSGA Driver Warning Message Data	Dynamic	Required	Vehicle Application Component	Driver Warning System	Integer	TBD	NA	Integer	TBD	NA	10 Hz		Determined by Roadside Signage System manufacturer specifications

Source: Battelle

APPENDIX B. Acronyms and Abbreviations

AAHSTO	American Associated of State Highway and Transportation Officials
CAN	Controller Area Network
CUCAS-SSA	Cooperative Intersection Collision Avoidance System – Stop Sign Assist
ConOps	Concept of Operations
CSW	Curve Speed Warning
DII	Driver-Infrastructure Interface
DMS	Dynamic Message Signs
DoCAN	Diagnostic Communication Over Controller Area Network
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
GNSS	Global Navigation Satellite Systems
ICWS	Intersection Conflict Warning Systems
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
OEMs	Original Equipment Manufacturers
RLVW	Red Light Violation Warning
RSZW/LC	Reduced Speed Zone Warning with Lane Closure
RTCM	Radio Technical Commission for Maritime Services
RWIS	Road-Weather Information System
SAE	Society of Automotive Engineers
SOI	System-of-Interest
SSGA	Stop Sign Gap Assist

SWIW-D	Spot Weather Information Warning – Diversion
SWIW-RS	Spot Weather Information Warning – Reduced Speed
TBD	To Be Determined
TMDD	Traffic Management Data Dictionary
TRB	Transportation Research Board
TSS	Transportation Sensor Systems
U.S. DOT	United States Department of Transportation
UTC	Universal Time, Coordinated
V2I	Vehicle-to-Infrastructure

APPENDIX C. Terms and Definitions

Advisory Message – An informative message to the driver regarding current roadway conditions; less urgent, i.e., not necessarily crash-imminent, than an alert or warning.

Alert – A cautionary message about an anticipated crash scenario and/or vehicle conflict; more urgent than an advisory message, less urgent than a warning.

Connected Vehicle – In the context of this document, refers to the methods, data and technologies used in the bi-directional exchange of information between infrastructure and vehicles for purposes of improving safety, mobility and environmental conditions.

Degraded – Mode of the safety application where it is capable of providing a subset of its intended function(s).

Failure – Mode of the safety application where the safety application is incapable of providing any of its intended function(s).

False Alarm – Situation where the safety application provides an alert/warning to the driver when the conditions to not warrant an alert/warning.

Functional Class of Roadway – The functional class of roadways are defined in FHWA "Functional Classification Guidelines". Revised 1989.

Missed Alarm – Situation where the safety application does not provide an alert/warning to a driver when the conditions warrant an alert/warning.

Non-volatile Storage – Type of storage that remains intact even when there is no power.

Offline – State of the safety application where the safety application is not processing data or providing advisories, alerts and/or warnings.

Online – State of the safety application where the safety application is functioning and providing advisories, alerts and/or warnings.

Operational – Mode of the safety application where the safety application is capable of providing all of its intended function(s).

Perform – To work in a manner to achieve the desired outcome.

Physical Security – Describes measures that are designed to deny access to unauthorized personnel (including attackers or even accidental intruders) from physically accessing a building, facility, resource, or stored information; and guidance on how to design structures to resist potentially hostile acts.[2] Physical security can be as simple as a locked door on a roadside cabinet.

Prohibitive Reference Frame – Indicates when *unsafe* conditions are present, as opposed to "safe" conditions; "unsafe" is much easier to quantify than "safe," indicates the requirement that users also apply their own judgment, and can lessen liability issues as compared to indicating a more definitive 'permissive' notification of when conditions are "safe".

[2] Task Committee; Structural Engineering Institute (1999). *Structural Design for Physical Security*. ASCE. ISBN 978-0-7844-0457-7.

Roadside Configuration Data – Data provided from the infrastructure data equipment or back office that details the lane(s), roadway geometry, and/or map of the area needed by a safety application

Road Weather Information – Data on road and weather conditions that may impact vehicle safety including visibility, wind speed, precipitation, air and road surface temperature, road surface condition, etc.

Roadway Work Zone Configuration Information – Data on work zone configuration elements that may impact vehicle safety including lane shifts, lane reductions, etc.

Roadway Work Zone Operations Information – Data on work zone operational elements that may impact vehicle safety including buffer zones, traffic control setup, temporary pavement markings, temporary traffic barriers, road closures, changed lighting conditions (during night work),etc.

Threshold – A point in both time and/or location, depending on the specific application, that the application would reach a decision point resulting in an action being taken. This action would typically be expected to include alerts and/or warnings issued to the driver, but could also include additional actions.

Vehicle Type – Identification of vehicle role (e.g., ambulance, police cruiser, maintenance vehicle, etc.) as specific class of vehicle satisfies in the surface transportation system. A specific, standardized nomenclature does not exist.

Vehicle Class – One of 13 FHWA designations of motorized vehicles ranging in size from a Class 1 Motorcycle through a Class 13 – Seven or more axle truck.[3]

Vehicle Telematics Data – Data made available from vehicle electronic systems that could be utilized by the connected vehicle in-vehicle application. Examples include vehicle operating speed; operational status of windshield wipers, headlights, etc.; driver application of brakes or accelerator; etc.

Warning – An urgent message for a more immediate, potentially crash imminent scenario and/or vehicle conflict; more urgent than both an advisory message and alert.

[3] Traffic Monitoring Guide, U.S. DOT, May 2001, http://www.fhwa.dot.gov/ohim/tmguide/tmg4.htm#app4c

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
www.its.dot.gov

FHWA-JPO-16-254

U.S. Department of Transportation