Prototype Development and Demonstration for Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.)

R.E.S.C.U.M.E. Prototype System Design Document

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16. Abstract

This report documents the System Design Document (SDD) for the prototype development and demonstration of the Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) application bundle, with a focus on the Incident Zone (INC-ZONE) and Response Staging (RESP-STG) applications. These two applications together comprise a tightly integrated bundle that is a key research and development effort within the Dynamic Mobility Applications (DMA) portion of the Connected Vehicle Program.

This SDD is a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the R.E.S.C.U.M.E. stakeholders.

This document provides a representation of the R.E.S.C.U.M.E. software system created to facilitate analysis, planning, implementation, and decision making. It is a blueprint or model of the R.E.S.C.U.M.E. software, communications, and to some extent, the hardware systems. The SDD is used as the primary medium for communicating design information.

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Executive Summary

This report documents the System Design Document (SDD) for two prototype Connected Vehicle (CV) applications for Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) under the U.S. Department of Transportation (U.S. DOT) Dynamic Mobility Applications (DMA) Program. The R.E.S.C.U.M.E. project incorporates prototype development and demonstration of Response Staging (RESP-STG) and Incident Zone (INC-ZONE) applications using integrated technologies that mutually support each other and comprise an integrated R.E.S.C.U.M.E. bundle that is a key research activity within the DMA program.

The RESP-STG application provides situational awareness to and coordination among emergency responders—upon dispatch and while en-route— to establish incident scene work zones both upon initial arrival and staging of assets, and afterward, if circumstances require, additional dispatch and staging. It provides valuable input to responder and dispatcher decisions and actions. A range of data will be provided through mobile devices and other types of communication to help support emergency responder vehicle routing, staging, and secondary dispatch decision-making.

The INC-ZONE application improves protection of personnel at incident sites from the threat of oncoming vehicles, particularly where those vehicles are being operated outside of recommended speed, and lane guidance where there have been crashes, incidents, or other events impacting traffic such as stalled vehicles or vehicles pulled over for moving violations. The INC-ZONE application includes an in-vehicle messaging system that provides oncoming drivers with merging and speed guidance around an incident. The INC-ZONE application also provides in-vehicle alerts and warnings to drivers in violation of speed and lane closure restrictions, both for the protection of the drivers and incident zone personnel. Finally, the INC-ZONE application includes a warning system for on-scene workers when a vehicle approaching or in the incident zone is being operated outside of safe parameters for the conditions.

Specific hardware and software components required for oncoming vehicles and responder vehicles have been identified for both the INC-ZONE and RESP-STG applications. This document presents a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the R.E.S.C.U.M.E. stakeholders. A representation of the R.E.S.C.U.M.E. prototype software system has been created to facilitate analysis, planning, implementation, and decision making. A blueprint or model of the R.E.S.C.U.M.E. software, communications, and to some extent, the hardware systems are presented. The structure of the hardware and software system has been structured to satisfy the requirements identified in the R.E.S.C.U.M.E. requirements specification. It is a translation of requirements into a description of the structure and behavior of the system, the hardware and software components, the interfaces, and the data necessary for implementing the software solution. Threat determination thresholds for the issuance of advisory, alert, and warning messages to oncoming drivers about the incident zone are presented for the INC-ZONE applications, as well as corresponding messages to responders.

Chapter 1 Introduction

Through the Dynamic Mobility Applications (DMA) Program, U.S. DOT desires to improve current operational practices and transform management of future surface transportation systems. The DMA program is designed to enhance deployment of the technologies and applications that emerge and promote collaboration in research and development (R&D) of the transformative mobility applications that emerge from the process. The DMA Program's current phase involves application prototype development and testing and coordinated research activities on a portfolio of selected high-priority mobility applications. Development of the Response, Emergency Staging, Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) System Design is informed by prior research in the Connected Vehicle (CV) Program and other Intelligent Transportation Systems (ITS) programs, as well as the development of this and other concurrent applications from other DMA projects.

The R.E.S.C.U.M.E. application bundle concept incorporates vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), infrastructure-to-vehicle (I2V), and center-to-center communications (referred to collectively as V2X). The automated V2X communications are predicated on Dedicated Short-Range Communications (DSRC) capabilities and associated infrastructure, but communications are not constrained to DSRC. For example, emergency responders will communicate via Mobile Data Terminals (MDTs) over a cellular connection, in addition to their existing radios , while operations centers will communicate with each other largely through secure telecommunications networks.

The R.E.S.C.U.M.E. project incorporates prototype development and demonstration of Response Staging (RESP-STG) and Incident Zone (INC-ZONE) using integrated technologies that mutually support each other within the R.E.S.C.U.M.E. application bundle. This report documents the System Design Document (SDD) for both prototype applications. These two applications together comprise an integrated bundle that is a key research activity within the DMA program.

This SDD is a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the R.E.S.C.U.M.E. stakeholders.

This document provides a representation of the R.E.S.C.U.M.E. prototype software system created to facilitate analysis, planning, implementation, and decision making. It is a blueprint or model of the R.E.S.C.U.M.E. software, communications, and to some extent, the hardware systems. The SDD is used as the primary medium for communicating design information.

The SDD illustrates how the hardware and software system will be structured to satisfy the requirements identified in the R.E.S.C.U.M.E. requirements specification. It is a translation of requirements into a description of the structure and behavior of the system, the hardware and software components, the interfaces, and the data necessary for implementing the software solution.

The overall approach to this SDD is based on the guidance described in IEEE Std 1016-2009, the *IEEE Standard for Information Technology – Systems Design – Software Design Description*.

Chapter 2 presents a high-level description of the R.E.S.C.U.M.E. application bundle, focusing on the inputs and output messages of the INC-ZONE and RESP-STG applications. Chapter 3 presents a description of the system components, specifically the responder vehicle, oncoming vehicle, and Internet-hosted services. Chapter 4 through Chapter 7 describe the details of the INC-ZONE application, and Chapter 8 and Chapter 9 describe the details of the RESP-STG application.

Chapter 2 R.E.S.C.U.M.E. Application Bundle Descriptions

There are two primary capabilities of the R.E.S.C.U.M.E. system that are included in the prototype development and demonstration: Response Staging (RESP-STG) and Incident Zone (INC-ZONE) management. Detailed descriptions of both can be found in the R.E.S.C.U.M.E. *Concept Development and Needs Identification* and the *Report on Detailed Requirements for the R.E.S.C.U.M.E. Prototype* documents. Below are brief summaries of each application.

INC-ZONE Application Description

The INC-ZONE application is a communication approach that improves protection of personnel at incident sites from the threat of oncoming vehicles, particularly where those vehicles are being operated outside of recommended speed, and lane guidance where there have been crashes, incidents, or other events impacting traffic such as stalled vehicles or vehicles pulled over for moving violations.

The INC-ZONE application features an in-vehicle messaging system that provides oncoming drivers with merging and speed guidance around an incident. The INC-ZONE application also provides in-vehicle alerts and warnings to oncoming drivers in violation of speed and lane closure restrictions, both for the protection of the drivers and incident zone personnel. Finally, the INC-ZONE application includes a warning system for on-scene workers when a vehicle approaching or in the incident zone is being operated outside of safe parameters for the conditions.

Although there are similarities such as the possible need for lane closures, incident zones and construction work zones are fundamentally different in nature. Specifically, a construction work zone is typically pre-planned and usually involves only a single agency (or at most a few agencies), while an incident zone is unplanned and frequently involves inter-agency responses. Incident zones are the focus of INC-ZONE.

Persons found in an incident zone could include crash victims, law enforcement, Emergency Medical Services (EMS), Fire and Rescue, HAZMAT Response, Towing and Recovery, and roadway/infrastructure repair workers.

Description of Inputs

Incident details are first entered by the scene commander using CapWIN at the scene of the incident, including lane closure restrictions, which may be changed as the incident zone evolves. These details are used to establish a pre-defined safety zone, or buffer zone, around the incident zone and pre-determined threshold inputs for issuing advisory, alert, and warning messages to oncoming vehicles.

The Oncoming Vehicle Application Component uses a number of inputs for determining the issuance of advisory, alert, and warning messages. The oncoming vehicle receives a number of inputs regarding its current operating status from vehicle data systems. An exchange of information must also occur between the responder vehicle, which defines an incident zone, and an oncoming vehicle which enters the incident zone for a threat determination to be made. Many inputs come from DSRC messages sent from responder vehicles located within the incident zone. The responder vehicle broadcasts an incident map to all oncoming vehicles to distribute the threat calculation required to each oncoming vehicle. This map includes speed and lane closure restrictions for the incident zone and adjacent roadway.

Specifically, the Traveler Information Message (TIM), which contains the incident zone location and map data and advised or posted speed for the incident zone, is used for messages related to speed restrictions and lane closures. The Emergency Vehicle Alert (EVA) message provides the location of the nearest responder vehicle to oncoming vehicles using global positioning system (GPS) in its Arada radio, and is used for the determination of collision warning messages. These two messages are broadcast from responder vehicles to oncoming vehicles for calculating the threat determination and issuing appropriate advisory, alert, and warning messages to oncoming drivers.

Threats to responders in the incident zone are issued by the threatening oncoming vehicle itself, based on the description of the incident zone and the location of the responder vehicles in the incident zone, as well as vehicle operating characteristics and positioning data of the oncoming vehicle itself. The oncoming vehicle sends a terse A la Carte Message (ACM) message to the responder vehicle with the result of the threat determination calculation. This eliminates the need to communicate the content of a Basic Safety Message (BSM) to the responder vehicle for this application.

The Responder Vehicle Application Component takes incident descriptions entered in CapWIN, in particular lane closure data as well as the location of the incident, and merges that data with its own responder vehicle-based sensor data to compile and issue TIM and EVA messages via DSRC to oncoming vehicles. The Responder Vehicle Application Component issues alert and warning messages to the responder's Personal Alerting Safety Subsystem (PASS) based primarily on the Oncoming Vehicle ACM Threat Messages that are sent via DSRC from individual oncoming vehicles. Each of these threat messages indicate an oncoming vehicle's threat status based on the messages being issued via the driver-vehicle interface (DVI) to the driver of the oncoming vehicle.

Description of Threat Determination

The Oncoming Vehicle Application Component uses the inputs described above to determine what message should be issued to the driver and when. This determination is based on the oncoming vehicle speed and location relative to the incident zone, responder vehicles within the incident zone, and the safety zone or buffer zone around and prior to the incident zone where reduced speeds and lane closures apply. The relative locations or distances prior to the incident zone and safety zone are primarily based upon guidance and standards within the Manual of Uniform Traffic Control Devices (MUTCD), as well as the content of the messages. Although used for roadside signage, this guidance is applicable for advanced placement distances for issuing messages to oncoming drivers and includes the consideration of deceleration rates, perception-reaction time, speeds, incident zone buffer space, and visibility distances.

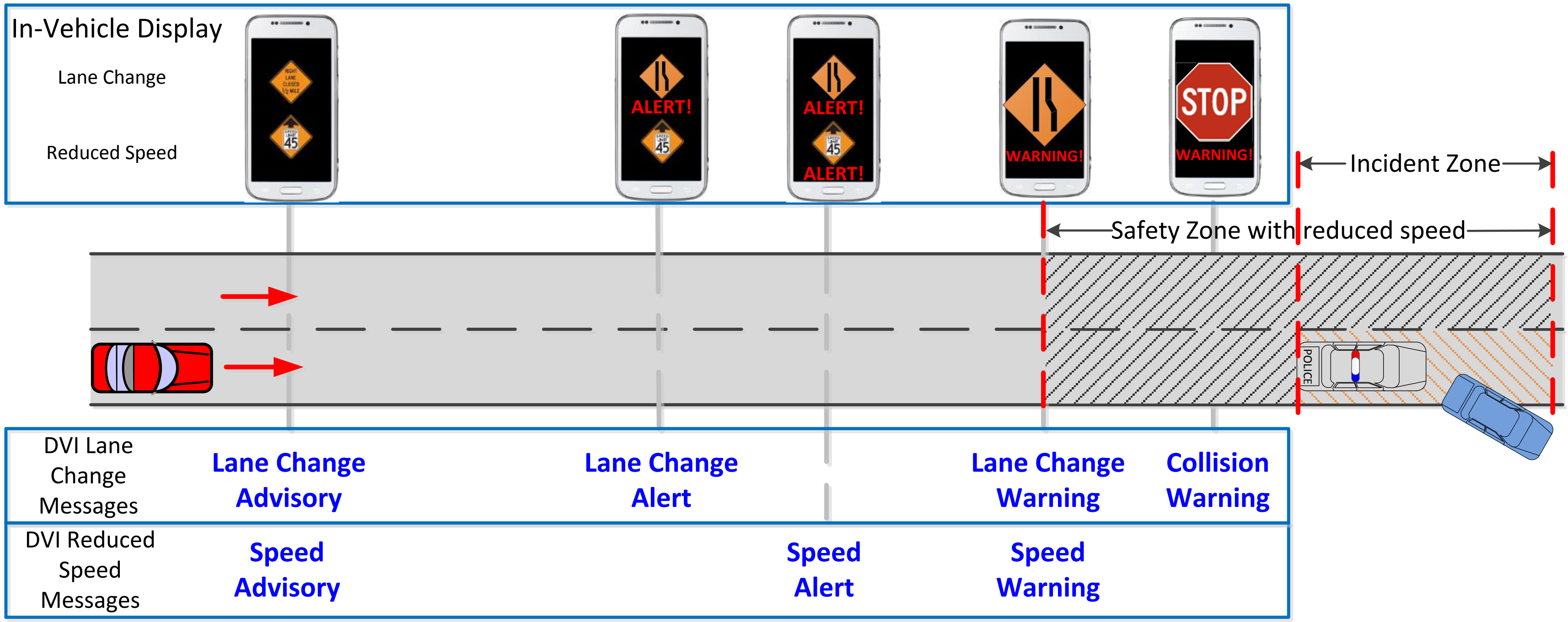
Description of the Oncoming Vehicle Alerts and Warnings

The INC-ZONE application issues various in-vehicle messages to the driver of an oncoming vehicle via the DVI, as shown in Figure 2-1. The application issues advisories and alerts to notify drivers in time for them to slow to the advisory or posted speed prior to the safety zone, and advisories and warnings to maintain a speed at or below that advisory or posted speed within the safety zone. The application also issues vehicle-specific, in-vehicle advisory, alert, and warning messages of upcoming shoulder or lane closures within the incident zone. Messages regarding the need for oncoming vehicles to reduce speed and change lanes will be displayed simultaneously. If the oncoming vehicle continues to approach the incident zone in a closed lane, an imminent collision warning is issued based on proximity to the “nearest” responder vehicle within the incident zone.

Additional details on threat determination for issuing in-vehicle alerts and warnings to drivers of oncoming vehicles can be found in Chapter 7.

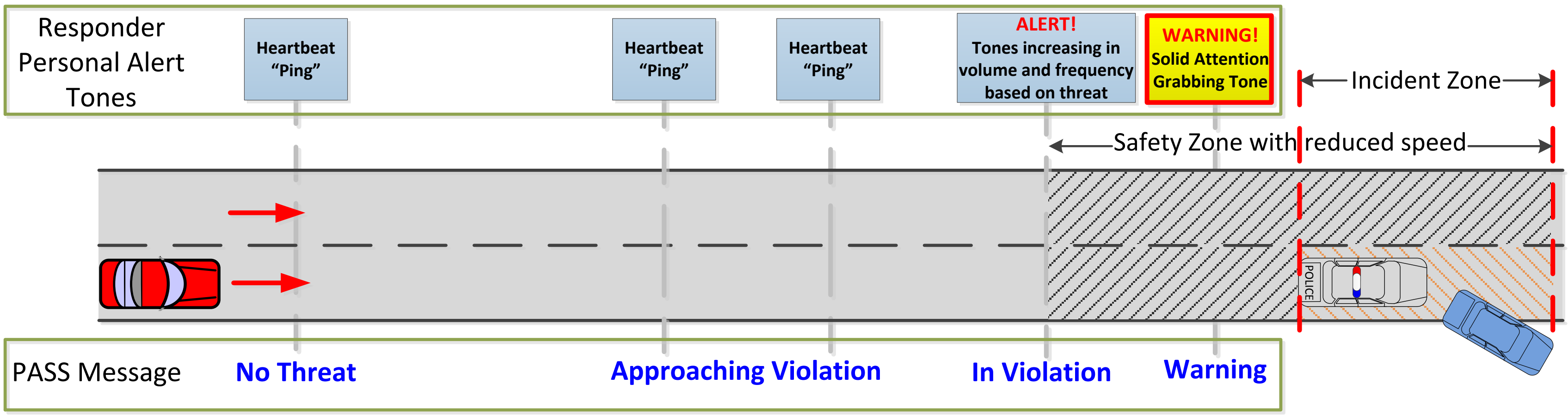
Description of the Responder Alerts and Warnings

The INC-ZONE application issues a series of escalating threat messages to on-scene workers in the incident zone regarding risks posed by oncoming vehicle speed or lane violations, as illustrated in Figure 2-2. Oncoming vehicles send messages via DSRC to the responder vehicle regarding their threat level, thereby triggering the issuance of an appropriate message from the responder vehicle to the on-scene responders’ personal alert safety system. The escalating threat message set is based on when oncoming vehicles are approaching a speed or lane violation, in violation of established speed or lane closures within the established safety zone, and a collision-imminent direct threat warning.



Source: Battelle

Figure 2-1. Illustration of the Issuance of In-Vehicle Advisory, Alert, and Warning Messages



Source: Battelle

Figure 2-2. Illustration of the Issuance of Responder PASS Advisory, Alert, and Warning Messages

Additional information on threat determination for issuing alerts and warnings to responders can be found in Chapter 7.

RESP-STG Application Description

The RESP-STG application provides situational awareness to and coordination among emergency responders—upon dispatch and while en-route— to establish incident scene work zones both upon initial arrival and staging of assets, and afterward, if circumstances require, additional dispatch and staging. It provides valuable input to responder and dispatcher decisions and actions. A range of data will be provided through mobile devices and other types of communication to help support emergency responder vehicle routing, staging, and secondary dispatch decision-making.

Improving situational awareness to public safety responders while they are en-route can help establish incident scene work zones that are safe for responders, travelers and crash victims while being less disruptive to traffic. Situational awareness information can also provide valuable input to responder and dispatcher decisions and actions.

Description of Inputs

There is a range of data that will be provided through mobile devices and other types of communications to help support emergency responder vehicle routing, staging, and secondary dispatch decision-making. These data will include staging plans, satellite imagery, GIS map graphics, camera images, current weather data, and traffic conditions. Incident details are entered by the scene commander using CapWIN at the scene of the incident, including details regarding speed and lane closure restrictions, which may be changed as the incident zone evolves.

Description of Functions

The RESP-STG application is a collection of integrated functions designed to minimize the adverse effects on mobility and safety caused by an incident affecting the roadways. This is achieved by increasing the preparedness and situational awareness of the emergency responders upon dispatch and while en-route to an incident scene. Awareness of this information in advance enables critical, time-saving, and potentially life-saving decisions to be made prior to arrival on scene. These decisions in turn enable the responders to clear the incidents sooner and to enhance the incident staging to facilitate mobility.

Vehicle and Equipment Staging

The Vehicle and Equipment Staging function supplies the en-route responders with additional information they can use to determine where to stage personnel and equipment prior to their arrival on-scene. This function is responsible for accessing a database of still photographs, satellite imagery, GIS overlays, video feeds, and modeling programs (e.g., predicted HAZMAT plumes) to provide a visual representation of the scene to facilitate the staging of equipment. Additional components such as the current traffic conditions and existing vehicles already on-scene are also critical components integrated into the situational awareness picture developed and provided by the Vehicle and Equipment Staging function.

This function receives information from a variety of sources, routed through the Communications function, and uses that information together with on-board databases and Internet-accessible sources to develop a multi-layered spatial representation of the incident. The arriving responder's approach and likely staging will be projected onto the incident as an additional layer.

Emergency Responder Status Reporting

This function continuously monitors the location of the en-route responder vehicles as well as the vehicles already on-scene (via the INC-ZONE and/or Information Broker). The function develops and maintains the current position of the responder's vehicles. Other information such as traffic encountered, speed, heading, and route to destination are also captured and processed by this function. This function does not report the type of vehicle, e.g., fire truck, tow truck, etc. This information is forwarded to the INC-ZONE and Information Broker via the Communications function.

Chapter 3 System Description

The R.E.S.C.U.M.E. system architecture is described in the *R.E.S.C.U.M.E. Architecture Description Document* (ADD). High-level details are repeated here for readability. For more detailed architecture information please consult the ADD.

System Architecture

Figure 3-1 illustrates the physical components of the R.E.S.C.U.M.E. Application Bundle for the prototype RESP-STG and INC-ZONE applications. Within the responder vehicle, the responder will interact with the RESP-STG application via an interface on the ruggedized laptop. The oncoming driver will interact with the INC-ZONE application via a smartphone device. When the responder is outside the vehicle, the INC-ZONE application will use the responder's personal radio to send audible alarms to the responder to warn of threatening situations.

Responder Vehicle Components

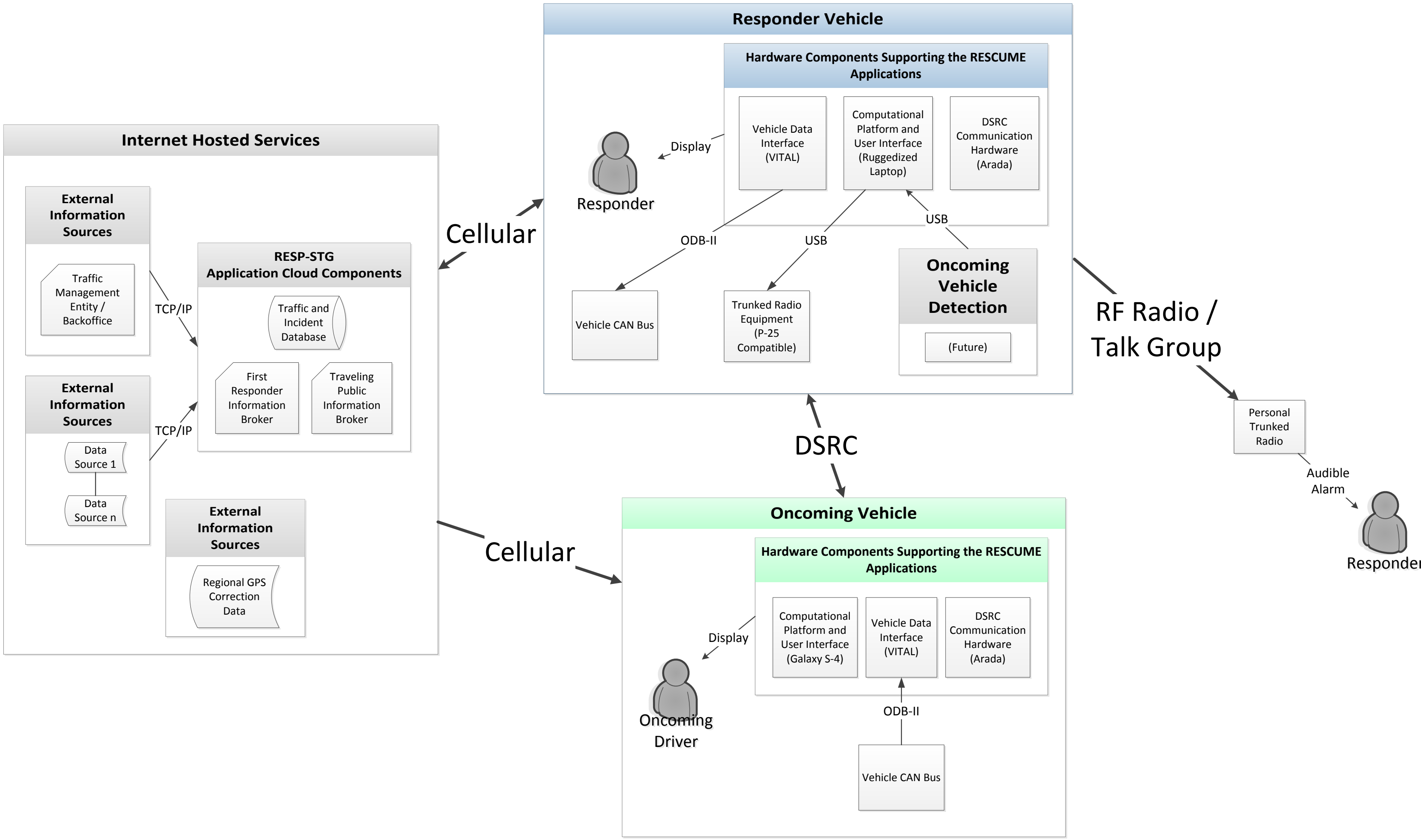
The responder vehicle will provide a cellular interface, DSRC communication hardware, a computational platform, a vehicle data interface, and a responder user interface. The Computational Platform in R.E.S.C.U.M.E. will be the ruggedized laptop. The vehicle data interface, Vehicle Initiated Telematics and Logging (VITAL), will connect to the responder vehicle CAN Bus (i.e., the specialized internal communications network that interconnects components inside the responder vehicle) via Bluetooth to obtain vehicle data that are used in the R.E.S.C.U.M.E. applications. The DSRC Communication Hardware for the R.E.S.C.U.M.E. applications will be the Arada Systems radio. The interface used by responders to input information in support of the RESP-STG application will also reside on the ruggedized laptop. Although not part of this prototype development activity, which focuses only on connected vehicles, radar-based oncoming vehicle detection will extend the coverage of the INC-ZONE application to unequipped oncoming vehicles.

Oncoming Vehicle Components

The oncoming vehicle will provide a cellular user interface, a computational platform, and a vehicle data interface. The cellular user interface, also known as a driver vehicle interface or DVI, for oncoming vehicles will be a Samsung Galaxy S4 smartphone, which conveys advisory, alert, and warning messages to the drivers of oncoming vehicles. The oncoming vehicle data interface, VITAL, will connect to the oncoming vehicle CAN Bus via Bluetooth to obtain vehicle data that is used in the R.E.S.C.U.M.E. applications for determination of issuing messages. The DSRC Communication Hardware component for the R.E.S.C.U.M.E. applications will be an Arada Systems radio.

Internet Hosted Services

Internet hosted services will also be used by the R.E.S.C.U.M.E. applications, and will communicate to the responding and oncoming vehicles via cellular communications. A variety of data and interfaces originate from this group, including external information sources and data sources internal to the CapWIN system utilized by the RESP-STG application. This will include the emergency responder back office, local traffic management center, detailed map information of the affected road segments, local policy regarding speed reduction guidance, and vehicle position corrections.



Source: Battelle

Figure 3-1. R.E.S.C.U.M.E. Physical Diagram

Chapter 4 INC-ZONE Hardware Components

This section identifies the physical components that will support the INC-ZONE application within the R.E.S.C.U.M.E. prototype system.

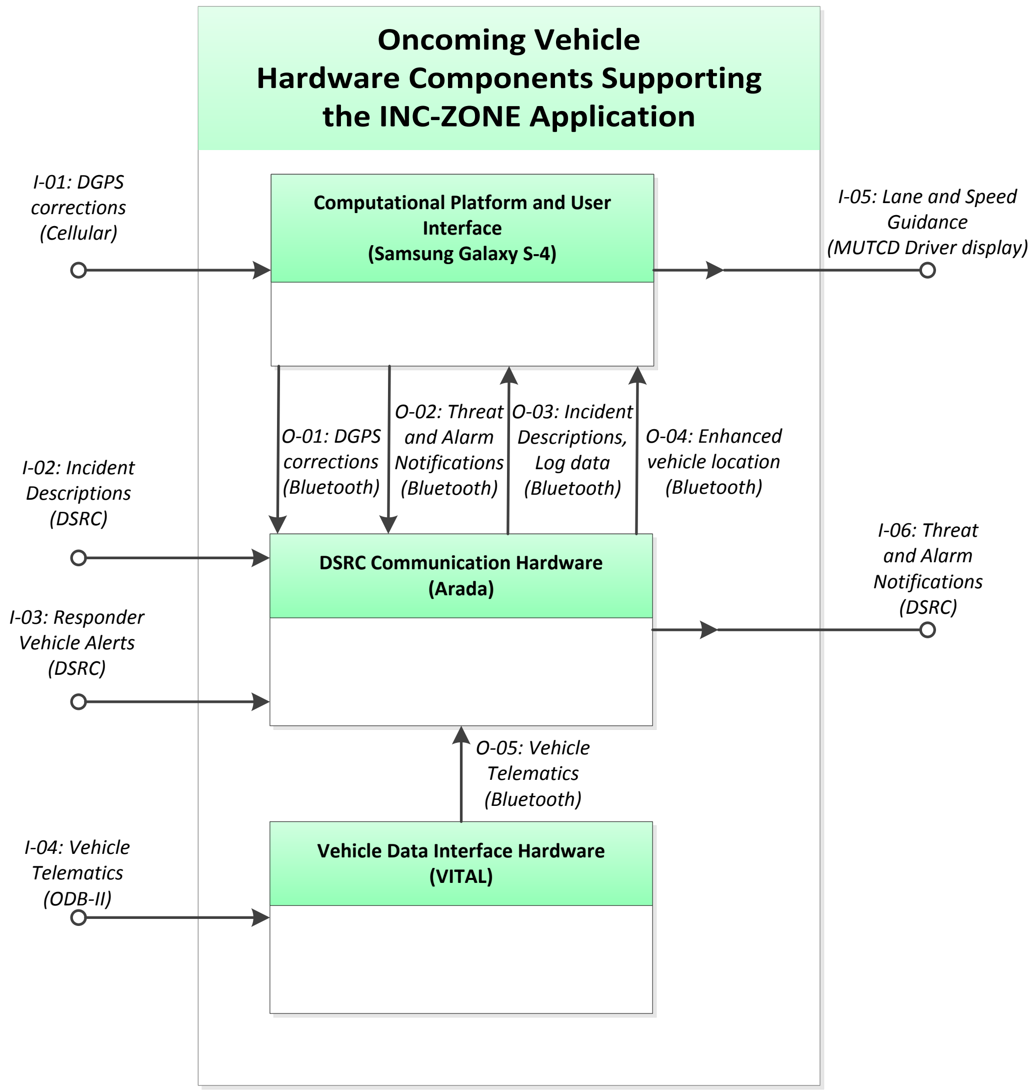
The hardware components that will support the INC-ZONE application are:

- The Oncoming Vehicle Computational Platform and User Interface component: Samsung Galaxy S4 smartphone
- The Responder Vehicle Computational Platform and User Interface component: Ruggedized Laptop
- The DSRC Communication Hardware component: Arada Systems radio
- The Vehicle Data Interface: Battelle VITAL
- Responder Radio Interface: Modified hand microphone

The following sections describe the general characteristics of each component, followed by a description of their deployment in each of the oncoming and responder vehicles.

Oncoming Vehicle Hardware Components

The components to be deployed in the oncoming vehicle to support the INC-ZONE application are shown in Figure 4-1. The numbered interfaces identified in Figure 4-1 are further described in Chapter 5.



Source: Battelle

Figure 4-1. Oncoming Vehicle Hardware

Computational Platform and User Interface

The Computational Platform and User Interface in the oncoming vehicle will be a Samsung Galaxy S4 smartphone running the Android operating system. The goals/features of this component are:

1. Provide a cellular interface to external data resources (i.e., in support of the Differential Global Positioning System [DGPS] correction data to provide improved locational accuracy via the Internet)
2. Graphical user interface to communicate the following to the user:
    - DSRC radio state
    - DGPS availability and accuracy
    - INC-ZONE guidance messages (for speed and lane guidance)
    - INC-ZONE warning messages (for imminent collision threats)
3. Interfacing with the DSRC radio module via a Bluetooth connection to send and receive incident zone descriptions and collision threat alarms and warnings to the user.

This device will be used as the primary INC-ZONE user interface in oncoming vehicles.

Development Stack

The software deployed on the Samsung Galaxy S4 will be built using Google's Android software development kit (SDK) and targeted at Android devices running at least Android 4.3 Jelly Bean (API level 18).

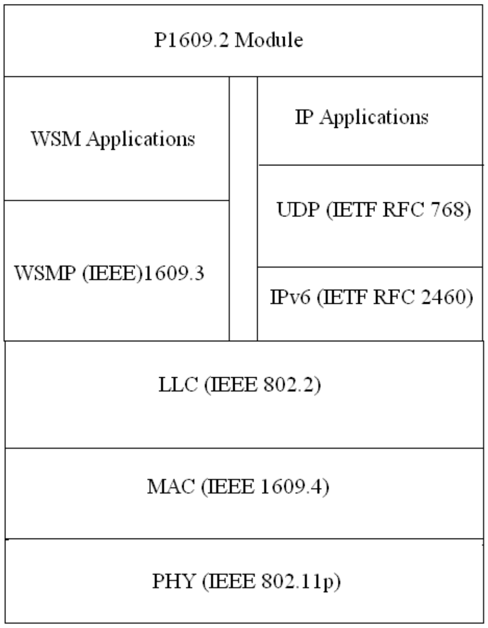
DSRC Communication Hardware

The DSRC Communication Hardware will be an Arada System's LocoMate™ GO OBU. The unit will receive messages from the DSRC radio.

The solution integrates GPS, Bluetooth and high-power 802.11p radios. It is fully compliant with Omni-Air's certification and used in worldwide deployments including the U.S. DOT's Safety Pilot Model Deployment in Ann Arbor, Michigan.

Development Stack

The Arada Systems application component will be written in C using an application programming interface (API) supplied by the manufacturer. The development for the application that resides on the unit will use Arada Systems' wireless access in vehicular environments (WAVE) API version 1.86. The application will be built to execute on a Linux operating system using the LocoMate™ tool chain version 1.42. This API includes Security, GPS positioning and Society of Automotive Engineers (SAE) J2735 messaging. Figure 4-2 shows the WAVE stack included on the Arada Systems DSRC devices.



Source: Arada Systems

Figure 4-2. Arada API Interfacing with the DSRC Stack

Vehicle Data Interface

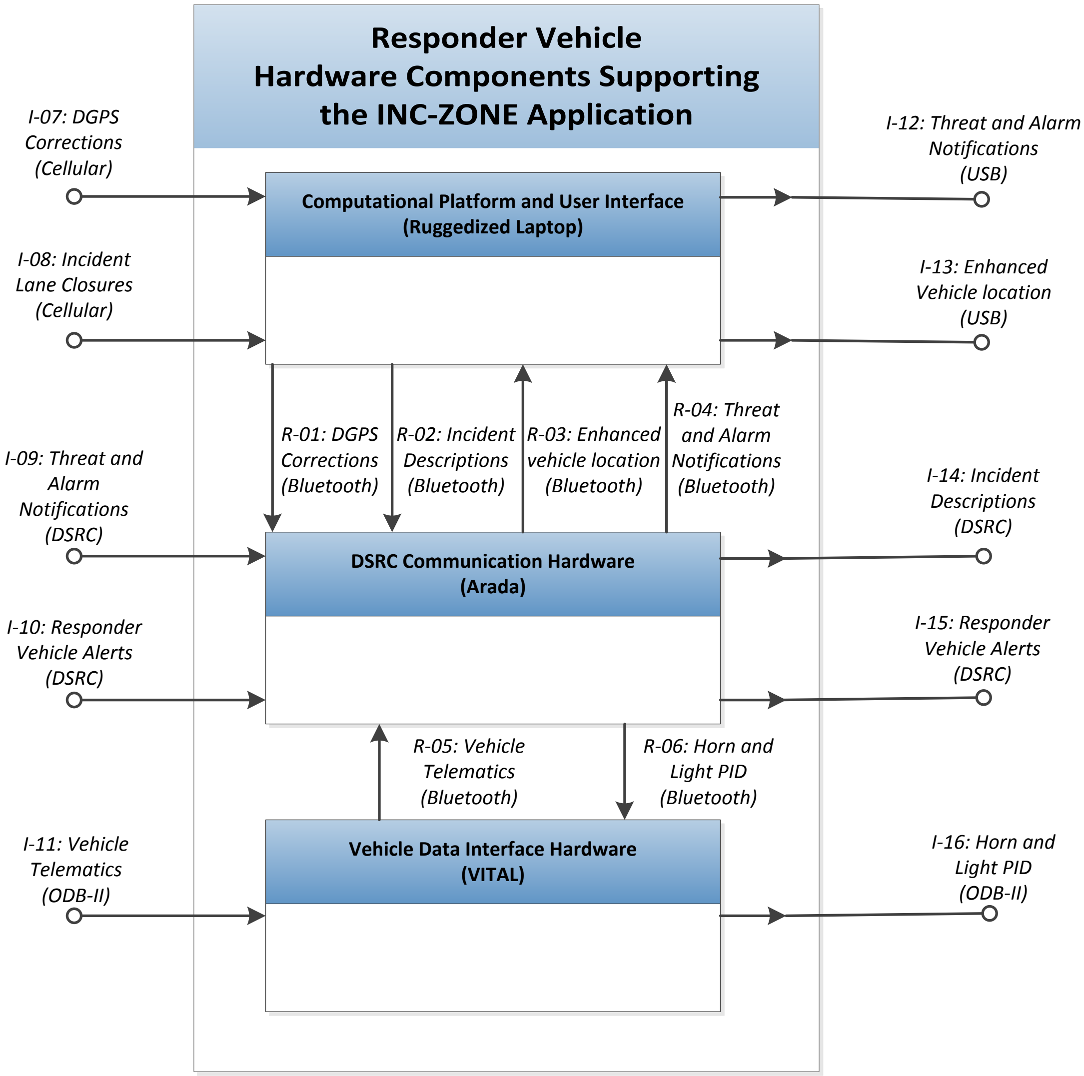
The Vehicle Data Interface for the oncoming vehicle will be the Battelle VITAL OBD-II module (see Figure 4-3). The VITAL module is a proprietary Battelle module that captures a vehicle's telematics data and sends them via Bluetooth to a connected device. The INC-ZONE application prototype described here will use the VITAL Bluetooth to communicate with the Arada Systems DSRC radio.

Source: Battelle

Figure 4-3. VITAL OBD-II Module

Responder Vehicle Hardware Components

The hardware components to be deployed in the responder vehicle to support the INC-ZONE application are shown in Figure 4-4. The numbered interfaces identified in Figure 4-4 are further described in Chapter 5.



Source: Battelle

Figure 4-4. Responder Vehicle Hardware

Computational Platform and User Interface

The Computational Platform and User Interface in the responder vehicle will be a ruggedized laptop running the Windows XP operating system. The goals/features of this component are:

1. Provide a cellular interface to external data resources (e.g., in support of the DGPS correction data via the Internet).
2. Provide an interface with the resident CapWIN application for lane closures in the incident zone.
3. Provide an interface with the DSRC radio module via a Bluetooth connection to send and receive incident zone descriptions and collision threat alarms.

Development Stack

The software deployed on the ruggedized laptop will be built using Microsoft's .NET framework.

DSRC Communication Hardware

The DSRC Communication Hardware will be an Arada System's LocoMate™ GO OBU battery powered unit, shown in Figure 4-5. The unit will receive messages from the DSRC radio.

Source: Arada Systems

Figure 4-5. The Arada Systems' LocoMate™ GO OBU

The solution integrates GPS, Bluetooth and high-power 802.11p radios. It is fully compliant with Omni-Air's certification and used in worldwide deployments including the U.S. DOT's Safety Pilot Model Deployment in Ann Arbor, Michigan.

Development Stack

The development stack for the Arada Systems DSRC radio will be identical to the one used in the oncoming vehicle.

Vehicle Data Interface

The Vehicle Data Interface for the responder vehicle will be the same unit used in the oncoming vehicle, the Battelle VITAL OBD-II module. As in the oncoming vehicle, the module communicates with a vehicle's telematics and forwards the data and messages using Bluetooth to a connected device (i.e., the Arada Systems GO). See Table 5-2 for details of the vehicle's telematics.

External Resource Components

DGPS Correction Network

DGPS is an enhancement to satellite-based GPS systems that uses fixed ground-based reference stations to correct for error and improve location accuracy. DGPS correction data will be used to improve the accuracy of the location services within the Arada Systems DSRC Communication

Hardware component. An Internet-based, regional source of correction data will be identified in the appropriate application .NET configuration file.

CapWIN Incident Data Feed

The CapWIN system will provide a cloud-based XML feed of all incident data collected from all deployed CapWIN clients running on any responder vehicle's ruggedized laptop. The CapWIN system will provide lane closure data to the INC-ZONE application.

Responder Radio Interface

Communication with the responder's P-25 radio equipment will be accomplished via a modified palm microphone replacing the existing microphone plugged into the P-25 radio itself. The replacement microphone will be modified to allow control of the talk key over a USB connection from the ruggedized laptop in the responder vehicle. The USB connection will allow the ruggedized laptop to not only key the microphone, but also to output a tone to the microphone speaker of a programmable duration. The P-25 radio, in turn, will be configured to broadcast input from the microphone connection to a pre-defined talk group for the personal radio worn by the responder. In this way, threat and alarm notifications generated by the INC-ZONE application will be communicated directly to dismounted responders (responders who have left their vehicle).

Source: Motorola

Figure 4-6. Motorola Palm Microphone

Normal operation of the palm microphone by the responder will not be altered by this modification.

The radio interface will contain no field programmable capabilities. It is essentially a cable connecting a USB port on the ruggedized laptop to a standard hand microphone connector that in turn plugs into the P-25 radio.

Chapter 5 INC-ZONE Application Interfaces

Inter-Vehicle DSRC Communication

DSRC messages will be exchanged between the oncoming and responder vehicles for the INC-ZONE application to communicate the existence of an incident zone to the oncoming vehicles, and to send threat messages from the oncoming vehicle to the responder vehicle.

All DSRC communications between the DSRC radios in the Arada Systems DSRC Communication Hardware component in both the oncoming and responder vehicles will transmit and receive messages conforming to the SAE J2735:2009 specification. The Oncoming Vehicle's DSRC radio will receive and process TIM and EVA messages broadcast by the responder vehicle. The Responder Vehicle's DSRC radio will receive and process a la carte messages (ACMs) broadcast by the oncoming vehicle.

The following sections describe the data elements in each of these messages.

Table 5-1. SAE J2735.2009 Messages used in the INC-ZONE Application

Message	
Emergency Vehicle Alert (EVA)	• Transmitted from every responder vehicle's DSRC radio based on the INC-ZONE application. • Received by oncoming vehicles and used by the INC-ZONE application to detect collision threats. • Received by the responder vehicle's DSRC radio and used by the INC-ZONE application to manage incident zone resources.
Traveler Information Message (TIM)	• Transmitted from only the responder vehicle that is closest to oncoming traffic via its DSRC radio based on the INC-ZONE application. • Constructed from data received from the Computational Platform and User Interface, including local map data as well as incident specific lane and speed information. • Received by oncoming vehicles and used by the INC-ZONE application to provide lane and speed guidance.
A la Carte Message (ACM) collision threat	• Generated by the oncoming vehicle from vehicle location data and incident zone descriptions broadcast from the responder vehicle. • Received by the responder vehicle and used by the INC-ZONE application to alert the responder to threats in the incident zone.

Source: Battelle

Responder Vehicle to Oncoming Vehicle

The Responder Vehicle to Oncoming Vehicle interface is represented in Figure 4-1 as interface I-02 for the oncoming vehicle, and in Figure 4-4 as interface I-14 for the responder vehicle for the TIM messages, and in Figure 4-1 as interface I-03 and in Figure 4-4 as interfaces I-10 and I-15 for the EVA messages. The data fields for the responder vehicle's EVA and TIM messages that define the incident zone descriptions for the INC-ZONE application are listed in Appendix B.

Oncoming Vehicle to Responder Vehicle

The Oncoming Vehicle to Responder Vehicle interface is represented in Figure 4-1 as interface I-06 for the oncoming vehicle, and in Figure 4-4 as interface I-09 for the responder vehicle. A threat message will be generated by an oncoming vehicle whenever that vehicle's operation does not conform to the lane or speed guidance presented in the INC-ZONE TIM, or when an oncoming vehicle is predicted to have an impact or near miss with a responder vehicle identified in an EVA message. In either case, a threat message will be broadcast by the oncoming vehicle, warning the responder of the danger. The threat message, as defined here, will be the only INC-ZONE DSRC message that uses a locally defined field (i.e., a field not defined in the SAE J2735.2009 standard) to implement INC-ZONE functionality. The data fields for the oncoming vehicle's ACM message that defines a vehicle threat to a responder are listed in Appendix B.

Oncoming Vehicle Interfaces

User Interface

The Oncoming Vehicle User Interface is represented in Figure 4-1 as interface I-05. The primary purpose of the INC-ZONE user interface in the oncoming vehicle will be to provide the driver with pertinent lane and speed guidance to navigate safely through the incident zone. Figure 5-1 shows a draft user interface developed by engineers for the INC-ZONE application running on the oncoming vehicle's Android device. (Original research on human factors and industrial design considerations are outside the scope of this prototype development.)

Source: Battelle

Figure 5-1. INC-ZONE Oncoming Vehicle User Interface

Source: Battelle

Figure 5-2. INC-ZONE Logging and Configuration Interface for the Oncoming Vehicle User Interface

In the mockups the screens are configured as simply as possible with the goal of displaying:

- Recommended speed
- Lane Advice
- Imminent collision warnings, featuring audible as well as visual cues

The INC-ZONE application's user interface will contain settings and debug/diagnostic screens in the oncoming vehicle as well (See Figure 5-2).

Vehicle Data Interface

The Vehicle Data Interface is represented in Figure 4-1 as interface I-04 for the oncoming vehicle. The data elements that will be read from the vehicle CAN bus for the INC-ZONE application are listed in Table 5-2, below. These data elements will also be used to generate Basic Safety Message (BSM) messages in the oncoming vehicle.[1] Several data elements that are also expected to be available from the Computational Platform and Radio component are listed here as optional. It is expected that those elements will likely be more accurately represented in the DGPS calculations when DGPS correction data are available.

[1] The BSM message is not required for the operation of the INC-ZONE application. It is included in this document because of its ubiquity in Connected Vehicle applications, and to give the reader a background context for the workings of the INC-ZONE application.

Table 5-2. VITAL Vehicle Telemetric Data Elements

Data Elements
Time
Location (Optional)
Speed (Optional)
Heading (Optional)
Lateral Acceleration
Longitudinal Acceleration
Yaw Rate
Rate of change of steering wheel
Brake Status
Brake Boost Status
Impact Sensor Status
Anti-lock braking status
External air temperature
Traction control status
Stability control status
Differential wheel speed

Source: Battelle

DGPS Correction Network

The DGPS Correction Network interface for the oncoming vehicle is represented in Figure 4-1 as interface I-01. The Arada Systems DSRC Communication Hardware used in both the responder and oncoming vehicles features a Ublox LEA-6S GPS receiver which will provide approximately road-level accuracy in vehicle positioning. In order to improve this accuracy to the lane-level accuracy required for the INC-ZONE application, correction data provided by a DGPS reference station network over the Internet will be fed to the receiver.

In accordance with specifications published by the Radio Technical Commission for Maritime Services (RTCM), the Networked Transport of RTCM via Internet Protocol (Ntrip) is a protocol for streaming differential GPS (DGPS) data over the Internet. This mechanism will take advantage of the available cellular-based Internet connection in the oncoming vehicle to provide correction data to the GPS receiver.

An Ntrip client on the Galaxy S4 Computational Platform and User Interface will be used to stream correction data from the regional source. Ntrip is a generic, stateless protocol based on HTTP/1.1

Ublox LEA-6S (used in ARADA SYSTEMS devices) supports the RTCM 2.3 streaming protocol for correction data.

Responder Vehicle Interfaces

The INC-ZONE application in the responder vehicle will interface with the CapWIN system, both cloud-based and client based within the responder vehicle, as well the responder vehicle's radio. These interfaces are described in this section.

Responder Radio Interface

The most important aspect of the INC-ZONE application is the ability to alert a dismounted responder (i.e., a responder away from the responder vehicle) to oncoming vehicles operating in an unsafe manner within the incident zone. The Responder Radio interface is represented in Figure 4-4 as interface I-12.

Table 5-3 outlines the signals that will be provided over USB to the modified palm microphone attached to the P25 radio equipment in the responder vehicle. The audible tone associated with each alarm level will have a configurable duration, frequency and periodicity, with default values as described in Table 5-4.

Table 5-3. Radio and Vehicle Alarm Descriptions

Alarm Level	Description	Radio Alarm	Vehicle Alarm
0	System inactive	None	None
1	System active, no threat. Oncoming vehicles in the vicinity of the incident are operating according to speed and lane guidance.	Heartbeat "ping", indicating the system is armed and actively scanning for threats. This state provides a baseline attention threshold for the responder.	None
2	Oncoming vehicles are approaching but not yet inside closed or speed controlled lanes, but given their trajectory are certain to violate speed and/or lane guidance.	None	None
3	Oncoming vehicles are approaching in closed or speed controlled lanes outside of guidance. Collision or near miss likely if corrective action not taken, beyond a configurable amount of time.	A tone "burst", of increasing loudness in proportion to excess speed, frequency of repeat tone in proportion to proximity of threatening vehicle, indicating a developing threat.	None
4	Collision or near miss imminent, unlikely that corrective action by oncoming vehicle possible, within a configurable amount of time.	Solid, attention grabbing tone, indicating an immediate and real threat.	Horn and lights

Source: Battelle

Table 5-4. Default Audible Alarm Characteristics

Alarm Level	Duration	Frequency	Loudness	Periodicity
0	na	na	na	na
1	.1 sec	220 Hz	20 db	.1 Hz
2	na	na	na	na
3	.2 sec	varies 220 Hz to 440 Hz	varies 20 db to 40 db	.5 Hz
4	.2 sec	440 Hz	40 db	4 Hz

Source: Battelle

Vehicle Data Interface

The Vehicle Data Interface is represented in Figure 4-4 as interface I-11 for the responder vehicle. The data elements required from the vehicle CAN bus for the INC-ZONE application listed in Table 5-2, will also be used in the responder vehicle to generate the BSM messages. Within the responder vehicle the VITAL module will also be used as a mechanism to activate the responder vehicle's lights and horn in the vehicle as an additional alarm mechanism to the dismounted responder. The On-board diagnostic parameter IDs (PID) descriptions that will be activated in these situations are listed in Table 5-5 below. The outgoing Vehicle Data interface for the responder vehicle is represented in Figure 4-4 as interface I-16.

Table 5-5. VITAL Vehicle Control

Vehicle Control
Horn
Siren (for vehicles having this feature)
Headlights
Running Lights
Brake Lights
Light Bar (for vehicles having this feature)

Source: Battelle

DGPS Correction Network

The DGPS Correction Network interface for the responder vehicle is represented in Figure 4-4 as interface I-07. Similar to the oncoming vehicle, an Ntrip client on the responder's ruggedized laptop Computational Platform and User Interface will be used to stream position correction data over cellular communications from the regional source.

CapWIN Incident Data Feed

The CapWIN Incident Data Feed interface is represented in Figure 4-4 as interface I-08. CapWIN hosts a secure Cloud Web Server over HTTPS protocol (Hypertext Transfer Protocol Secure). This secure Cloud Web Server implements a simple Representational State Transfer (REST) architecture that will be used to service requests from the Responder Vehicle's Computational Platform and User Interface component. A representative payload for a request to the CapWIN Incident Data Feed, providing the incident ID and associated lane closure data, is shown in the following figure.


```
- <ActivityIdentification xmlns="http://niem.gov/niem/niem-core/2.0">
  <IdentificationID>695beaab-fc54-11e2-9c11-b9237190ad67</IdentificationID>
    </ActivityIdentification>
  <ActivityDescriptionText xmlns="http://niem.gov/niem/niem-
    core/2.0">Incident type: accident</ActivityDescriptionText>
  <ActivityName xmlns="http://niem.gov/niem/niem-
    core/2.0">MDOT_CHART:US 50 EAST PRIOR TO MD 611</ActivityName>
- <IncidentLocation xmlns="http://niem.gov/niem/niem-core/2.0">
- <LocationAddress>
- <StructuredAddress>
- <LocationStreet>
  <StreetNumberText>0</StreetNumberText>
    </LocationStreet>
  <LocationCountyCode>047</LocationCountyCode>
  <LocationStateFIPS5-2NumericCode>24</LocationStateFIPS5-2NumericCode>
    </StructuredAddress>
    </LocationAddress>
- <LocationTwoDimensionalGeographicCoordinate>
- <GeographicCoordinateLatitude>
  <LatitudeDegreeValue>38.337803</LatitudeDegreeValue>
    </GeographicCoordinateLatitude>
- <GeographicCoordinateLongitude>
  <LongitudeDegreeValue>-75.111623</LongitudeDegreeValue>
    </GeographicCoordinateLongitude>
    </LocationTwoDimensionalGeographicCoordinate>
    </IncidentLocation>
```


Figure 5-3. CapWIN Cloud-based RESTful Service XML Sample

Incident Zone information, in particular, lane closures, will be received on the responder vehicle's Computational Platform and User Interface over an Internet connection from CapWIN cloud-based services.

A web client in the INC-ZONE application on the responder vehicle's Computational Platform and User Interface will request a persistent HTTPS connection (Keep-Alive) with the CapWIN Web Server to reduce the overhead otherwise required to repeatedly open temporary HTTPS client connections.

The XML schema for the cloud-based CapWIN Incident Data Feed is included in Appendix B.

CapWIN Vehicle Position Feed

The CapWIN Vehicle Position Feed interface is represented in Figure 4-4 as interface I-13. The current vehicle position, enhanced by the DGPS correction data described previously, will be passed from the GPS receiver on the Arada Systems DSRC Communication Hardware over Bluetooth to the Computational Platform and User Interface. These enhanced vehicle location data will be provided to CapWIN as National Marine Electronics Association (NMEA) sentences for Global Positioning System Fix Data (GGA) over a serial com port. The data, described in Table 5-6 below, will provide essential fix data, including 3D location and accuracy data to the CapWIN client as generated by the Arada Systems Computational Platform and Radio hardware.

Table 5-6. NMEA current Fix Data Elements

Attribute	Description	Value/Format
Talker	NMEA Data Type	"GPGGA"
Time	Time of fix in UTC	HHMMSS
Latitude	Latitude	DDMM.MMM,"N"
Longitude	Longitude	DDMM.MMM,"E"
FixQuality	Fix quality	0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 4 = Real Time Kinematic 5 = Float RTK 6 = estimated (dead reckoning) 7 = Manual input mode 8 = Simulation mode
sats	Number of satellites being tracked	99
HorizontalDilution	Horizontal dilution of position	9.9
Altitude	Altitude, Meters, above mean sea level	999.9,"M"
HeightOfGeoid	Height of geoid (mean sea level) above WGS84 ellipsoid	999.9,"M"
LastUpdate	time in seconds since last DGPS update	999.9
StationID	DGPS station ID number	999
Checksum	the checksum data, always begins with *	*99

Source: Battelle

The XML schema for the CapWIN Vehicle Position Feed is included in Appendix B.

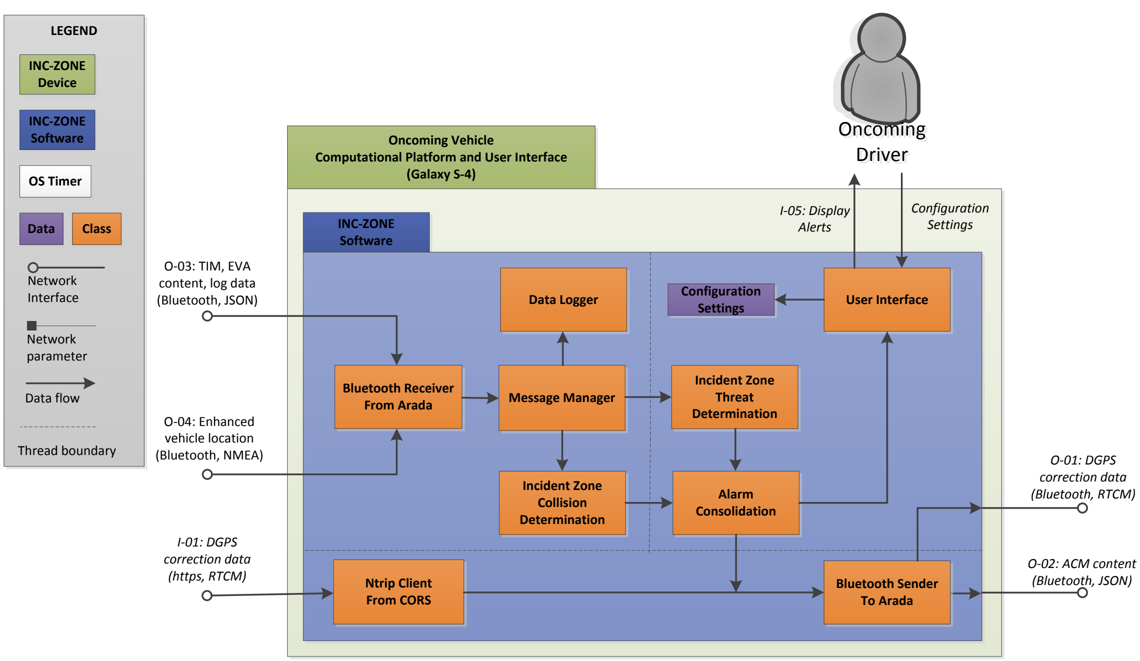
Chapter 6 INC-ZONE Component Software

Although there will be a considerable difference in the functionality of the INC-ZONE system on the responder and oncoming vehicles, the hardware and much of the software deployed to achieve that functionality will be common between the two vehicles. The following sections describe the software deployed to each of the INC-ZONE hardware components.

Oncoming Vehicle Computational Platform and User Interface Application Component

The Android application deployed to the Galaxy S4 Cellular and User Interface hardware is intended to be the only executing application on the device, but the system must support the user switching to other activities (applications) or responding to operating system events.

The Android application structure is shown in Figure 6-1. The application will communicate over Bluetooth to the Arada Systems radio unit and over cellular to cloud-based GPS correction data services.



Source: Battelle

Figure 6-1. Application Data Flow in the Oncoming Vehicle Android Application

Software Modules

Arada Systems Bluetooth Sender and Receivers

To support communications between the Galaxy S4 and the Arada Systems radio, the application will leverage the Android support for the Bluetooth network stack, which allows a device to wirelessly exchange data with Bluetooth devices. The application framework provides access to the Bluetooth functionality through the Android Bluetooth APIs (for both Bluetooth Low Energy and standard Bluetooth). These APIs let applications wirelessly connect to other Bluetooth devices, enabling point-to-point and multipoint wireless features.

The Android Service object supports developers by providing a way to manage long running or persistent operations while not blocking the main user interface activities.

Ntrip Client from DGPS Reference Data Network

The DGPS reference data network connections will be handled through this module. Correction data from the DGPS reference data network will be retrieved from the Internet-based network over cellular communications and relayed to the Arada Systems radio over the Bluetooth interface, where the data are subsequently used to improve the performance of the GPS processor embedded in the DSRC radio unit.

Message Manager

The message manager's function will be to route messages from the Arada Systems Bluetooth message stream to the appropriate component of the Android application. No transformation of the messages will be performed beyond routing to the appropriate application module.

Data Logger

The data logger will record a log of all activity performed by the INC-ZONE application to a persistent data store for subsequent analysis. The activities logged will be viewed through the User Interface, either historically or in real time through a scrolling view port. All activities will be logged with the time stamp that the activity was logged.

Alarm Consolidation

This module will resolve priority differences between the lane and speed threat and collision threats, and will forward the results on to the user interface portion of the application.

Incident Zone Threat Determination

This portion of the INC-ZONE application will be used in the oncoming vehicle to determine lane and speed violations based on incident zone descriptions in the received TIM messages.

The threat algorithm will use a variety of parameters including the oncoming vehicle's current speed and vehicle-specific emergency and aggressive braking deceleration rates for the determination of messages to the driver and responders. The exact distances for issuing messages will vary based on these parameters, which are based largely on MUTCD guidance for temporary traffic control zones and speed reduction. The current oncoming vehicle conditions relative to the restrictions for the safety zone, that is the buffer space around the incident zone, must be met for a message to be issued to the driver at a determined distance in advance of the incident zone. The issued message will be terminated based on a given set of criteria, which may consist of an escalated or lower threat message. These escalating threat messages and the algorithm for determining which message(s) to issue and at what distance are summarized in Table 6-1 below. Further details of this module can be found in Chapter 7.

Incident Zone Collision Determination

This portion of the INC-ZONE application will be used in the oncoming vehicle to determine imminent collision threats to responder vehicles, based on the location and trajectory of the oncoming vehicle relative to the responder vehicles' positions in the incident zone.

The details of this module can be found in Chapter 7.

User Interface

This module will be responsible for the displays presented to the driver of the oncoming vehicle. Details of the screens presented to the oncoming driver are found in Chapter 5.

Table 6-1. Incident Zone Threat Determination

Oncoming Vehicle Message (DVI)	Responder Message (PASS)	Escalating Threat Algorithm Determination			Document Reference	MUTCD Reference for Distance to Issue Message	MUTCD Reference for DVI Icon(s)
		Oncoming Vehicle Conditions Relative to Safety Zone Restrictions	Oncoming Vehicle Distance in advance of Incident Zone to Issue Message[1]	Terminate Message Criteria			
Reduced Speed Advisory[2,5]	(No Threat)	Oncoming vehicle approaching an incident and safety zone with closures or speed restrictions	With Shoulder or Lane Closure Advisory; otherwise: Advance Placement Distance + Buffer Space + 180 feet legibility distance	Oncoming Vehicle exits Incident and Safety Zone [revert to default/no message]	Table 11, Table 12, Figure 7-1	Table 2C-4, Table 6C-2, Figure 6H-33	 W3-5
Shoulder or Lane Closure Advisory[2,4]	(No Threat)	Oncoming vehicle approaching an incident and safety zone with closures or speed restrictions	Distance A + Distance B + Distance C + Buffer Space + 180 ft legibility distance	Oncoming Vehicle passes beginning of Incident Zone [revert to default/no message]	Table 10, Table 12, Figure 7-1	Table 6C-1, Table 6C-2, Figure 6H-33	 W20-5  R4-9

Table 6-1. Incident Zone Threat Determination (Continued)

Oncoming Vehicle Message (DVI)	Responder Message (PASS)	Escalating Threat Algorithm Determination			Document Reference	MUTCD Reference for Distance to Issue Message	MUTCD Reference for DVI Icon(s)
		Oncoming Vehicle Conditions Relative to Safety Zone Restrictions	Oncoming Vehicle Distance in advance of Incident Zone to Issue Message[1]	Terminate Message Criteria			
Reduced Speed Alert[2,5]	Oncoming Vehicle Advisory – Approaching Violation	Oncoming vehicle approaching safety zone requires aggressive braking action to slow to advisory or posted speed in safety zone (Buffer Space)	Buffer Space + 1/2 * [(Advisory or Posted Reduced Speed)[2] - (Current oncoming vehicle speed)[2] / (Vehicle-Specific Aggressive Braking Deceleration Rate)	Oncoming Vehicle speed and location below deceleration rate threshold [revert to Reduced Speed Advisory]; OR Oncoming Vehicle enters Safety Zone [revert to Reduced Speed Warning]	Equation 1	n/a	 W3-5
Lane Closure Alert[2,4]	Oncoming Vehicle Advisory – Approaching Violation	Oncoming vehicle approaching safety zone in a closed lane	Distance A + Buffer Space + 180 ft legibility distance	Oncoming Vehicle merges to a through lane [revert to Lane Closure Advisory] OR Oncoming Vehicle enters Safety Zone [revert to Lane Closure Warning]	Table 10, Table 12, Figure 7-1	Table 6C-1, Table 6C-2, Figure 6H-33	 W4-2  W1-8

		Escalating Threat Algorithm Determination					
Oncoming Vehicle Message (DVI)	**Responder Message (PASS)**	**Oncoming Vehicle Conditions Relative to Safety Zone Restrictions**	**Oncoming Vehicle Distance in advance of Incident Zone to Issue Message[1]**	**Terminate Message Criteria**	**Document Reference**	**MUTCD Reference for Distance to Issue Message**	**MUTCD Reference for DVI Icon(s)**
Reduced Speed Warning[3,5]	Oncoming Vehicle Alert – In-Violation	Oncoming vehicle exceeding advisory or posted reduced speed within safety zone (Buffer Space)	Buffer Space	Oncoming Vehicle speed reduces to or below advisory or posted speed [revert to Reduced Speed Advisory]; OR Oncoming Vehicle exits Incident and Safety Zone [revert to default/no message]	Table 12	Table 6C-2	 R2-1

Table 6-1. Incident Zone Threat Determination (Continued)

		Escalating Threat Algorithm Determination					
Oncoming Vehicle Message (DVI)	**Responder Message (PASS)**	**Oncoming Vehicle Conditions Relative to Safety Zone Restrictions**	**Oncoming Vehicle Distance in advance of Incident Zone to Issue Message[1]**	**Terminate Message Criteria**	**Document Reference**	**MUTCD Reference for Distance to Issue Message**	**MUTCD Reference for DVI Icon(s)**
Lane Closure Warning[3,4]	Oncoming Vehicle Alert – In-Violation	Oncoming vehicle in closed lane within safety zone (Buffer Space)	Buffer Space	Oncoming Vehicle merges to a through lane [revert to Lane Closure Advisory]; OR Oncoming Vehicle approaches responder vehicle [revert to Collision Warning]; OR Oncoming Vehicle exits Incident and Safety Zone [revert to default/no message]	Table 12	Table 6C-2	 W9-1  W9-2

		Escalating Threat Algorithm Determination					
Oncoming Vehicle Message (DVI)	**Responder Message (PASS)**	**Oncoming Vehicle Conditions Relative to Safety Zone Restrictions**	**Oncoming Vehicle Distance in advance of Incident Zone to Issue Message[1]**	**Terminate Message Criteria**	**Document Reference**	**MUTCD Reference for Distance to Issue Message**	**MUTCD Reference for DVI Icon(s)**
Collision Warning[3,4]	Oncoming Vehicle Warning	Oncoming vehicle in closed lane within safety zone (Buffer Space) approaching responder vehicle	[-1/2 * (Current oncoming vehicle speed)[2] / (Vehicle-Specific Emergency Braking Deceleration Rate)] - (Distance to nearest responder vehicle)	Oncoming Vehicle merges to through lane [revert to default/no message]; OR Oncoming Vehicle stops prior to collision [revert to Lane Closure Warning]	Equation 2	n/a	 R1-1

[1] Distances may vary based upon oncoming driver visibility distance (e.g., horizontal and vertical curvature of the roadway) and range of DSRC

[2] Advisory and Alert messages for Reducing Speed and Closures are shown together, when applicable.

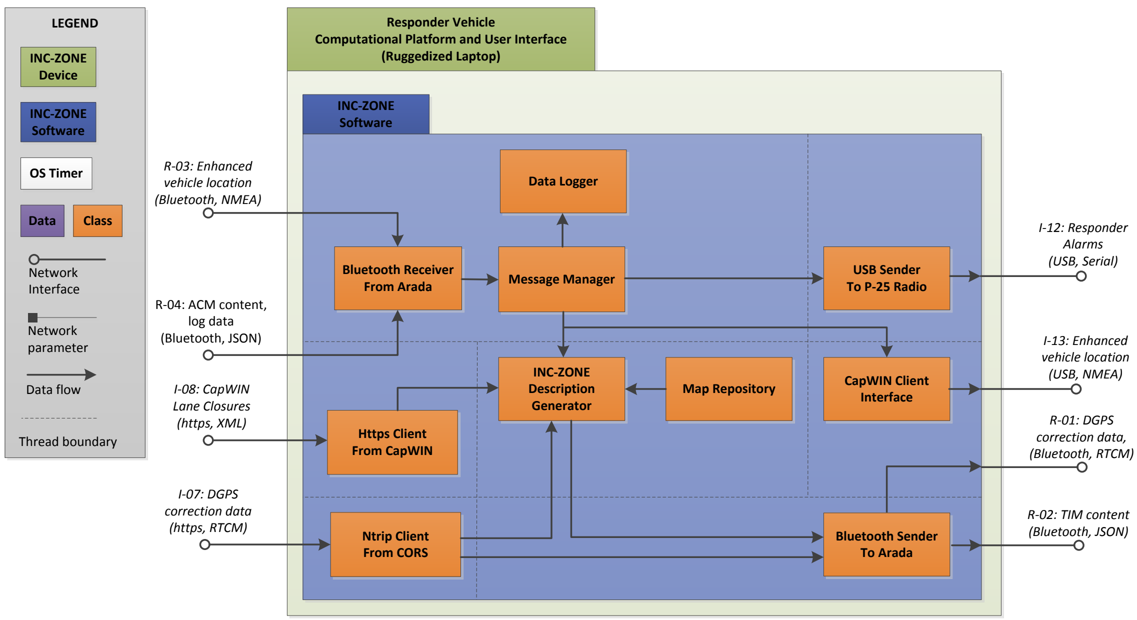
[3] Shown alone, order of presence from most to least important are Collision Warning, Lane Closure Warning, and Reduced Speed Warning

[4] Escalating message set displayed for lane closure, take priority over reduced speed messages

[5] Escalating message set displayed for reducing speed

Responder Vehicle Computational Platform and User Interface Application Component

The .NET application on the Responder Vehicle's ruggedized laptop is shown in Figure 6-2. The application will communicate over Bluetooth to the Arada Systems radio unit and over cellular to cloud-based GPS correction data services. The Responder Vehicle's version of the application will also be responsible for initial construction of the incident zone description, and relaying alarm data to both the responder vehicle's radio and vehicle's CAN bus.



Source: Battelle

Figure 6-2. Application Data Flow in the Responder Vehicle Application

Software Modules

Arada Systems Bluetooth Sender and Receivers

These modules will rely on underlying driver support for a Bluetooth device plugged into one of the ruggedized laptop's USB ports.

Ntrip Client from DGPS Reference Data Network

The DGPS reference data network connections will be handled through this module. Correction data from the DGPS reference data network will be retrieved from the Internet-based network over cellular communications and relayed to the Arada Systems radio over the Bluetooth interface, where the data are subsequently used to improve the performance of the GPS processor embedded in the DSRC radio unit.

Http Client from CapWIN

This portion of the INC-ZONE application will be used to interact with CapWIN Internet services over a secure network connection. This is the source of lane closure information for an incident.

Message Manager

The message manager's function will be to route messages from the Arada Systems message stream to the appropriate component of the .NET application. No transformation of the messages will be performed beyond routing to the appropriate application module.

Data Logger

The data logger will record a log of all activity performed by the INC-ZONE application to a persistent data store for subsequent analysis. The activities logged will be viewed through XP file management tools. All activities will be logged with the time stamp that the activity was logged.

INC-ZONE Description Generator

This portion of the INC-ZONE application will be used by responder vehicles to retrieve map data from a local repository of map data (see below), fuse that data with lane closure information from the CapWIN incident feed, and generate a consistent incident zone description including a map of open and closed lanes, speed guidance, and other details to be transmitted to oncoming vehicles in the form of a Traveler Information Message by the Arada Systems radio. The data will be relayed to the Arada Systems radio using the connection to that device.

Map Repository

The INC-ZONE application will contain a repository of roads of the geographic region the application is expected to support for the prototype demonstration. When an incident zone is established, a portion of the map data corresponding to the location of the incident zone will be extracted under program control and relayed to the Arada Systems radio for transmission in a TIM message as a key portion of the incident zone description transmitted to the oncoming vehicles. Details of the structure of the map repository are found in the next section.

USB Sender to P-25 Radio

This module will be used only in the responder vehicle to communicate serially over the USB communication channels to the responder radio.

CapWIN Client Socket

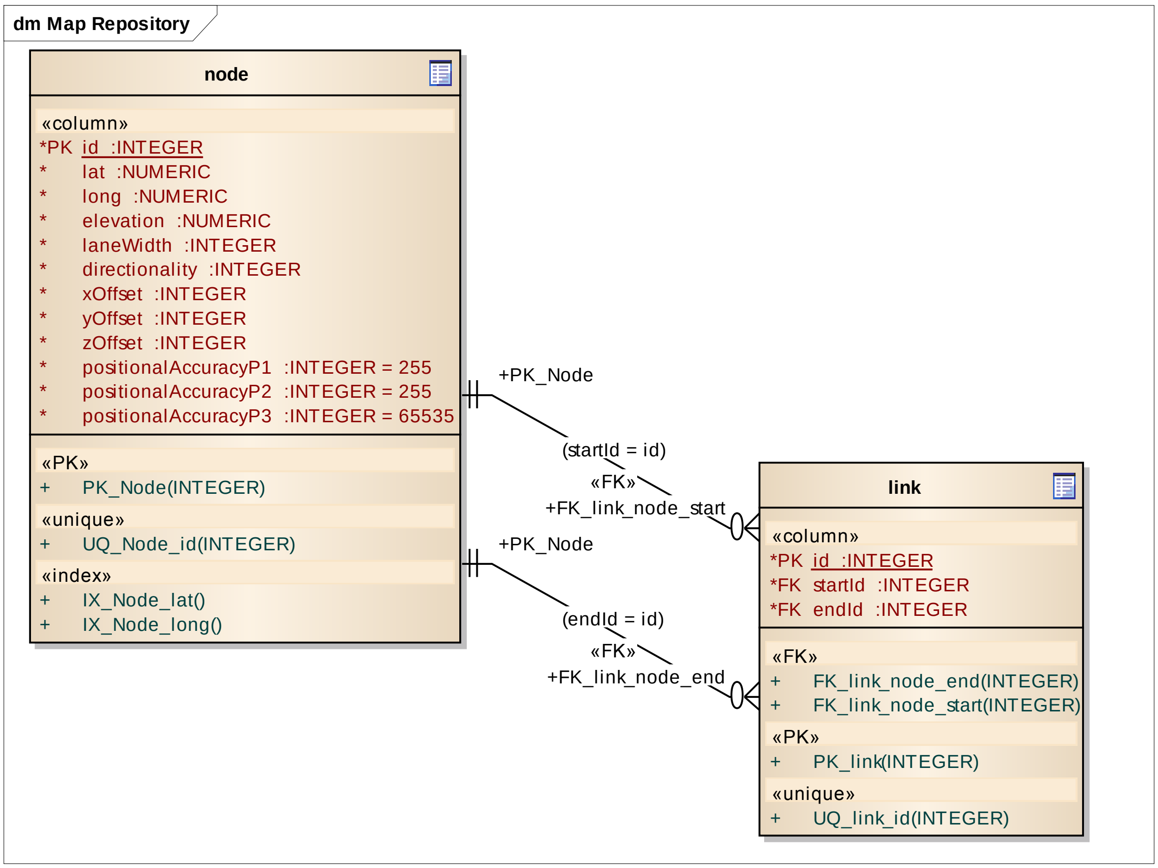
The enhanced vehicle location data streamed from the Arada Systems radio will be formatted as NMEA sentences and sent to the CapWIN Client emulating a serial over USB com port.

Map Repository

Precise, lane-level highway maps will be a key component of the INC-ZONE application. Appropriate lane guidance specific to the oncoming vehicle can only be generated by the INC-ZONE application by knowing which lanes are available and closed within the incident zone, knowing the precise location of those lanes, and knowing the oncoming vehicle's location in relation to those lanes. This section describes the structure of the repository of lane-level map data that will be used in the INC-ZONE application to construct portions of the Traveler Information Messages broadcast by the responder vehicle that describe an incident zone to the oncoming vehicle.

For the Prototype demonstration, this repository will reside on the responder vehicle's ruggedized laptop, pre-loaded with data describing the usable highway lane and shoulder data for the entire region where the INC-ZONE application is to be tested. When an incident is declared in the CapWIN system, the location of the responder vehicle is used to identify a subset of the highway lane and shoulder data in the map repository that will be used to construct the incident zone map. For the Prototype, the entire map repository will reside on the responder vehicle's Computational Platform and User Interface. In a fully deployed system, the map repository would likely be deployed to a cloud-based service where a variety of maintenance issues could be addressed that are currently not addressed in the context of the Prototype demonstration.

The map repository schema is shown in Figure 6-3.



Source: Battelle

Figure 6-3. The Map Repository Schema

The node Relational Database Table

The node table will contain the basic data for representing highway lanes and shoulders. Each row of data in the table will define a short, straight or nearly straight lane segment of a highway. Segment length will vary with the geometry of the road, but typically will be no more than 50 m. The lat, long and elevation columns will provide a definitive and precise location in the WSG-84 coordinate system for the center of the starting position of the lane segment from which short offsets in the x, y and z dimensions define the centerline of the segment.

The data in the node table are modelled after the *Position3D* and *NodeList* data types for representing similar concepts in the SAE J2735.2009 standard. However, the data in the node table in this schema is deliberately de-normalized, i.e. it is not the most compact representation of the data. In this representation, all fields are required; none of the data are optional. In the node table, every row of data will record a lane segment's anchor latitude, longitude and elevation, whereas in the SAE standard, sequences of nodes may be listed with offsets relative to the previous node in the sequence, ultimately relative to a single anchoring 3D position. The highly compressed representation of the transmitted message is necessitated by the bandwidth constraints of the DSRC medium.

In the INC-ZONE representation, every row of data in the node table will stand alone, independent of other data in the table. This scheme will allow all of the lane segments to be easily indexed and retrieved by location in an efficient manner. Furthermore, this representation will allow any arbitrary number of contiguous nodes to be trivially rendered into the compact *NodeList* representation found in the SAE standard, as necessary, for eventual transmission as a component of an appropriately compact Traveler Information Message.

Table 6-2. node Relational Database Table Columns

Name	PK	Type	Not Null	Unique	Notes
id	True	INTEGER	True	True	Primary key
lat	False	NUMERIC	True	False	Latitude of this segment, in 1/10th micro degrees, in the WSG-84 coordinate system.
long	False	NUMERIC	True	False	Longitude of segment, in 1/10th micro degrees, in the WSG-84 coordinate system.
elevation	False	NUMERIC	True	False	Elevation of segment. The geographic position above or below the WSG-84 reference ellipsoid, with a resolution of 1 decimeter and represents an asymmetric range of positive and negative values.
laneWidth	False	INTEGER	True	False	Lane width, INTEGER (0..32767), units of 1 cm

Table 6-2. node Relational Database Table Columns (Continued)

Name	PK	Type	Not Null	Unique	Notes
directionality		INTEGER	True	False	The allowed direction of travel. forward (0) direction of travel follows node ordering reverse (1) direction of travel is the reverse of node ordering both (2) direction of travel allowed in both directions
xOffset		INTEGER	True	False	Values from -32767..32767, where in units of 1.0 cm.
yOffset		INTEGER	True	False	Values from -32767..32767, where in units of 1.0 cm.
zOffset		INTEGER	True	False	Values from -32767..32767, where in units of 1.0 cm.
positionalAccuracyP1		INTEGER	True	False	Semi-major accuracy at one standard deviation, where 0-253 represents the range 0-12.7 meter, LSB = .05m 254=any value equal or greater than 12.70 meter 255=unavailable semi-major value
positionalAccuracyP2		INTEGER	True	False	Semi-minor accuracy at one standard deviation, where 0-253 represents the range 0-12.7 meter, LSB = .05m 254=any value equal or greater than 12.70 meter 255=unavailable semi-minor value
positionalAccuracyP3		INTEGER	True	False	Orientation of semi-major axis relative to true north (0~359.9945078786 degrees), LSB units of 360/65535 deg = 0.0054932479, where 0 shall be 0 degrees 1 shall be 0.0054932479 degrees 65534 shall be 359.9945078786 degrees 65535 shall be used for orientation unavailable (In NMEA GPGST)

Source: Battelle

Table 6-3. node Table Column Constraints

Name	Type	Columns
PK_Node	Public	id
UQ_Node_id	Public	id
IX_Node_lat	Public	lat
IX_Node_long	Public	long

Source: Battelle

Table 6-4. node Table Relationships

Columns	Association	
(endId = id)	**0..***	link.FK_link_node_end
	1	node.PK_Node
(startId = id)	**0..***	link.FK_link_node_start
	1	node.PK_Node

Source: Battelle

The link Relational Database Table

Identifies a pair of nodes that will be connected to each other, i.e., where the implied endpoint of one node coincides with the latitude, longitude and elevation of another node.

Note that the data in this table will be able to be completely derived by a *post hoc* analysis of the data in the *node* table. The purpose of the *link* table in this schema will be to provide the INC-ZONE Description Generator an efficient means to chain through the entries in the *node* table in the service of creating an incident zone description containing lane definitions of an arbitrary length.

Table 6-5. link Relational Database Table Columns

Name	PK	Type	Not Null	Unique	Notes
id	True	INTEGER	True	True	Primary key.
startId	False	INTEGER	True	False	The starting node id.
endId	False	INTEGER	True	False	The ending node id.

Source: Battelle

Table 6-6. link Table Column Constraints

Name	Type	Columns
FK_link_node_end	Public	endId
FK_link_node_start	Public	startId
PK_link	Public	id
UQ_link_id	Public	id

Source: Battelle

Table 6-7. link Table Relationships

Columns	Association	
(endId = id)	**0..***	link.FK_link_node_end
	1	node.PK_Node
(startId = id)	**0..***	link.FK_link_node_start
	1	node.PK_Node

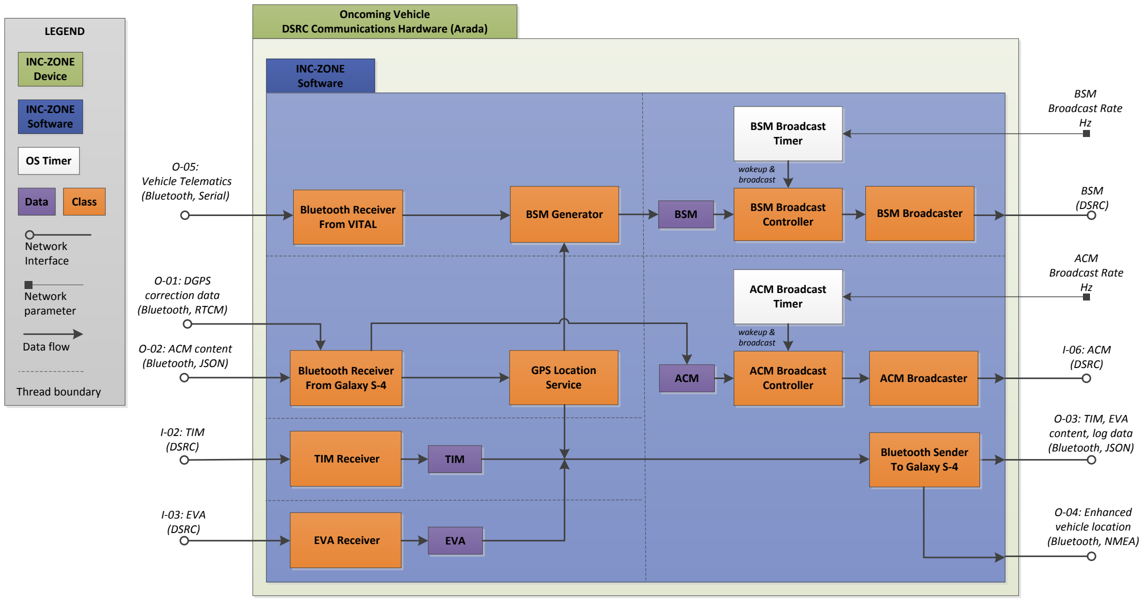
Source: Battelle

DSRC Communication Hardware Application Component

The INC-ZONE DSRC Communication Hardware Component application in both the oncoming and responder vehicles will be based on Arada Systems' example code for the On-Board Equipment (OBE) deployment. This example implements the messaging, logging, and security for the DSRC messages. Additional functionality will be added to this application to incorporate the following.

Oncoming Vehicle Application Component

The design of the application for the oncoming vehicle is shown in Figure 6-4.



Source: Battelle

Figure 6-4. Application Data Flow in the Oncoming Vehicle Arada Systems Application

Software Modules

As reflected in the above figures, much of the functionality of the Arada Systems radio, and hence much of the software, will be common to both the oncoming and responder vehicles. The following describes each of the software modules that will make up the Arada Systems software builds found on each of the vehicles.

Bluetooth Receiver to VITAL

Vehicle data will be collected from the VITAL OBD-II module via Bluetooth, allowing the application to determine specific states of the vehicle. The receiver will connect to the module and receive raw CAN messages from the vehicle. The data that will be received from the vehicle is listed in Table 5-2. These data are utilized primarily in the oncoming vehicle to determine driver intention.

This module will be common to both the oncoming and responder vehicle’s versions of the application.

Galaxy S4 Bluetooth Sender and Receivers

The Bluetooth Sender will relay messages to the Samsung Galaxy S4 to be displayed to the user. The data comprising this alert message will come from the on-board INC-ZONE application. The alert will contain International Traveler Information Systems (ITIS) Codes for the text display, which will be decoded in the user interface using a table lookup. The DGPS Bluetooth Receiver will handle any incoming GPS correction message from the DGPS Reference Network received by the Computational Platform and User Interface.

This module will be common to both the oncoming and responder vehicle’s versions of the application.

GPS Location Service

The GPS Location Service will inject DGPS correction data into the GPS ublox position correction processor within the Arada Systems GO unit.

This module will be common to both the oncoming and responder vehicle’s versions of the application.

ACM Broadcast Timer
This will be an OS Timer used to invoke the ACM Broadcast Controller on a 10 Hz frequency.

ACM Broadcast Controller
This module will retrieve the latest data structure containing the data required to create an A la Carte Message from shared storage and send it to the ACM Broadcast module.

ACM Broadcaster
In oncoming vehicles, the ACM Broadcaster will fill all applicable fields in the ACM from data that it receives from the threat determination module on the oncoming vehicle, convert to the appropriate ASN.1 format and broadcast the threat message over the DSRC radio to any other DSRC radio within range at 10 Hz.

The content of the ACM threat message is described in Table B-3.

BSM Generator
This module will collect data from the Vehicle Data Interface and the GPS Location Services to populate an updated data structure for the Basic Safety Message.

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcast Timer
This will be an OS Timer used to invoke the BSM Broadcast Controller on a 10 Hz frequency.

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcast Controller
This module will retrieve the latest data structure containing the data required to create a Basic Safety Message from shared storage and send it to the BSM Broadcast module.

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcaster
This module will convert its input to the appropriate ASN.1 format and broadcast the threat message over the DSRC radio to any other DSRC radio within range.

The content of the ACM threat message is described in Table B-3.

This module will be common to both the oncoming and responder vehicle's versions of the application.

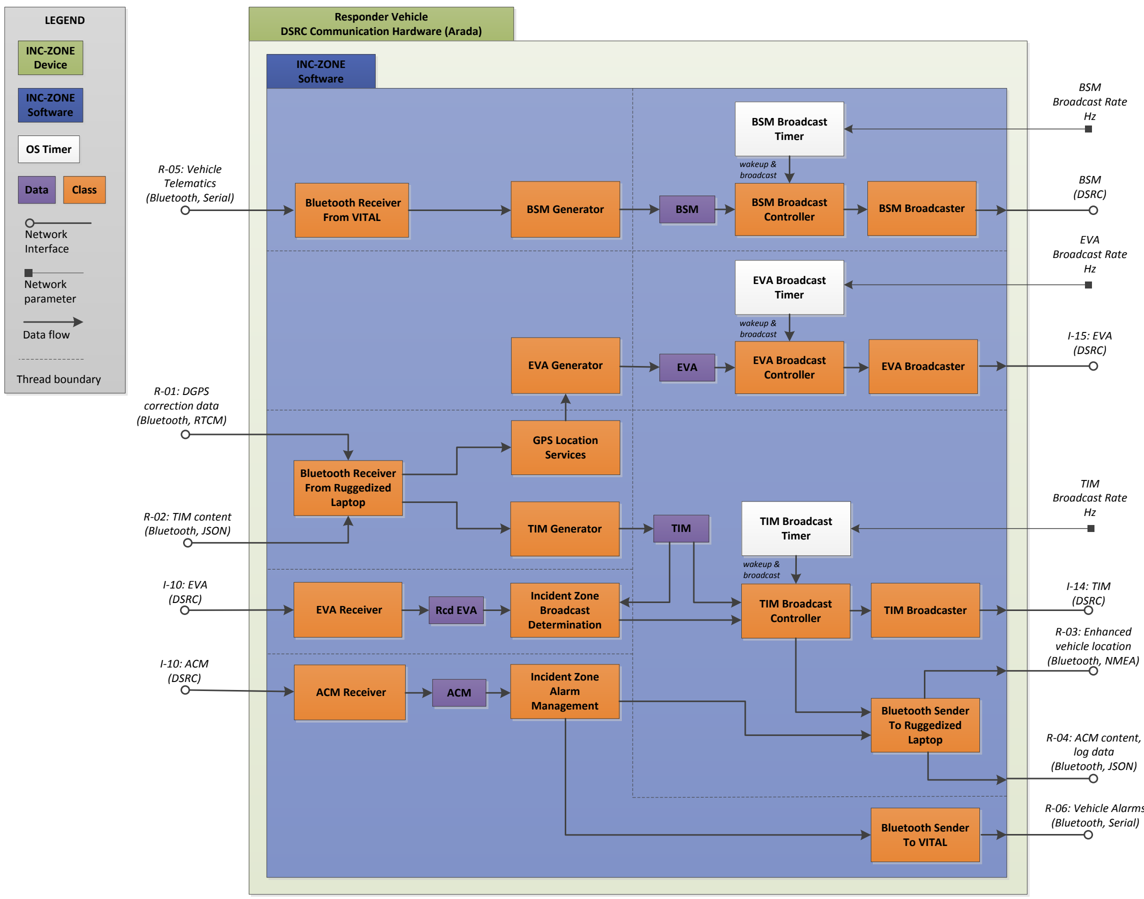
EVA Receiver
This module will receive and process EVA messages. This module will be responsible for managing the list of responder vehicles in the incident zone, keeping that list of vehicles and their associated locations current from the stream of EVA messages, and discarding redundant EVA messages.

In the oncoming vehicle, these data will be used as input to the threat processing module.

TIM Receiver
The TIM Receiver in the oncoming vehicle will receive and parse TIM messages broadcast by a responder vehicle in the incident zone, and hand that data to the threat processing module.

Responder Vehicle Application Component

The responder vehicle's version of the INC-ZONE DSRC Communication Hardware Component will also be based on Arada Systems' example code for the On-Board Equipment deployment. Additional functionality supports the construction and broadcast of incident zone descriptions in the form of EVA and TIM messages. The modules and data flow of the INC-ZONE application software on the Arada Systems unit can be seen in Figure 6-5.



Source: Battelle

Figure 6-5. Application Data Flow in the Responder Vehicle Arada Systems Application

Software Modules

As reflected in the above figures, much of the functionality of the Arada Systems radio, and hence much of the software, will be common to both the oncoming and responder vehicles. The following describes each of the software modules that will make up the Arada Systems software builds found on each of the vehicles.

Bluetooth Sender to VITAL

This module will be used by the responder vehicle to activate the vehicle's horn and lights. The responder vehicle subsystems activated are listed in Table 5-5.

Bluetooth Receiver to VITAL

This module will be common to both the oncoming and responder vehicle's versions of the application.

Ruggedized Laptop Bluetooth Sender and Receivers

The Bluetooth Sender will relay messages to the ruggedized laptop. The data comprising this alert message will come from the on-board INC-ZONE application as relayed from the oncoming vehicle.

This module will be common to both the oncoming and responder vehicle's versions of the application.

GPS Location Service

This module will be common to both the oncoming and responder vehicle's versions of the application.

Incident Zone Broadcast Management

This portion of the INC-ZONE application will be used in the responder vehicle to determine the most appropriate vehicle to handle TIM broadcasts of the incident zone to oncoming vehicles. This component will determine whether or not the responder vehicle's DSRC radio will broadcast the incident zone description in a Traveler Information Message.

This module will use the known location of the responder vehicles currently on scene based on the received EVA messages, prioritizing the vehicles nearest the oncoming traffic to broadcast the TIM message, with secondary preference given to the earliest vehicle on scene. In the event the selected vehicle is incapable of broadcasting a TIM message, the prioritized list of on scene vehicles will be used to select an alternate. An alternate vehicle will be activated after a configurable time period elapses where no TIM message is being broadcast.

ACM Receiver

This module will receive and processes threat ACM messages. In the responder vehicle, this module will parse the ASN.1 data message received on the DSRC radio and hand the results off to the Bluetooth Sender for logging purposes, as well as to the VITAL Bluetooth Sender to activate the responder vehicle's horn and lights as appropriate.

BSM Generator

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcast Timer

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcast Controller

This module will be common to both the oncoming and responder vehicle's versions of the application.

BSM Broadcaster

This module will be common to both the oncoming and responder vehicle's versions of the application.

EVA Generator

This module will collect data from the Vehicle Data Interface and the GPS Location Services to populate an updated data structure for the Emergency Vehicle Alert Message.

EVA Broadcast Timer

This will be an OS Timer used to invoke the EVA Broadcast Controller on a 10 Hz frequency.

EVA Broadcast Controller

This module will retrieve the latest data structure containing the data required to create an Emergency Vehicle Alert Message from shared storage and send it to the EVA Broadcast module.

EVA Broadcaster

This module will convert its input to the appropriate ASN.1 format and broadcast the threat message over the DSRC radio to any other DSRC radio within range.

The content of the EVA message is described in Table B-1.

EVA Receiver

This module will receive and processes EVA messages. This module will be responsible for managing the list of responder vehicles in the incident zone, keeping that list of vehicles and their associated locations current from the stream of EVA messages, and discarding redundant EVA messages.

In the responder vehicle, this module will also hand off the results to the ruggedized laptop Bluetooth Sender for recording and incident zone management in the responder's Computational Platform and User Interface component.

TIM Generator

This module will collect data from the VITAL Vehicle Data Interface and the GPS Location Services to populate an updated data structure for the Traveler Information Message.

TIM Broadcast Timer

This will be an OS Timer used to invoke the TIM Broadcast Controller on a 10 Hz frequency.

TIM Broadcast Controller

This module will retrieve the latest data structure containing the data required to create the Traveler Information Message from shared storage and send it to the TIM Broadcast module.

TIM Broadcaster

In a single, designated responder vehicle, the Traveler Information Message Broadcaster will broadcast the current TIM over the DSRC radio to any other DSRC radio within range at 1 Hz. The designated vehicle will be determined by the Incident Zone Broadcast Management module.

The content of the TIM message is described in Table B-2.

Chapter 7 INC-ZONE Threat Determination

At the heart of the INC-ZONE application will be the algorithms for determining when an oncoming vehicle becomes a discernable threat to a responder or vehicle within the incident zone. This section describes this important aspect of the application.

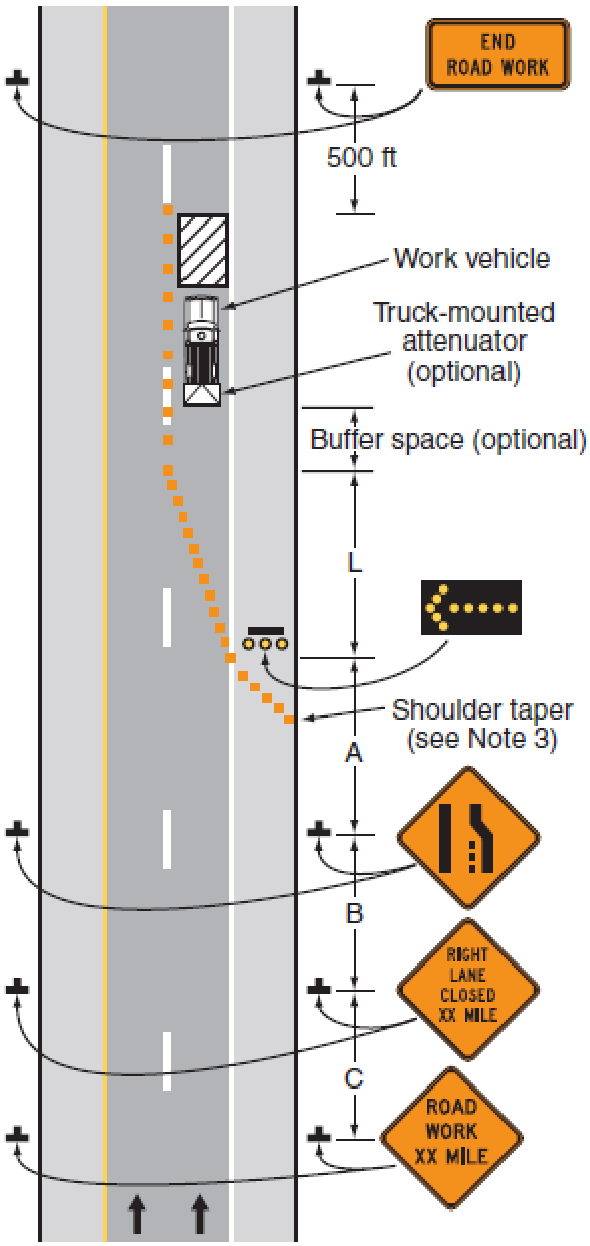
Speed and Lane Violation Determination

The objective of the INC-ZONE application is to deliver vehicle-based advisories, alerts, and warnings that notify the oncoming driver of potentially unsafe vehicle speeds and/or need to change lanes in sufficient time and to slow the vehicle to the advisory or posted speed prior to and within the incident zone. Additionally, the application is intended to deliver alert and warning messages to on-scene workers when an oncoming vehicle speed or position threatens their safety.

The INC-ZONE application assumes reduced speeds for the incident zone are determined by local policy and that they are fixed throughout the zone (e.g., do not vary with vehicle type). Designated safe advisory or posted speeds may change for the type of incident zone, visibility, or weather conditions. Incident details are entered by the scene commander using CapWIN at the scene of the incident, including details regarding speed and lane closure restrictions, which may be changed as the incident zone evolves. This input affects the pre-determined location for the beginning of the safety zone. The safety zone includes the incident zone and a buffer zone around and in advance of the incident zone. The incident zone is more narrowly defined as the restricted area where on-scene workers and responder vehicles are present, the beginning point of which is defined by the location of responder vehicles.

The INC-ZONE application addresses shoulder or lane closures that are typical for an incident zone even though they are also not usually marked in advance by signage or lane markings due to their temporary nature. As such, the INC-ZONE application will issue messages for reduced speeds and shoulder/lane closures based on a designated safety zone. Vehicles approaching the safety zone are expected to travel at the advisory or posted speed and be in the appropriate lane throughout the duration of the safety zone. Shoulder and lane closures technically begin at the Incident Zone, which is marked by the presence and lights on responder vehicles, but the lane closure (and reduced speed) messages intend for all approaching vehicles to have merged out of the closed lane by the beginning of the safety zone. Message graphics, the timing/advanced distance for issuing messages, recommended speeds, and the boundaries for the safety zone will be based on guidance in the Manual of Uniform Traffic Control Devices (MUTCD) for temporary traffic control zones, such as that illustrated in Figure 7-1. Because INC-ZONE uses in-vehicle messaging and not roadside signage, this guidance will be adapted, as necessary.

While speed reduction is required in INC-ZONE for safety, it may not represent an imminent threat of a crash. Consequently, even though the application issues reduced speed advisories, alerts, and warnings, it prioritizes messages regarding the need to merge, which is a more crash-imminent threat.

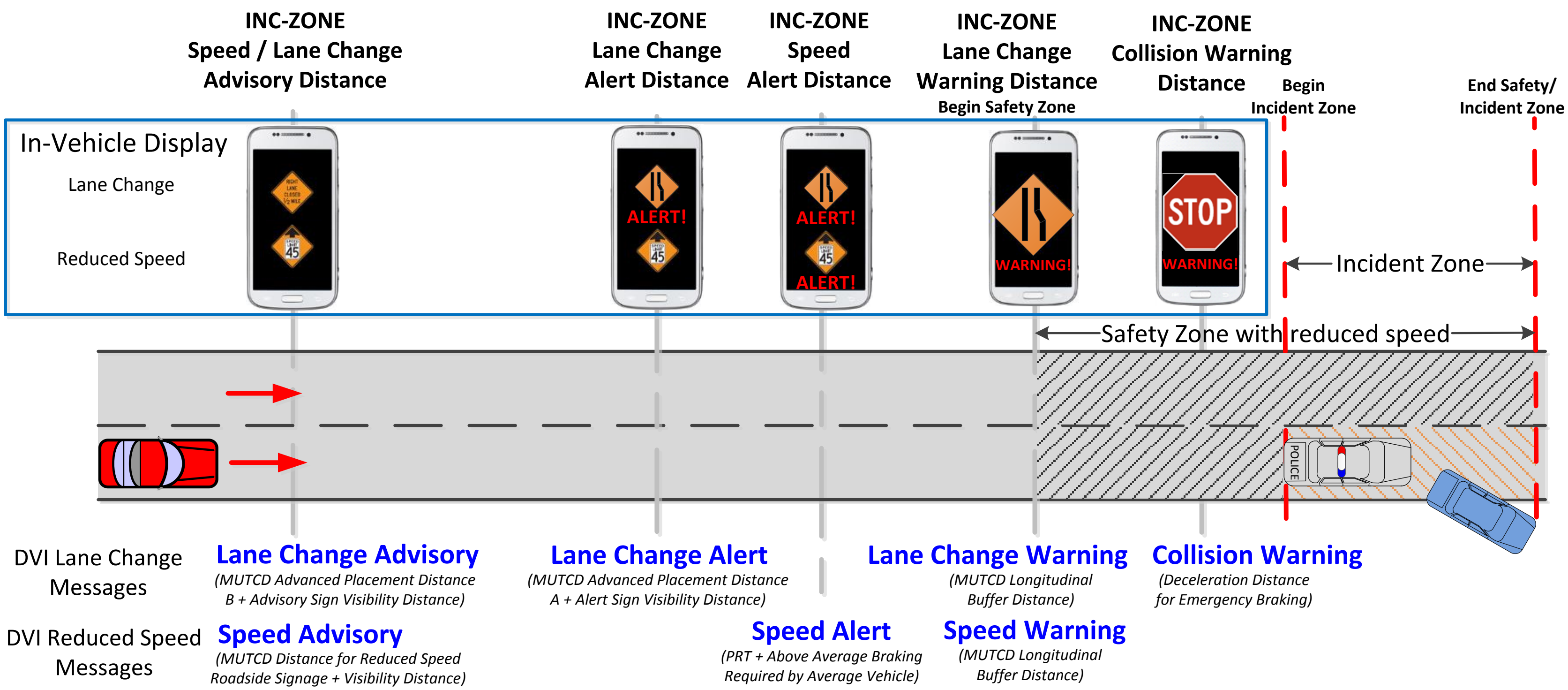


Source: MUTCD

Figure 7-1. MUTCD Depiction of a Temporary Traffic Control zone (MUTCD Figure 6H-33)

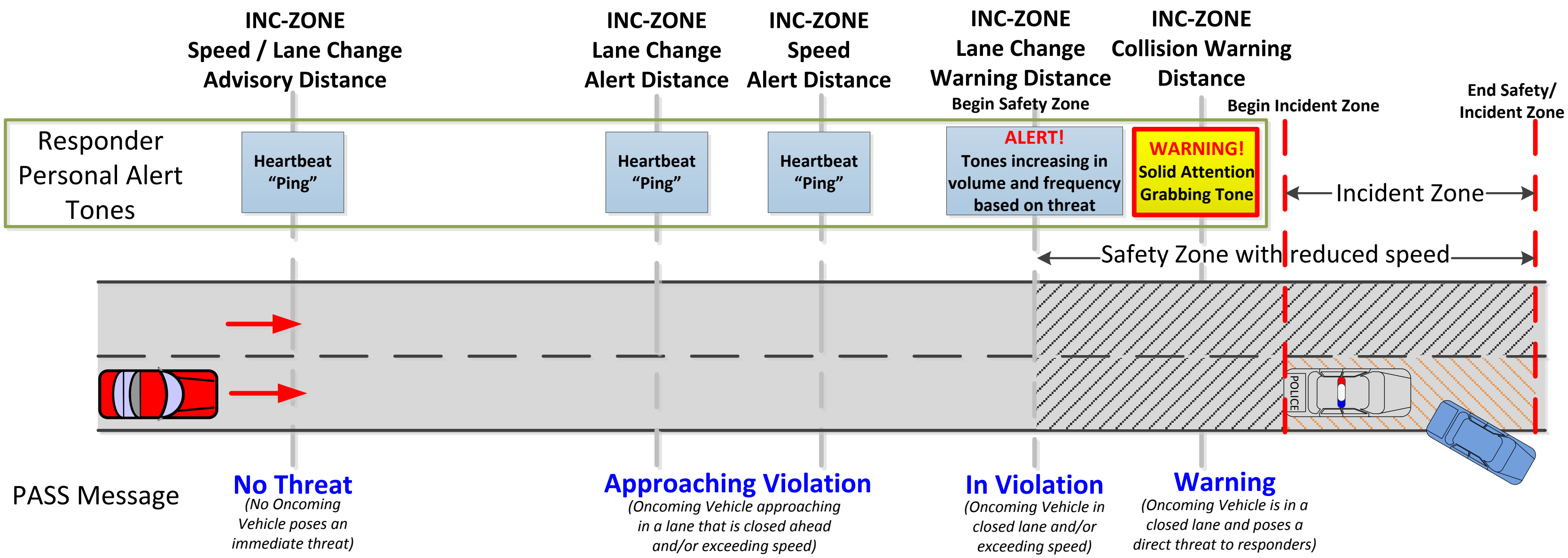
Figure 7-2 and Figure 7-3 illustrate INC-ZONE in-vehicle signage and responder message concepts. The figure shows the vehicle approaching an incident zone. The box above the roadway in Figure 7-2 illustrates the *in-vehicle signage* displays on the vehicle DVI. The boxes above the roadway in Figure 7-3 illustrate *responder messages* displayed to on-scene workers with a Personal Alert Safety Subsystem (PASS). These illustrations portray the oncoming vehicle with a graphical Driver Vehicle Interface (DVI) display and the responder messages as audio-based. As the vehicle approaches the incident zone illustrated in Figure 7-2, the Oncoming Vehicle Application Component receives a wireless Emergency Vehicle Alert (EVA) and Traveler Information Message (TIM) from the responder vehicle containing the incident zone location and map data, and advised or posted speed for the safety zone, which is a buffer area that includes the incident zone.

Given a shoulder or lane closure within the incident zone, the DVI displays closure advisories and vehicle-specific alerts simultaneously with reduced speed advisories and alerts, as described by the MUTCD. In Figure 7-2 the driver first receives an advisory message informing the driver of an impending incident zone, any shoulder or lane closures, and the advisory or posted speed for all vehicles at approximately the same time that a driver would typically observe a static roadside advisory signs for this information. If no speed alerts or warnings are warranted subsequently, the DVI continues to display an INC-ZONE Speed Advisory continuously until the vehicle exits the safety zone. Similarly, if an oncoming vehicle approaches the incident zone in the correct lane, the DVI continues to display the INC-ZONE Closure Advisory until the beginning of the incident zone. On-scene responders continue to receive a PASS No-Threat Message, which consists of a heartbeat “ping”. The Driver Vehicle Interface (DVI) message may include a graphic or text indicating the need to merge for a closed shoulder or lane, such that shown in Figure 7-4, with an accompanying reduced speed ahead graphic or text and the advisory or posted speed limit, such as that shown in Figure 7-5.



Source: Battelle

Figure 7-2. Illustration of the Issuance of In-Vehicle Advisory, Alert and Warning Messages based on Oncoming Vehicle Proximity to the Safety Zone, Incident Zone, and Responder Vehicle



Source: Battelle

Figure 7-3. Illustration of the Issuance of Responder PASS Advisory, Alert and Warning Messages based on the Threat of an Oncoming Vehicle Threat based on its Proximity to the Safety Zone, Incident Zone, and Responder Vehicle

For INC-ZONE deployments with shoulder or lane closures, appropriate advisory and alert signage may be displayed simultaneously with reduced speeds, or issuance may be staggered depending upon appropriate advisory and alert distances for informing the driver. In-vehicle alert messages are given precedence (i.e., appearing before or first in the message) over advisory messages. The order of precedence in descending order for displaying DVI messages is warning, alert, and advisories. When a warning is warranted, the INC-ZONE application will display the warning message by itself. The order of precedence for displaying DVI warning messages is based on crash imminence and is, in descending order: collision warnings, lane closure warnings, and speed warnings.

Source: MUTCD 2009 Ed.

Figure 7-4. Example of Signs Used to Indicate a Changed Roadway Configuration Involving a Lane Closure

Source: MUTCD 2009 Ed.

Figure 7-5. Example of Signs Used to Indicate a Reduction in the Speed Limit Ahead

If the driver fails to change lanes and/or reduce speed, he or she receives a DVI Alert Message to do so. At this time, on-scene responders receive a PASS message that an oncoming vehicle is on the verge of being in violation and may pose a threat. When the subject vehicle fails to change lanes, the INC-ZONE Vehicle Application Component issues a Lane Closure Alert based on the vehicle distance from the beginning of the safety zone. The INC-ZONE DVI Lane Closure Alert Distance is a distance at which the vehicle *should merge immediately* into a through lane prior to the entrance to the safety zone. Likewise, if the vehicle approaches the incident zone above the advisory or posted speed, (i.e., recommended speed or enforceable speed limit, respectively) beyond the point where aggressive braking is required to achieve the advisory or posted speed prior to entering the safety zone, an INC-ZONE Speed Alert is issued by the DVI to the driver. The distance at which an INC-ZONE Speed Alert is issued to the driver is based on the oncoming vehicle speed and acceleration capability as shown in the equation below:

$(x - x_0) = (v_f^2 - v_0^2) / (2a)$

Equation 1

Either of these messages prompts the issuance of a PASS Approaching Violation Message to on-scene workers.

If oncoming vehicle enters the safety zone in an imminently closed lane or exceeding the advisory or posted speed, the driver receives a DVI Warning Message to change lanes or reduce speed, respectively. The INC-ZONE DVI Lane Closure Warning Distance is the MUTCD buffer distance in advance of the incident zone where the vehicle *should have already merged* to avoid a collision with emergency vehicles or debris within the incident zone. If the vehicle is in violation of both the speed and lane restrictions for the incident zone, only the DVI Lane Closure Warning Message will be given because this is crash imminent and a prioritized message. Whenever an oncoming vehicle issues a warning message, the on-scene responder receives a PASS In Violation Message that an oncoming vehicle is in violation of safety zone speed and closure restrictions and could pose an imminent threat.

Alert and Warning Distances are not vehicle specific. Lane Closure Alerts are based on the MUTCD Advanced Placement Distance, Speed Alerts are based on a generic vehicle aggressive braking deceleration rate for the oncoming vehicle speed, and the Lane Closure and Speed Warnings are based on the MUTCD Buffer Zone.

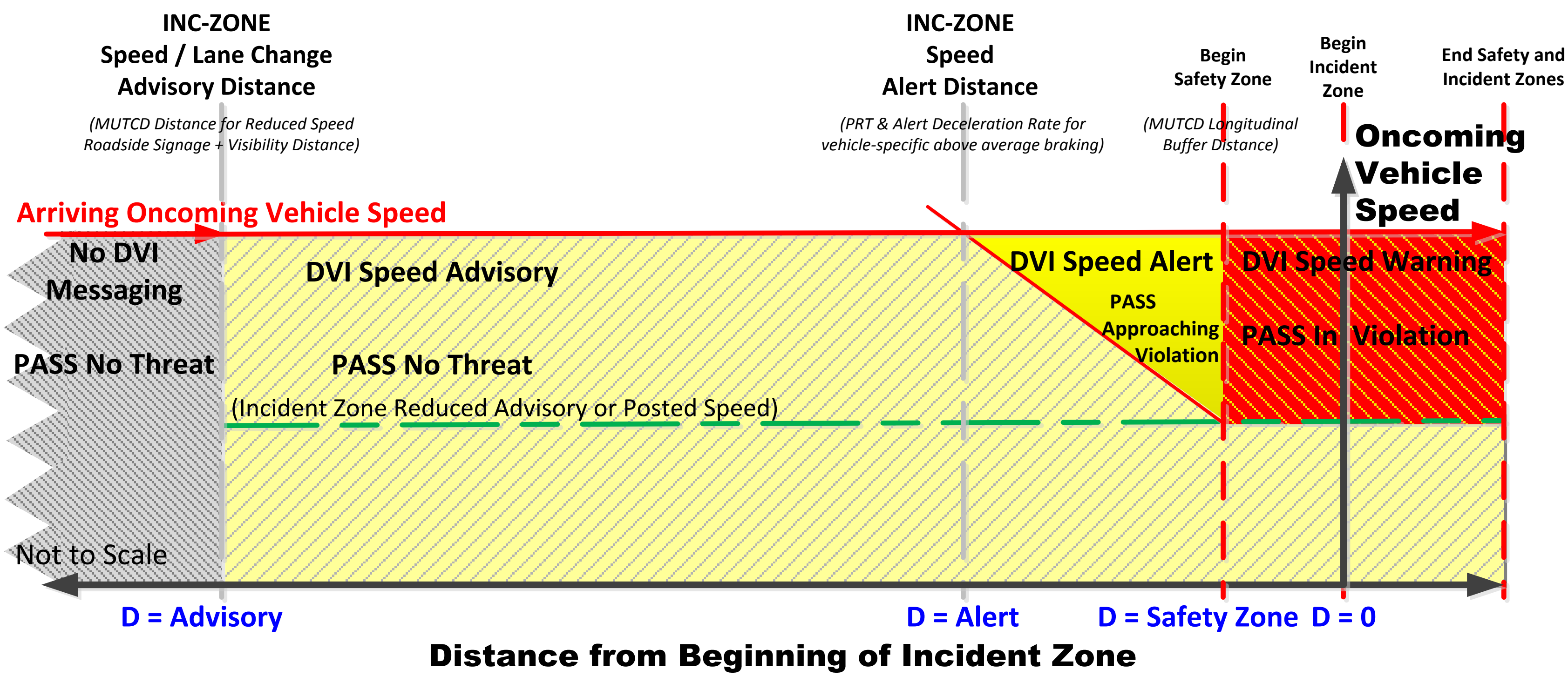
If the oncoming vehicle decelerates to the advisory or posted speed before the Speed Alert Distance thresholds are crossed, no DVI alert or warning are issued. As noted earlier, an INC-ZONE Speed Advisory is displayed by default through the end of the safety zone. Likewise, when the oncoming vehicle merges out of the closed lane, the DVI Lane Closure Alert or Warning is no longer displayed. If the oncoming vehicle merges into a through lane before the Alert or Warning Distance thresholds are crossed, no INC-ZONE DVI Lane Closure alerts or warnings are issued. Regardless, an INC-ZONE Closure Advisory is displayed until the beginning of the incident zone.

As discussed in the next section, after receiving a DVI Lane Closure Message, collision warning messages are issued if the oncoming vehicle proximity to a stopped responder vehicle in the closed lane is determined to be crash imminent

Figure 7-6 illustrates speed advisories, alerts, and warnings displayed within the oncoming vehicle and to responders as a function of vehicle speed and distance from the entrance to the Safety Zone. The Speed Advisory Distance is based upon the MUTCD advanced placement distance and the sign visibility distance, and is the same point where a driver would see (i.e., receive) the message from the sign. The INC-ZONE DVI Speed Alert Distance is the distance at which *above average braking* is required by the *specific vehicle* to achieve the INC-ZONE Speed at the entrance to the Safety Zone. If the oncoming vehicle exceeds the advisory or posted INC-ZONE speed within the safety zone, a DVI Speed Warning Message and PASS In Violation Message are issued. The beginning of the safety zone is set as the MUTCD Buffer Distance in advance of a temporary traffic control area. The INC-ZONE Speed is supplied to the vehicle application component by the responder vehicle via the TIM for INC-ZONE messages.

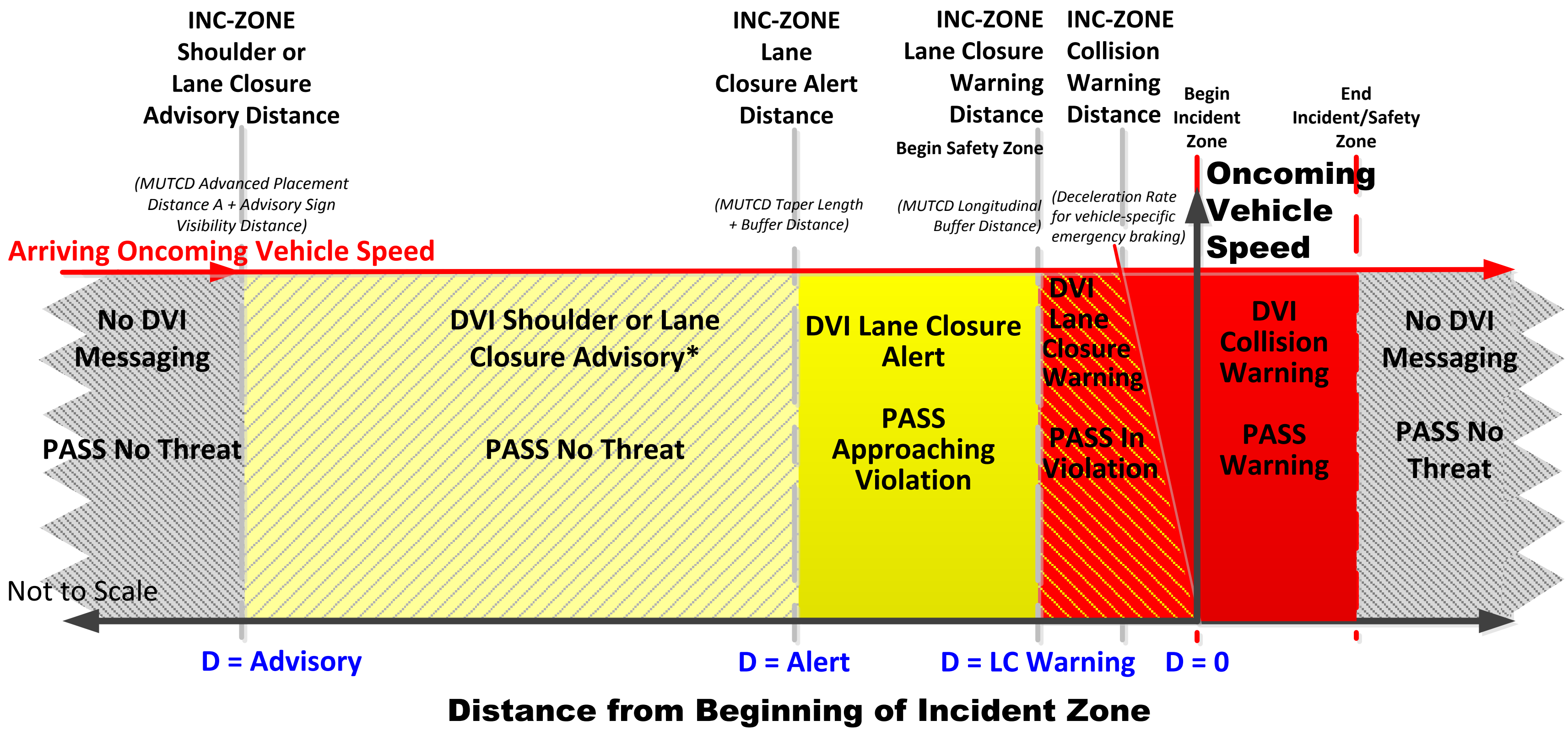
Figure 7-7 illustrates Shoulder and Lane Closure advisories, alerts, and warnings and Collision warning displayed within the oncoming vehicle and to responders as a function of vehicle distance from the end of the lane and proximity to the safety zone and responder vehicles within the incident zone. It illustrates the Lane Closure Advisory Distance and Lane Closure Alert Distance, which are functions of MUTCD Advanced Placement Distances and sign visibility distances, and the Lane Closure Warning Distance is the beginning of the MUTCD-defined buffer zone in advance of the incident zone. The distances at which Speed alerts and Lane Closure alerts are issued are not expected to coincide. The distances at which Speed Advisories and Lane Closure Advisories are issued could coincide.

Figure 7-9 below shows the processes and inputs for the oncoming vehicle and responder vehicle to issue INC-ZONE advisory, alert, and warning messages. Table 7-5 provides definitions of the terms used here for the INC-ZONE advisory, alert and warning messages. Table 7-6 provides a tabular summary of the INC-ZONE DVI and responder PASS display advisory, alert and warning criteria, the correlation between these two message sets, display signage and their distances from the entrance to the safety and incident zones and, where applicable, the end of the lane. It is expected that a shoulder or lane closure message will coincide with a reduced speed message. With the exception of warnings, the closure and speed messages are expected to be shown simultaneously. In general, alerts have priority over advisories. Because Lane Closure is considered crash imminent while Reduced Speed or Shoulder Closure is not, Lane Closure messaging has priority over Reduced Speed.



Source: Battelle

Figure 7-6. Illustration of Speed-related In-vehicle Signage (DVI) and Responder Messages (PASS) as a Function of Vehicle Speed and Distance from Beginning of Incident Zone, with or without a Shoulder or Lane Closure



*Note that shoulder closures do not merit alerts or warnings; only a DVI Advisory Message will be issued through the end of the Incident/Safety Zone

Source: Battelle

Figure 7-7. Illustration of Lane Closure Related In-vehicle Signage (DVI) and Responder Messages (PASS) as a Function of Vehicle Speed and Distance from Start of an Incident Zone

The MUTCD provides guidance for a series of advisory messages that should be given in advance of the temporary traffic control zone. The distances between these messages are described by Table 7-1. Because the INC-ZONE DVI advisory is continuously displayed in advance of the incident zone (unless an alert or warning is warranted), the INC-ZONE application does not require three separate messages, but instead will use the sum of Distance A, Distance B, and Distance C plus a sign legibility distance (to account for the fact that a driver would see a sign in advance of its placement distance) as the point for issuing the initial advisory message. Given limitations in the DSRC range, it is unlikely that drivers will receive an advisory message as early as is recommended by the MUTCD, and instead will receive the advisory message upon entering the DSRC range. The distances in this table are illustrated in Figure 7-1.

Table 7-1. MUTCD Guidelines for Advance Placement of Signs for a Temporary Traffic Control (TTC) Zone to Be Used for Issuing DVI Advisory Messages

Road Type	Distance Between Signs**		
	A	B	C
Urban (low speed)*	100 feet	100 feet	100 feet
Urban (high speed)*	350 feet	350 feet	350 feet
Rural	500 feet	500 feet	500 feet
Expressway / Freeway	1,000 feet	1,500 feet	2,640 feet

* Speed category to be determined by the highway agency
** The column headings A, B, and C are the dimensions shown in Figures 6H-1 through 6H-46. The A dimension is the distance from the transition or point of restriction to the first sign. The B dimension is the distance between the first and second signs. The C dimension is the distance between the second and third signs. (The "first sign" is the sign in a three-sign series that is closest to the TTC zone. The "third sign" is the sign that is furthest upstream from the TTC zone.)

Source: MUTCD, Table 6C-1

The MUTCD provides guidance for taper length, which is intended as additional distance for placing orange barrels or flares across the closed lane to direct vehicles to merge. Because it is the point at which vehicles should be actively merging, the beginning of the taper length marks the point at which a DVI Lane Closure Alert will be issued, as directed in Table 7-2.

Table 7-2. MUTCD Guidelines for Taper Length in Advance of Incident Zone Work Space to Be Used for Issuing the DVI Lane Closure Alert Message

Speed (S)	Taper Length (L) in feet
40 mph or less	$L = WS^2 / 60$
45 mph or more	$L = WS$

Where:

- L = taper length in feet
- W = width of offset in feet
- S = posted speed limit, or off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed in mph

Source: MUTCD, Table 6C-4

Table 7-3 below comes directly from MUTCD Section 2C.05 and provides guidelines for the advance placement of signs, specifically in regards to a reduction in speed. This guidance can inform the timing for the issuance of DVI speed reduction messages for the oncoming vehicle prior to the safety zone, as well as inform the issuance of the collision warning message. The distances in this table are for the placement of signs, but footnotes indicate that drivers are expected to view the sign an extra 180-250 feet in advanced based on estimated sign legibility distance. Thus, the distance where the DVI would issue a message should be based on the appropriate value in the table plus the sign legibility distance listed in the respective footnote. The first column of Table 7-3 lists posted or 85th-percentile speeds on the roadway (whichever is higher on the roadway is to be used), by which to establish the distance for placing advance warning signs. The second column, "Condition A" would pertain to INC-ZONE scenarios when a lane closure is present. The "Condition B" columns (except for the "0" column) would pertain to DVI speed messages that are issued based on the oncoming vehicle distance to the safety zone.

Table 7-3. MUTCD Guidelines for Advance Placement of Warning Signs

Posted or 85th-Percentile Speed	Advance Placement Distance[1]								
	Condition A: Speed reduction and lane changing in heavy traffic[2]	Condition B: Deceleration to the listed advisory speed (mph) for the condition							
		0[3]	10[4]	20[4]	30[4]	40[4]	50[4]	60[4]	70[4]
20 mph	225 ft	100 ft[6]	N/A[5]	—	—	—	—	—	—
25 mph	325 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
30 mph	460 ft	100 ft[6]	N/A[5]	N/A[5]	—	—	—	—	—
35 mph	565 ft	100 ft[6]	N/A[5]	N/A[5]	N/A[5]	—	—	—	—
40 mph	670 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—	—
45 mph	775 ft	175 ft	125 ft	100 ft[6]	100 ft[6]	N/A[5]	—	—	—
50 mph	885 ft	250 ft	200 ft	175 ft	125 ft	100 ft[6]	—	—	—
55 mph	990 ft	325 ft	275 ft	225 ft	200 ft	125 ft	N/A[5]	—	—
60 mph	1,100 ft	400 ft	350 ft	325 ft	275 ft	200 ft	100 ft[6]	—	—
65 mph	1,200 ft	475 ft	450 ft	400 ft	350 ft	275 ft	200 ft	100 ft[6]	—
70 mph	1,250 ft	550 ft	525 ft	500 ft	450 ft	375 ft	275 ft	150 ft	—
75 mph	1,350 ft	650 ft	625 ft	600 ft	550 ft	475 ft	375 ft	250 ft	100 ft[6]

1. The distances are adjusted for a sign legibility distance of 180 feet for Condition A. The distances for Condition B have been adjusted for a sign legibility distance of 250 feet, which is appropriate for an alignment warning symbol sign. For Conditions A and B, warning signs with less than 6-inch legend or more than four words, a minimum of 100 feet should be added to the advance placement distance to provide adequate legibility of the warning sign.
2. Typical conditions are locations where the road user must use extra time to adjust speed and change lanes in heavy traffic because of a complex driving situation. Typical signs are Merge and Right Lane Ends. The distances are determined by providing the driver a PRT of 14.0 to 14.5 seconds for vehicle maneuvers (2005 AASHTO Policy, Exhibit 3-3, Decision Sight Distance, Avoidance Maneuver E) minus the legibility distance of 180 feet for the appropriate sign.
3. Typical condition is the warning of a potential stop situation. Typical signs are Stop Ahead, Yield Ahead, Signal Ahead, and Intersection Warning signs. The distances are based on the 2005 AASHTO Policy, Exhibit 3-1, Stopping Sight Distance, providing a PRT of 2.5 seconds, a deceleration rate of 11.2 feet/second2, minus the sign legibility distance of 180 feet.
4. Typical conditions are locations where the road user must decrease speed to maneuver through the warned condition. Typical signs are Turn, Curve, Reverse Turn, or Reverse Curve. The distance is determined by providing a 2.5 second PRT, a vehicle deceleration rate of 10 feet/second^2, minus the sign legibility distance of 250 feet.
5. No suggested distances are provided for these speeds, as the placement location is dependent on site conditions and other signing. An alignment warning sign may be placed anywhere from the point of curvature up to 100 feet in advance of the curve. However, the alignment warning sign should be installed in advance of the curve and at least 100 feet from any other signs.
6. The minimum advance placement distance is listed as 100 feet to provide adequate spacing between signs.

Source: MUTCD, Table 2C-4

The third column, “0” might serve as inputs to guidance for the imminent collision warning for advanced warning when emergency is required. However, these values include perception-reaction time, but since oncoming drivers have been receiving other advisory and alert messages before a collision warning is issued, distance accounting for PRT can be removed. Further, values in this column account for a deceleration rate of 11.2 ft/s^2, whereas studies show that most drivers decelerate at a rate greater than 14.8 ft/s^2 when confronted with the need to stop for an unexpected object in the roadway[2].

Finally, as shown in Figure 7-1, the MUTCD defines an area known as the buffer space, which is a longitudinal area separating traffic flow from the work space (i.e., incident zone) that is intended to provide recovery space for an errant vehicle, e.g., driven by a distracted driver. The values shown in Table 7-4 are the MUTCD guidance for determining the length of this buffer space and are based on stopping sight distance as a function of the upstream posted speed on the roadway. The INC-ZONE application is designed such that the beginning of this buffer space marks the beginning of the safety zone, which extends to the end of the incident zone, where the advisory or posted speed and lane restrictions are in place (despite the lack of any visible cones, lane markings, or barrels to delineate the space).

The distances at which messages are issued to oncoming vehicles vary from MUTCD guidance for several conditions, such as visibility distance and DSRC range. For instance, the buffer space distance should be greater when horizontal or vertical curvatures obstruct the oncoming driver visibility of the incident zone. This is needed due to the increased risk posed to an incident zone by oncoming vehicles with limited visibility. Other distances at which messages are issued will increase, as needed. Conversely, the distances at which advisory messages are issued may be smaller than is indicated by MUTCD guidance due to limitations in the DSRC range.

Table 7-4. MUTCD Guidelines for Buffer Space in Advance of Incident Zone Work Space to Be Used for Setting the Beginning of the Safety Zone and Issuing DVI Lane Closure and Speed Warning Messages

Speed*	Distance
20 mph	115 feet
25 mph	155 feet
30 mph	200 feet
35 mph	250 feet
40 mph	305 feet
45 mph	360 feet
50 mph	425 feet
55 mph	495 feet
60 mph	570 feet
65 mph	645 feet
70 mph	730 feet
75 mph	820 feet

* Posted speed, off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed

Source: MUTCD, Table 6C-2

[2] "A Policy on the Geometric Design of Highways and Streets." 6th ed. American Association of State Highway and Transportation Officials, 2011.

Figure 7-8 provides an example of the timing and distances at which advisory, alert, and warning messages are issued based on MUTCD guidance. Again, note that due to the large distance from the incident zone to the location where an advisory message should be issued, this will likely be issued as soon as the oncoming vehicle enters the DSRC broadcasting range.

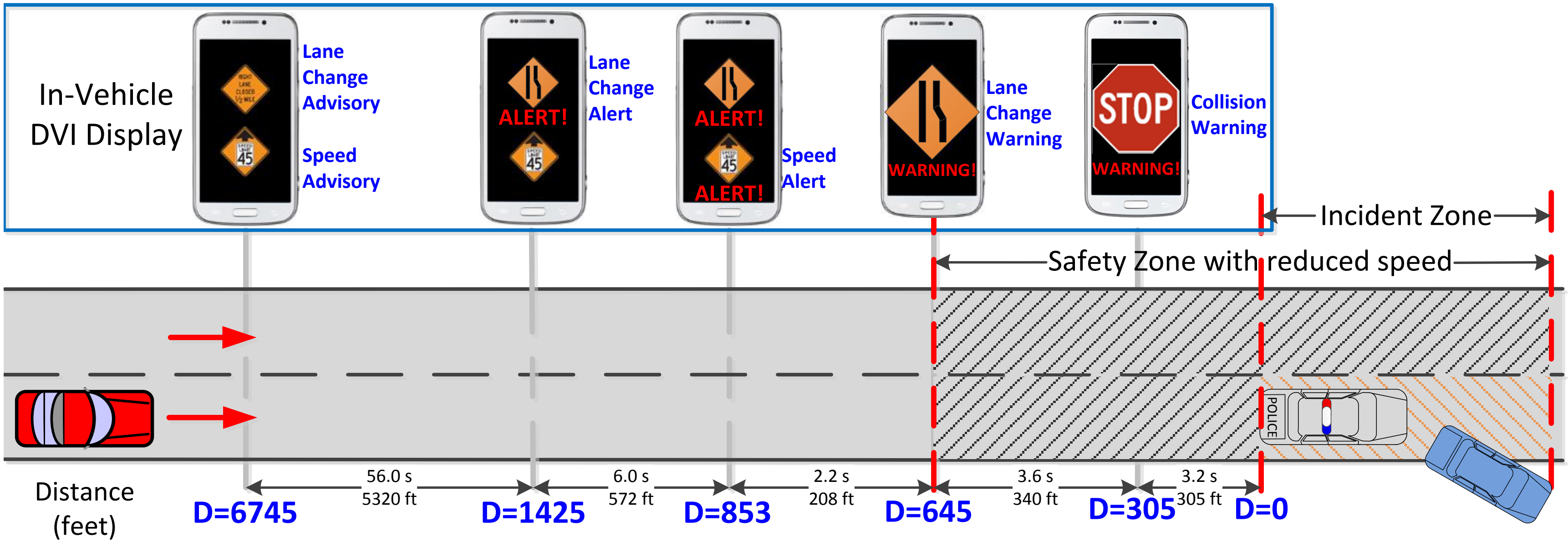


Figure 7-8. Example of the timing for issuing In-Vehicle Advisory, Alert and Warning Messages based on an Oncoming Vehicle traveling at a constant 65 mph in a closed lane and its distance to the beginning of the Incident Zone and nearest Responder Vehicle on a 65 mph freeway and a reduced speed of 45 mph

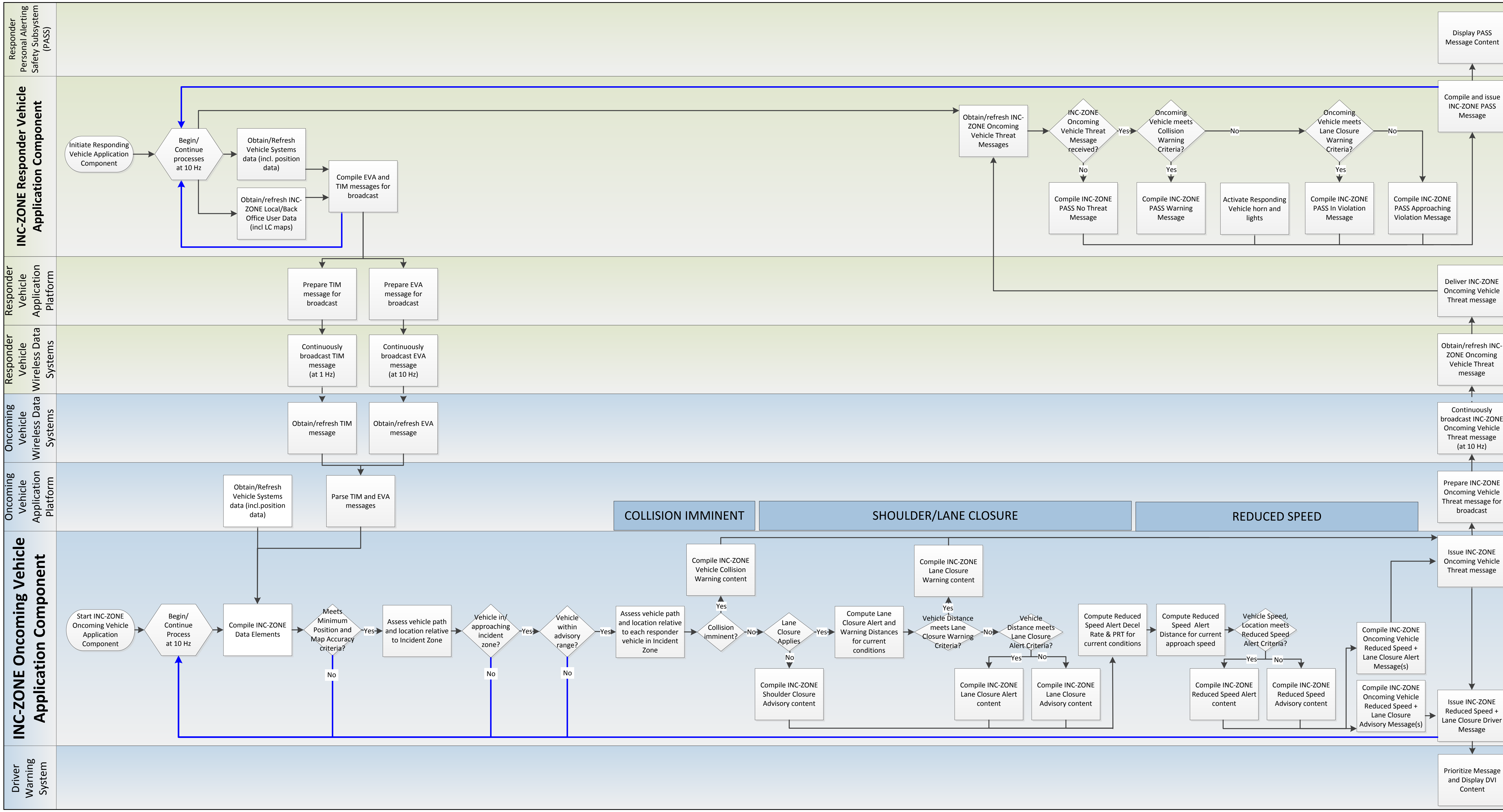


Figure 7-9. Swimlane Depicting the Processes for Determining and Issuing INC-ZONE Messages

Table 7-5. Definition of INC-ZONE Speed and Lane Violation Related Terms

INC-ZONE Speed	The reduced advisory or enforceable speed within the incident zone.
Incident Zone	An area encompassing the scene of a crash or incident, responder vehicles, on-scene personnel, and crash victims.
Safety Zone	An area encompassing the incident zone, a buffer zone in advance of the incident zone as defined by the MUTCD, and adjacent lanes. Reduced speeds and lane closure restrictions established for the roadway cross-section at the incident zone apply throughout the entire safety zone.
INC-ZONE DVI Speed Advisory	Informative in-vehicle message to drivers in oncoming vehicles indicating a reduced speed in the safety zone ahead. Displayed in conjunction with, but secondarily to, appropriate INC-ZONE DVI Lane Closure Advisory or INC-ZONE DVI Lane Closure Alert.
INC-ZONE DVI Shoulder or Lane Closure Advisory	Informative in-vehicle message to drivers in oncoming vehicles indicating a shoulder or lane closure in the incident zone ahead. Displayed in conjunction with appropriate INC-ZONE DVI Speed Advisory or INC-ZONE DVI Speed Alert, but given precedence over INC-ZONE DVI Speed Advisory for a through-lane closure.
INC-ZONE DVI Advisory Distance	Generic distance(s) at which to display INC-ZONE DVI Shoulder or Lane Closure Advisory and/or INC-ZONE DVI Speed Advisory messages. Message could be issued simultaneously or separately, based on MUTCD advanced placement plus sign visibility distance, MUTCD Table 6C-1, and/or local policy.
INC-ZONE DVI Speed Alert	Dynamic in-vehicle message to drivers in oncoming vehicles indicating that they must apply above average braking to transition to the reduced speed at the safety zone. Displayed in conjunction with appropriate INC-ZONE DVI Lane Closure Advisory (and given precedence) or INC-ZONE DVI Lane Closure Alert.
INC-ZONE DVI Speed Alert Distance	Vehicle-specific recommendation for distance at which to display INC-ZONE DVI Speed Alert on the oncoming vehicle DVI. Distance at which above average braking is required by the specific oncoming vehicle to achieve the INC-ZONE Speed at the entrance to the safety zone. Dependent upon perception-reaction time, INC-ZONE DVI Speed Alert Deceleration Rate, and current environmental conditions.
INC-ZONE DVI Speed Alert Deceleration Rate	Vehicle-specific recommendation regarding oncoming vehicle deceleration rate to the reduced speed used in computing DVI Speed Alert Distance.
INC-ZONE DVI Lane Closure Alert	In vehicle display indicating to the oncoming vehicle an escalating need to change lanes prior to the safety zone with a lane closure. Displayed in conjunction with, but given precedence over, appropriate INC-ZONE DVI Speed Advisory or INC-ZONE DVI Speed Alert.
INC-ZONE DVI Lane Closure Alert Distance	Vehicle specific recommendation for distance at which to display INC-ZONE DVI Lane Closure Alert in the vehicle DVI. Distance based on MUTCD Table 6C-1 and local work zone temporary traffic control plan.
INC-ZONE PASS Approaching Violation Advisory	Informative responder personal alert message that an oncoming vehicle has received an INC-ZONE Lane Closure Alert or Speed Alert, and is approaching but not yet inside closed or speed controlled lanes of the safety zone. However, given the trajectory the oncoming vehicle is certain to violate speed and/or lane guidance within the safety zone. No sound.
INC-ZONE DVI Speed Warning	In-vehicle message to drivers in oncoming vehicles indicating that are exceeding the INC-ZONE speed within the safety zone. Displayed alone.

INC-ZONE DVI Lane Closure Warning	In vehicle message issued when oncoming vehicle violates the lane closure restriction of the safety zone, indicating to the oncoming vehicle an urgent need to change lanes prior to the imminent end of lane. Takes precedence over any INC-ZONE DII Speed Advisory or INC-ZONE DII Speed Alert message and is displayed alone.
INC-ZONE DVI Lane Closure Warning Distance	Vehicle specific recommendation for distance at which to display INC-ZONE DVI Lane Closure Warning. Distance at which immediate action is required by the subject vehicle to avoid imminent danger at the end of lane at the beginning of the incident zone. Distance based on MUTCD buffer zones for temporary traffic control zones.
INC-ZONE PASS In Violation Alert	Informative responder personal alert message that an oncoming vehicle has received an INC-ZONE DVI Lane Closure Warning or DVI Speed Warning and is approaching the incident zone in violation of the safety zone closure and/or speed restrictions. A collision or near miss is likely if corrective action is not taken, beyond a configurable amount of time. The oncoming vehicle may pose a threat to on-scene responders and others within the incident zone. Consists of audible repeating tone with loudness increasing in proportion to excess speed, frequency of repeat tone in proportion to proximity of threatening vehicle, indicating a developing threat.

Source: Battelle

Table 7-6. Summary and Correlation between INC-ZONE Oncoming Vehicle and Responder Personal Alert Displays

<table>
<tr><th colspan="4">Driver Vehicle Interface (DVI)</th><th colspan="4">Responder Personal Alert Safety Subsystem (PASS) Interface</th></tr>
<tr><th>Message</th><th>Display Criterion</th><th>Display*</th><th>Distance from Safety Zone</th><th>Message</th><th>Display Criterion</th><th>Display*</th><th>Oncoming Vehicle Distance from Safety Zone</th></tr>
<tr><td>Reduced Speed Advisory</td><td>Received INC-ZONE TIM</td><td>DVI Speed Reduction Advisory: display in-vehicle advisory to reduce speed to the INC-ZONE speed prior to entering the safety zone.</td><td>MUTCD Advanced Placement Distance +
Sign Visibility Distance</td><td rowspan="2">No Threat</td><td rowspan="2">No INC-ZONE Oncoming Vehicle Alert Message received; this indicates no threat to on-scene workers.</td><td rowspan="2">No threat: no oncoming vehicle is in the immediate vicinity of the incident zone.</td><td rowspan="2">Greater than MUTCD Advanced Placement Distance +
Sign Visibility Distance</td></tr>
<tr><td>Shoulder or Lane Closure Advisory</td><td>Received INC-ZONE TIM.</td><td>DVI Closure Advisory: display in-vehicle advisory of upcoming shoulder or lane closure</td><td>MUTCD Advanced Placement Distance +
Sign Visibility Distance</td></tr>
<tr><td>Reduced Speed Alert</td><td>Received INC-ZONE TIM. Subject oncoming vehicle within distance at which above average braking is required to achieve the INC-ZONE reduced speed prior to entering the safety zone.</td><td>DVI Speed Reduction Alert: display in-vehicle advisory to reduce speed to the INC-ZONE speed prior to entering the safety zone.</td><td>Distance at which above average braking is required by subject vehicle to achieve the INC-ZONE Speed prior to entering the safety zone.</td><td rowspan="2">Oncoming Vehicle Advisory – Approaching Violation</td><td rowspan="2">Received INC-ZONE Oncoming Vehicle Alert Message</td><td rowspan="2">Approaching Violation: Oncoming vehicle is approaching a safety zone violation and has received an INC-ZONE reduced speed and/or lane closure alert.</td><td rowspan="2">MUTCD Advanced Placement Distance +
Sign Visibility Distance</td></tr>
<tr><td>Lane Closure Alert</td><td>Subject vehicle is in a non-through lane and the vehicle must merge prior to the safety zone.</td><td>DVI Closure Alert: vehicle-specific alert to merge into a through lane prior to safety zone.</td><td>Distance at which subject vehicle should already have merged into a through lane prior to the safety zone; MUTCD Advanced Placement Distance + Sign Visibility Distance.</td></tr>
</table>

Driver Vehicle Interface (DVI)				Responder Personal Alert Safety Subsystem (PASS) Interface			
Message	**Display Criterion**	**Display***	**Distance from Safety Zone**	**Message**	**Display Criterion**	**Display***	**Oncoming Vehicle Distance from Safety Zone**
Lane Closure Warning	Received INC-ZONE TIM. Oncoming vehicle is in a non-through lane and must merge immediately to avoid a collision at the lane termination.	DVI Lane Closure Warning: vehicle-specific warning to merge into a through lane prior to lane termination.	Distance at which subject vehicle must merge immediately to avoid a collision at the lane termination.	Oncoming Vehicle Alert – In-Violation	Received INC-ZONE Oncoming Vehicle Alert Message that at least one oncoming vehicle is in violation of safety zone reduced speed or lane closures.	In-Violation: Repeating tone, increasing volume in proportion to threat of oncoming vehicle. Oncoming vehicle is violating reduced speed and lane closure restrictions within safety zone, has been issued an in-vehicle alert, and may pose a threat to on-scene workers.	MUTCD Buffer Zone Distance at which vehicle should have already merged and/or be traveling at a reduced speed.
Reduced Speed Warning	Received INC-ZONE TIM. Oncoming vehicle is exceeding advisory or posted speed within the safety zone.	DVI Speed Warning: vehicle-specific warning to reduce speed.	MUTCD Buffer Zone Distance in advance of the incident zone.				

Note: where applicable, advisory and alert messages for reducing speed and a closure may be displayed together on the DVI. In general, alerts have priority over advisories. Because Lane Closure is considered crash imminent while Shoulder Closure or Reduced Speed is not, Lane Closure messaging has priority over Reduced Speed messaging. Lane Closure Warning is shown by itself with no other messaging, even if a Speed Warning is warranted.

Source: Battelle

Imminent Collision Determination

The imminent collision determination is based on the speed and distance of an oncoming vehicle to the “nearest” responder vehicle within the incident zone, as determined by responder vehicle list. The vehicle-specific distance threshold for emergency braking is based on the current speed and deceleration capability of the oncoming vehicle as shown in the equation below:

$$(x - x_0) = -v_0^2 / (2a)$$

Equation 2

When an oncoming vehicle passes the vehicle-specific distance threshold for emergency braking, based on the equation above, a DVI Collision Warning message is issued to the oncoming vehicle driver, as shown in Figure 7-2 above. Given an oncoming vehicle’s speed and position to the incident zone, a PASS Warning Message is issued to on-scene responders that they should immediately vacate the closed lane area, as shown in Figure 7-3 above. The timing and issuance of this message in relation to other INC-ZONE messages is shown in Figure 7-7. The swimlane in Figure 7-9 shows the inputs and process by which the imminent collision determination is made prior to issuing a DVI Collision Warning and PASS Warning.

A PASS Warning Message may be issued separately from a DVI Collision Warning Message. Responders need sufficient time to vacate the area threatened by an oncoming vehicle that is crash imminent. The time to collision after an oncoming vehicle is issued a DVI Collision Warning may not provide enough time for responders. Thus, a PASS Warning Message may be issued earlier than a DVI Collision Warning Message. Additionally, given the absence of responder vehicles within a closed lane of the incident zone, a PASS Warning Message is issued to responders when an oncoming vehicle receives a DVI Lane Closure Warning.

Table 7-7 provides definitions of the terms used here for the INC-ZONE Collision Warning. Table 7-8 provides a tabular summary of the INC-ZONE DVI and PASS Collision Warning criteria, the correlation between these two messages, display signage and the point at which they are issued. It is expected that a Collision Warning message will be issued after the oncoming vehicle has entered the safety zone and received a Lane Closure Warning. Although both apply, a Collision Warning takes precedence over a Lane Closure Warning Message (and every other INC-ZONE advisory, alert, or warning message) and is displayed alone. A Collision Warning is only issued based on the presence of responder vehicles, and is not intended to prevent incidents caused by an oncoming vehicle striking any debris within the incident zone.

Table 7-7. Definition of INC-ZONE Collision Warning Related Terms

Incident Zone	An area encompassing the scene of a crash or incident, responder vehicles, on-scene personnel, and crash victims.
INC-ZONE DVI Collision Warning	In vehicle display indicating to the oncoming vehicle driver to forcefully apply the brakes to prepare for an imminent collision with a responder vehicle within the incident zone. Takes precedence over any other INC-ZONE advisory, alert, or warning message and is displayed alone.
INC-ZONE PASS Warning	Informative responder personal alert message that an oncoming vehicle has received an INC-ZONE Collision Warning, will experience an imminent collision with a nearby responder vehicle, and is an imminent threat to individuals within the incident zone. Consists of solid audible, attention grabbing tone from the device and responder vehicle activation of horn and lights.

Source: Battelle

Table 7-8. Summary and Correlation between INC-ZONE Oncoming Vehicle and Responder Personal Alert Displays for Collision Warnings

Driver Vehicle Interface (DVI)				Responder Personal Alert Safety Subsystem (PASS) Interface			
Message	**Display Criterion**	**Display**	**Distance from Incident Zone**	**Message**	**Display Criterion**	**Display**	**Oncoming Vehicle Distance from Incident Zone**
Collision Warning	Received INC-ZONE EVA. Oncoming vehicle must take immediate action, i.e., emergency braking, to prepare for an imminent collision with a responder vehicle given its current speed and position.	DVI Collision Warning: vehicle-specific warning to forcefully apply brakes.	Distance at which collision or near miss with responder vehicle is imminent, unlikely that corrective action by oncoming vehicle possible, within a configurable amount of time. Likely issued in advance of the incident zone, but within the safety zone.	Oncoming Vehicle Warning	Received INC-ZONE Oncoming Vehicle Warning Message that at least one oncoming vehicle will imminently crash with a nearby responder vehicle.	Warning: Solid, attention grabbing tone, indicating an immediate and real threat by oncoming vehicle to individuals within the incident zone, who must leave the area as quickly as possible.	Distance for which time to collision allows sufficient time for responders to vacate the area, i.e., closed lane. Issued at a distance greater than or equal to DVI Collision warning.

Source: Battelle

Chapter 8 RESP-STG Component Description

This section identifies the components that will make up the RESP-STG application within the R.E.S.C.U.M.E. prototype system as seen both logically and physically.

Overview

As noted in the R.E.S.C.U.M.E. Concept of Operations, emergency responders do not currently have the capability to factor in all potentially important information that could be modeled to help them arrive and position themselves in a way that best supports the needs of the incident and the objectives of the incident commander. The purpose of RESP-STG is to provide this supplemental information to responders on-scene and en-route in order to improve situational awareness among all participants, including incident commanders and center-based users. In addition, the integration of this information with direct input from first responders in the field to the INC-ZONE Threat Detection and Alerting functions will help to improve the safety of first responders at the incident scene.

The primary components of the RESP-STG solution will be realized through specific enhancements to the CapWIN Mobile Client suite of applications and backend server infrastructure. Currently, the CapWIN Mobile Client provides the following capabilities:

- Incident information from transportation center systems via RITIS as well as CapWIN user created incidents. This information includes:
    - Incident Name
    - Incident Type
    - Incident Location (if available)
    - List of users who have “joined” the incident via the CapWIN Mobile Client
    - Incident log of system and CapWIN user updates to the incident information
    - Messaging (one-to-one and group) for incident participants

RESP-STG enhancements to the CapWIN Mobile Client include the following *new* functions:

- Real-Time AVL display for all responders denoting themselves as “On-Scene” or “En-Route” to the Incident scene, which includes information on the agency and discipline for each responder. The R.E.S.C.U.M.E. team will be using advanced AVL components providing “hyper accurate” (< 1M resolution) GPS location coordinates (X,Y’s) for responders.
- An interface to allow first responders identify the types of vehicles and the vehicles lane level positions on the incident scene

- Enhanced mapping functions and data, including:
  - New core mapping engine based on Open Street Maps
  - “Lane level” satellite imagery,
  - Hospital Locations
  - Highway Rerouting Plans
  - Live Traffic Data
  - Live Weather Data
  - Dash Cam video (if available).
  - Lane-Level AVL for all Incident Participants, including a visual denotation of each participant’s agency, discipline and asset

The CapWIN Mobile Client and supporting database (IBM DB2) will be modified to capture information on the type of vehicle (“asset”) used by each CapWIN user.

In addition to the enhancements to the CapWIN Mobile Client Suite, significant enhancements are also being made to the CapWIN server infrastructure and CapWIN Business Layer (CBL). Specific enhancements include:

- Creation of near real-time NIEM-compliant XML feed of CapWIN incident data, including CapWIN Mobile Client user updates for ingestion into the INC-ZONE Threat Determination and Alerting solution. This new Incident Feed will include lane condition status based on user input as well as center updates. The CapWIN XML Feeder will be available through a secure connection and can be accessed by other external consumers, including, but not limited to, transportation and emergency management center systems.
- Incorporation of near real-time AVL data from all CapWIN Mobile Client users who have denoted themselves as either on-scene or en-route to an incident scene. This AVL data is not currently captured or distributed by the CapWIN infrastructure and must be done so in a way to enable the real-time “push” of this location data to CapWIN Mobile Client users as well as to the CapWIN XML Feeder.

Integration with INC-ZONE

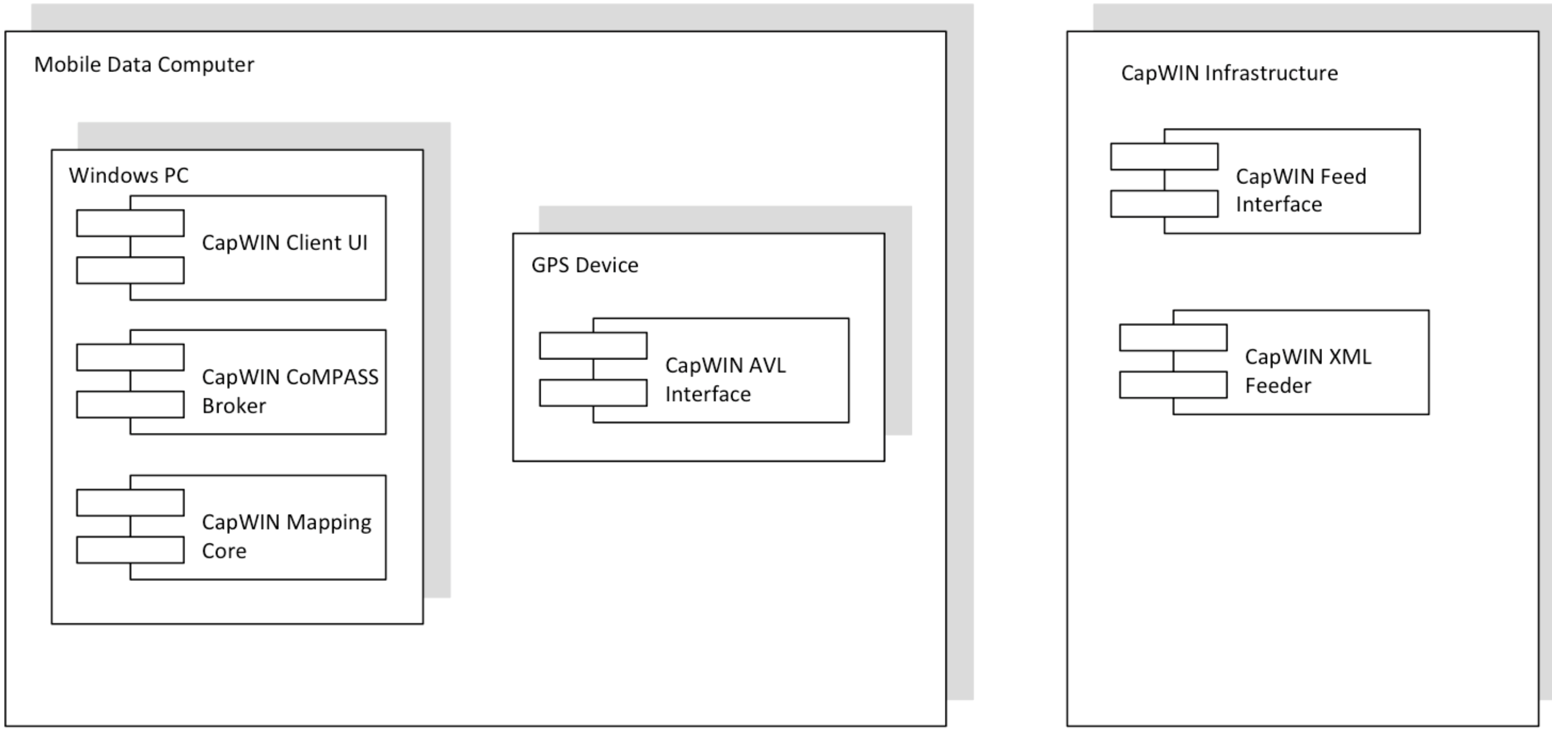
The primary data integration between RESP-STG and INC-ZONE supports the Threat Determination and Alerting function by providing near real-time information on lane status and first responder locations based on AVL data and user input made in the CapWIN Mobile Client. These data will be accessible to INC-ZONE via the CapWIN XML Feeder. This information will be algorithmically incorporated as part of the threat determination for alerting purposes.

Decomposition Description

The objective of this section is to divide the system into separate components that can be considered, implemented, changed, and tested with minimal effect on other entities. The RESP-STG system can be broken into a first level decomposition as follows:

- CapWIN Mobile Client Software/Infrastructure (CapWIN Business Layer)
- CapWIN Feed Interface
- CapWIN XML Feeder
- CapWIN Mapping Core
- CapWIN AVL Interface
- CapWIN CoMPASS Broker

Figure 8-1 shows a high level Deployment Diagram that models the physical deployment of the above components. In other words it depicts a static view of the run-time configuration of processing nodes and the components that run on those nodes.



Source: University of Maryland

Figure 8-1. High Level Deployment Diagram

Component Selection

Table 8-1 further specifies the specific make/buy components and the rationale for their use.

Table 8-1. Components selected for RESP-STG

Component	Selection Specifics	Rationale
CapWIN Mobile Client Software/Infrastructure	Panasonic Toughbook CF30/31/32 CapWIN Mobile Client Software V. 2.8.x CapWIN CBL 2.x	Existing field deployment across multiple first responder disciplines Support of existing incident management functions
CapWIN Feed Interface	CapWIN CBL 2.x	Long-term, existing interface to Regional Integrated Transportation Information System (RITIS)
CapWIN XML Feeder	CapWIN CBL 2.x	Existing NIEM-based XML feed of CapWIN user updates to CapWIN incidents (externally or internally generated)
CapWIN Mapping Core	CapWIN CBL 2.x	Existing CapWIN Mobile Client mapping core software (enables multiple standard (e.g., KML) dynamic and static mapping components
CapWIN AVL Interface	CapWIN Mobile Client Software 2.8x	Exiting NMEA compliant GPS/AVL interface supporting multiple GPS devices
CapWIN CoMPASS	CapWIN CoMPASS V 1.3	Existing MS Windows Pub/Sub Service that enables multiple peripheral device support

Source: University of Maryland

Chapter 9 RESP-STG Component Design

CapWIN Mobile Client/Infrastructure and CapWIN Business Layer (CBL)

The CapWIN Mobile Client software and backend infrastructure (CapWIN Business Layer (CBL)) incorporates a number of commercial and open source software components, including the CapWIN Mobile Client, a MS Windows 32bit Application and the set of backend services (CapWIN Infrastructure/CBL). The majority of these components will be utilized as part of the RESP-STG Component Design.

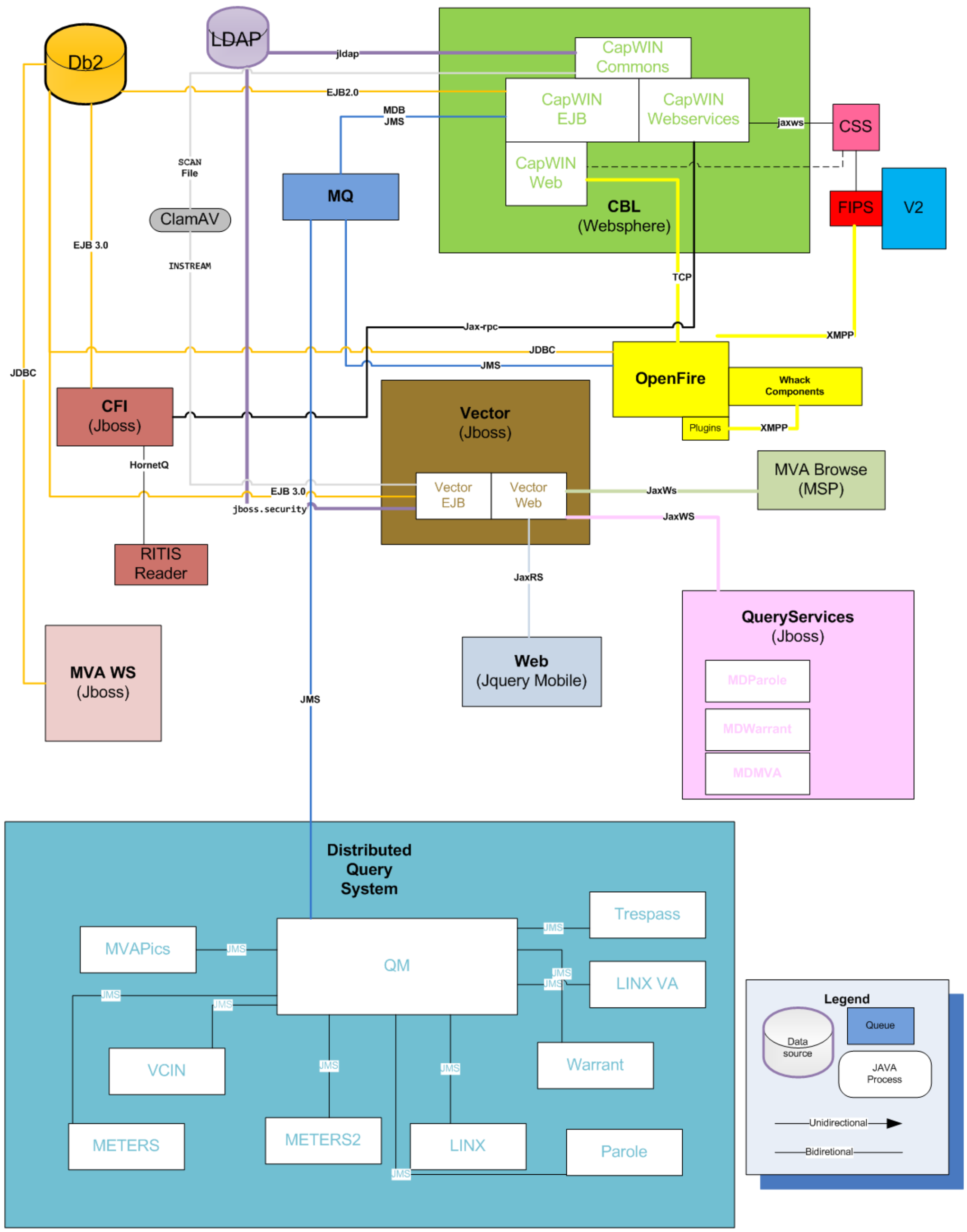
At a high-level, the CapWIN software architecture includes the following major elements:

- C# Web Services Client (CapWIN Mobile) Designed for Wireless Environments (Low and High Bandwidth)
- Java/J2EE Components Running on High Performance AIX and Linux servers
- XMPP Messaging Server (OpenFire)
- Custom software developed by the University of Maryland accesses Law Enforcement Databases

Figure 9-1 is a high-level software diagram denoting the primary CapWIN system components for the CapWIN Infrastructure. Shaded areas denote specific infrastructure elements and functions. The major elements are:

- **CBL**: CapWIN's "Business Layer," which serves as the primary web services interface to the CapWIN Mobile Client software, which is based, primarily, on web services calls.
- **DB2**: CapWIN's Enterprise database solution
- **LDAP**: CapWIN's authentication directory protocol
- **MQ**: CapWIN's messaging oriented middleware, enabling non-concurrent application communication
- **CFI**: CapWIN's interface to external data feeds based on the JBoss open source solution, (e.g., RITIS) and serves as the basis for CapWIN's Incident XML Feeder
- **OpenFire**: CapWIN's XMPP messaging core supporting all communications functions in CapWIN, including query responses through "pub-sub"
- **Distributed Query System**: CapWIN's java-based robust query solution supporting multiple interfaces to external criminal justice datasets

- **Vector JBoss**: CapWIN's mobile handheld solution, based on the JQuery javascript library.



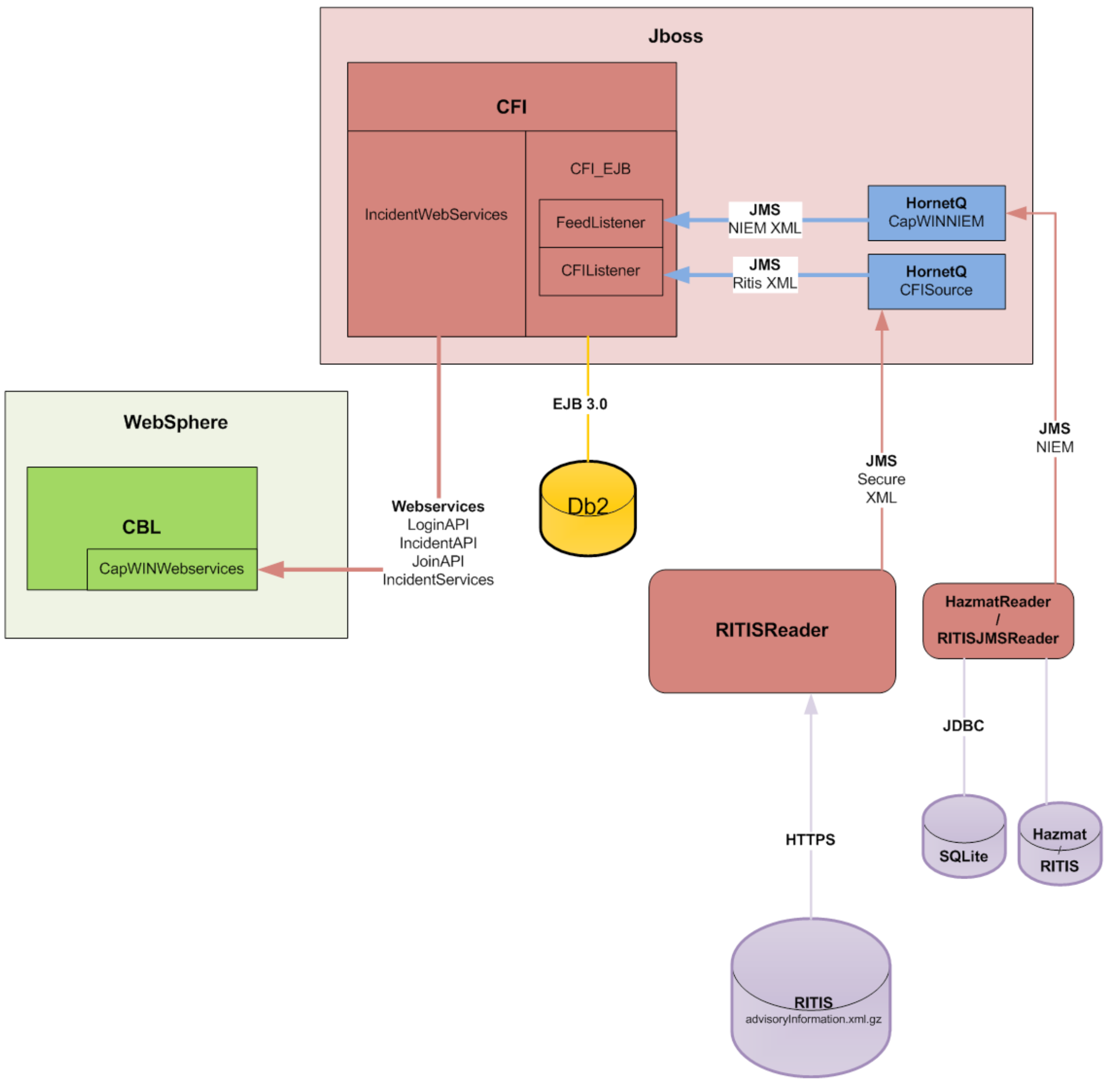
Source: University of Maryland

Figure 9-1. CapWIN Infrastructure

CapWIN Feed Interface (CFI)

The CapWIN Feed Interface (CFI) is a JBoss j2ee application. The main purpose of the application is to retrieve messages off a JBoss messaging queue, using a Message Driven Beans (MDB) and process these messages. These messages can be new incidents or updates to existing incidents. These messages are processed and updated or created as needed. New RITIS incidents are added to the database, as well as updates to older RITIS incidents. These incidents are then created in the CBL using Web Service calls. CFI was developed in Eclipse Indigo, using the JBoss plugin and a JBoss 7 server. RITIS Reader is a standard java process while CFI runs as a JavaEE project in the JBoss server.

Figure 9-2 provides a diagram of the information flow for CFI.



Source: University of Maryland

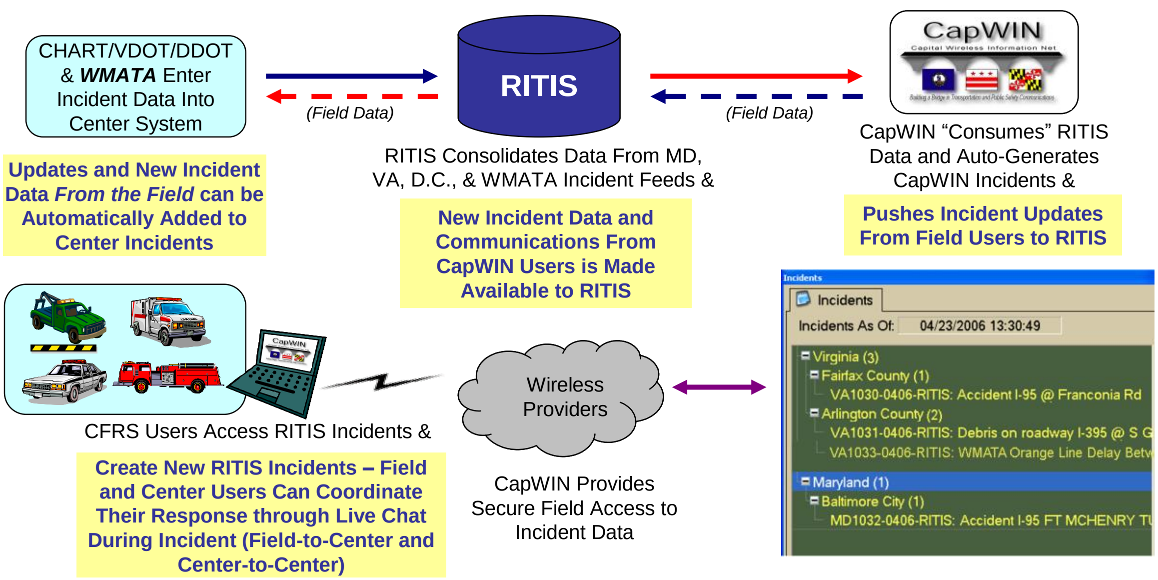
Figure 9-2. CapWIN Feed Interface

CapWIN XML Feeder

The CapWIN XML Feeder is an interface that posts xml of CapWIN incidents for other external clients to view. It runs on the same JBoss server as the CFI interface, with CFI being the input and the feeder being the output. SCP copies the xml over to the server to be posted. The feeder interface is a "cronjob" that runs every "X" seconds from the JBoss user: The xml is checked against the CapWIN incident schema: CapWINIncident.xsD.

The purpose of the CapWIN Feeder is to enable seamless data exchange across multiple systems and user interfaces. Data generated in a center based system, e.g., the MD CHART system is automatically ingested by the CapWIN CFI and presented to CapWIN mobile users in the field environment. User updates made via the CapWIN Mobile Client are then incorporated into the CapWIN Feeder XML which can then be ingested by external consumers, e.g., CHART and RITIS.

Figure 9-3 illustrates the flow of incident data from a center based system to the CapWIN infrastructure and client, and back again via the CapWIN Feeder.



Source: University of Maryland

Figure 9-3. CapWIN XML Feeder

CapWIN Mapping Core

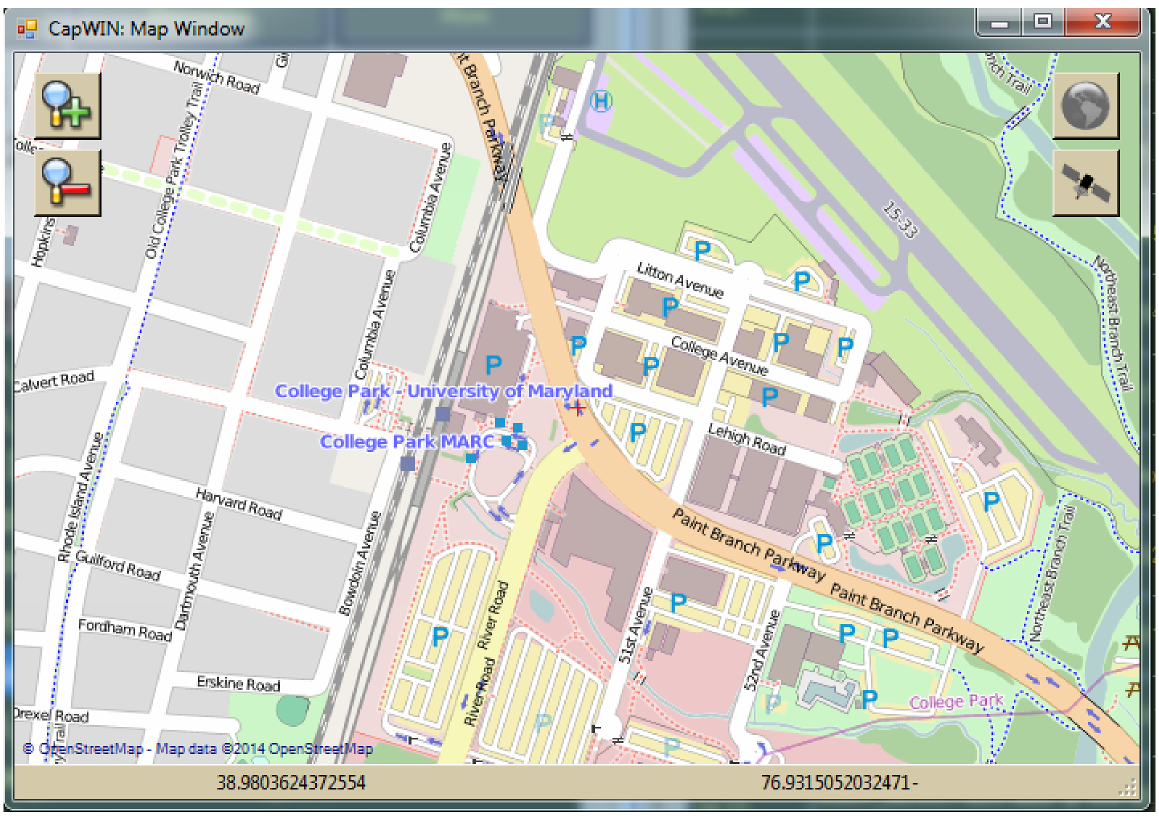
The CapWIN Mapping Core engine is a GIS framework for local and external GIS data built on the GMap.net open source .NET control. GMap enables routing, geocoding, directions and maps from Google, Yahoo!, Bing, OpenStreetMap, ArcGIS, Pergo, SigPac, Yendux, Mapy.cz, Maps.lt, iKarte.lv, NearMap, OviMap, CloudMade, WikiMapia, MapQuest in Windows Forms & Presentation, supports caching and runs on windows mobile environments.

The CapWIN Mobile Client uses GMap in a Windows Form integrated into the CapWIN Mobile Client C# development environment.

The following map layers will be incorporated into the CapWIN GMap solution as part of the R.E.S.C.U.M.E. prototype and accessed via the listed sources (in brackets):

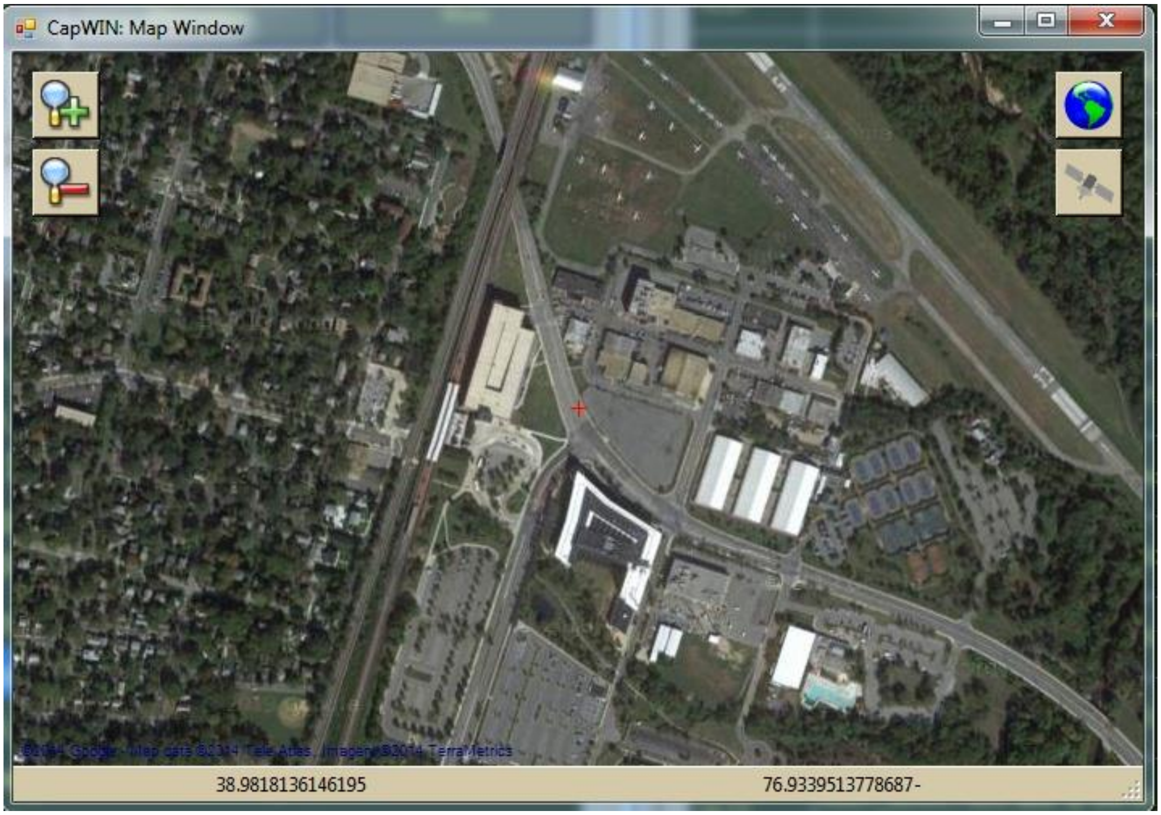
- Freeway Incident Traffic Management (FITIM) Plans [Local, client stored]
- Hospital Locations [MEMA]
- Live traffic speed [MEMA]
- Satellite Imagery with lane-level zoom [Google/MEMA]
- Live Weather [NOAA]
- On Scene and En-route Users will be displayed on Incident Map (refresh every 20 seconds) [CapWIN AVL Interface]
- Hazmat Data [MEMA]
- Dash Cam Video [Maryland State Highway Administration]

Figure 9-4, Figure 9-5, and Figure 9-6 provide sample screenshots of the GMap interface displaying base maps from OpenStreetMap and Google Satellite.



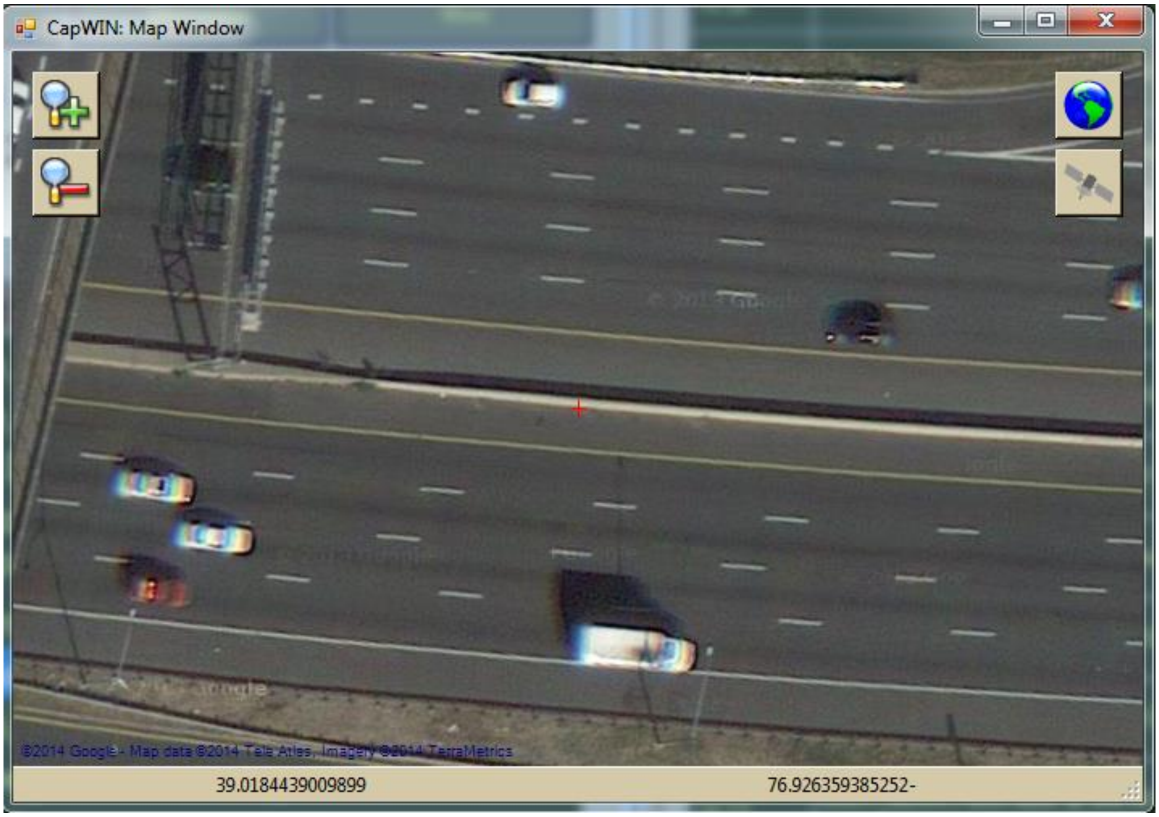
Source: University of Maryland

Figure 9-4. OpenStreetMap



Source: University of Maryland

Figure 9-5. Google Streetmap



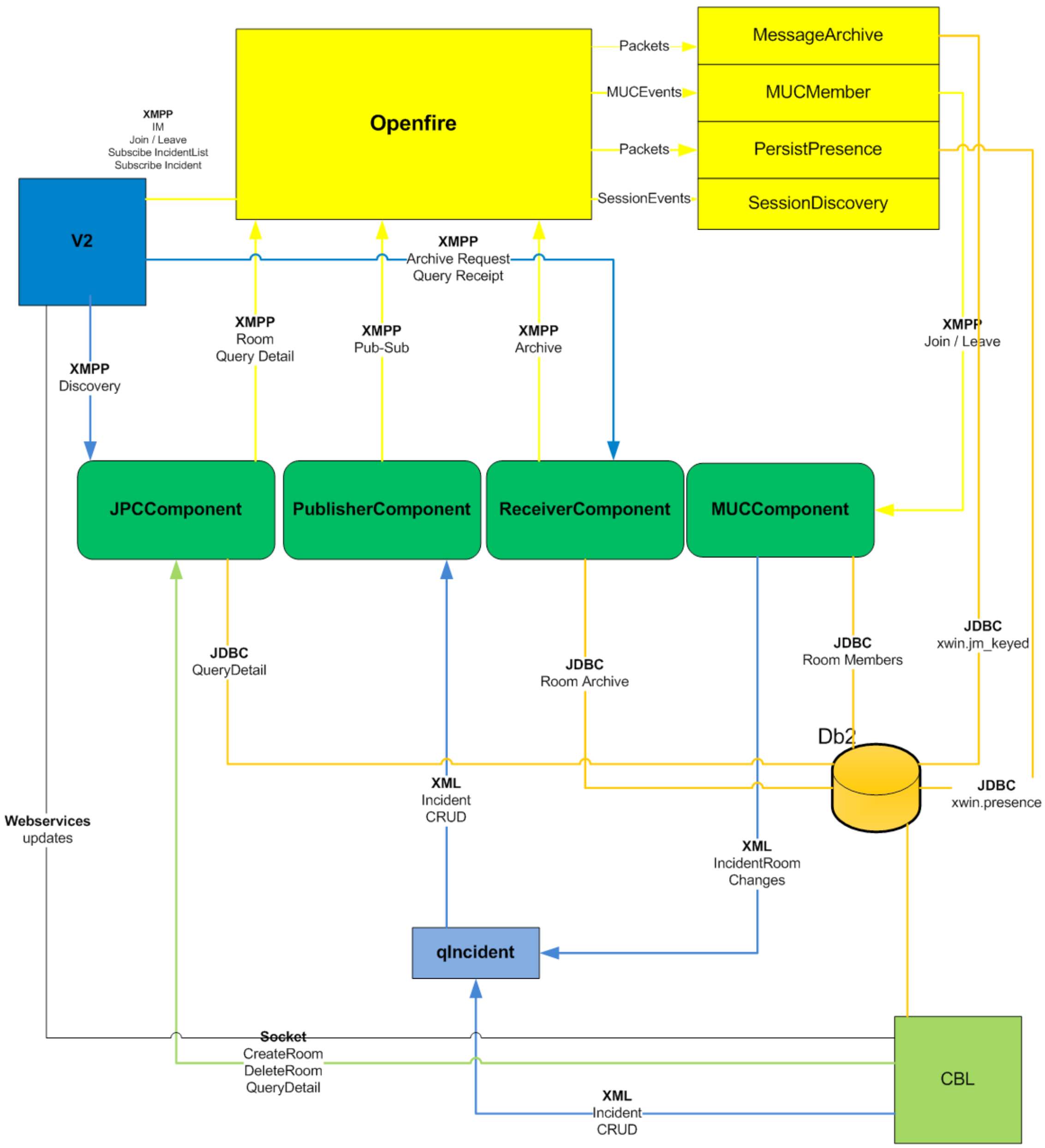
Source: University of Maryland

Figure 9-6. Google Streetmap

CapWIN AVL Interface

The CapWIN AVL interface uses a CapWIN Jabber (OpenFire) component to insert X/Y coordinate values from the CapWIN Mobile Client (V2) in postgres using postgis functionality. The CapWIN Geoserver uses postgis to display the coordinates on the CapWIN mapping core and/or to create georss feeds.

Figure 9-7 provides a summary of the CapWIN OpenFire implementation, which is utilized by the CapWIN AVL Interface.



Source: University of Maryland

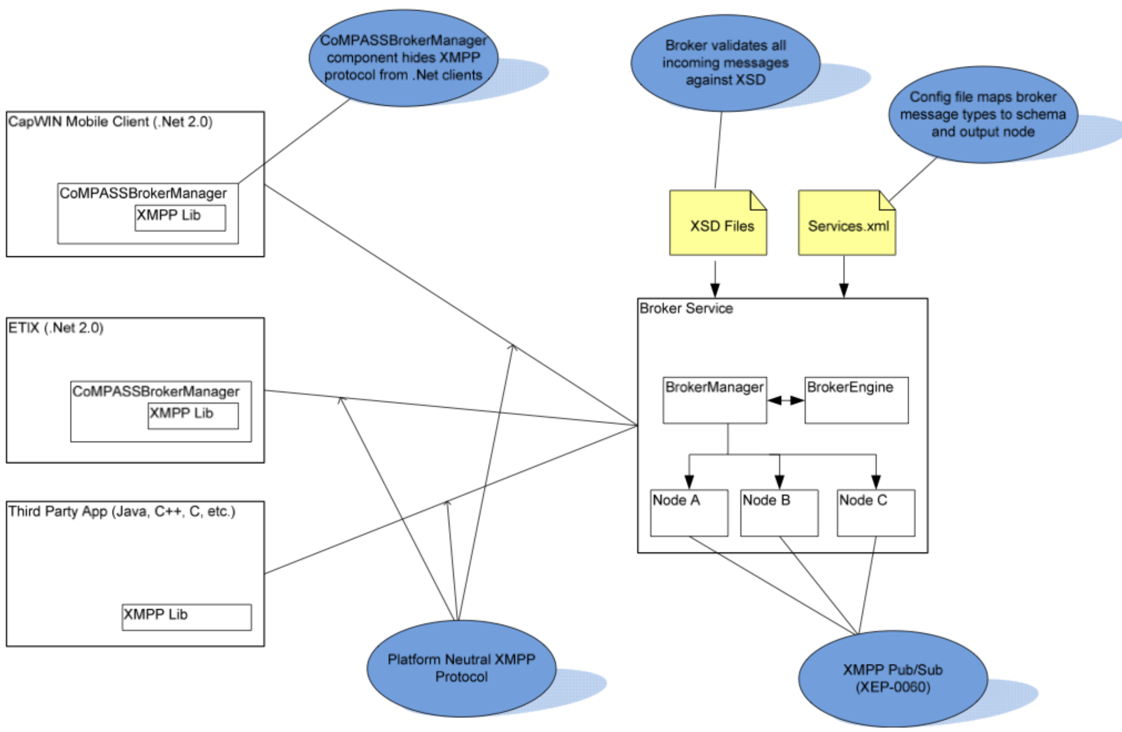
Figure 9-7. The CapWIN Openfire Implementation

CoMPASS Broker

The CoMPASS Broker is a Windows service that facilitates communication between "CoMPASS aware" applications. The Broker is built on an eXtensible Messaging and Presence Protocol (XMPP) toolkit to provide a platform independent communication framework. Conceptually the Broker is a very lightweight XMPP messaging server. A limited number of XMPP concepts have been utilized to provide a service with a low resource overhead.

The Broker is written in C# using .Net 2.0. It uses AG Software's XMPP library to support XMPP communication.

Figure 9-8 illustrates the main components of the CoMPASS Broker with example applications connected.



Source: University of Maryland

Figure 9-8. The CoMPASS Broker

APPENDIX A. Abbreviations

ACM	A la Carte Message
ADD	Architecture Description Document
API	Application Programming Interface
ASN	Abstract Syntax Notation
BSM	Basic Safety Message
CAN	Controller Area Network
CBL	CapWIN Business Logic
CFI	CapWIN Feed Interface
CV	Connected Vehicle
DGPS	Differential Global Positioning System
DMA	Dynamic Mobility Applications
DSRC	Dedicated Short Range Communications
DVI	Driver Vehicle Interface
EMS	Emergency Medical Services
EVA	Emergency Vehicle Alert
FITIM	Freeway Incident Traffic Management
GGA	Global Positioning System Fix Data
GPS	Global Positioning System
HTTPS	Hypertext Transfer Protocol Secure
I2V	Infrastructure-to-vehicle
INC-ZONE	Incident Zone
ITIS	International Traveler Information Systems
ITS	Intelligent Transportation Systems
MAP	Map Data Message
MDB	Message Driven Beans
MDT	Mobile Data Terminal
MUTCD	Manual of Uniform Traffic Control Devices
NMEA	National Marine Electronics Association
Ntrip	Networked Transport of RTCM via Internet Protocol
OBD	On-board Diagnostics
OBE	On-Board Equipment
PASS	Personal Alerting Safety Subsystem
PID	Parameter IDs
R.E.S.C.U.M.E.	Response, Emergency Staging, Communications, Uniform Management, and Evacuation
RESP-STG	Response Staging

REST	Representational State Transfer
RITIS	Regional Integrated Transportation Information System
RSA	Road Side Alert
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers
SDD	System Design Document
SDK	Software Development Kit
TIM	Traveler Information Message
TTC	Temporary Traffic Control
U.S. DOT	United States Department of Transportation
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
VITAL	Vehicle Initiated Telematics and Logging
WAVE	Wireless Access in Vehicular Environments
XMPP	eXtensible Messaging and Presence Protocol

APPENDIX B. DSRC Message Content

Table B-1. Emergency Vehicle Alert (EVA) Message Field Descriptions and Usage

Data Item	Description	Source of Data	Usage	Comments
msgID	Message Type	"5"		Required by J2735.2009 standard
id	Vehicle ID	Arada Systems DSRC unit	Basic Threat Algorithm Input	Identifies a particular emergency vehicle. Used to identify a responder vehicle involved in an imminent collision threat situation and limit alarms to that vehicle only.
rsaMsg.msgID	Message Type	"11"		Required by J2735.2009 standard
rsaMsg.msgCnt	Count	Arada Systems DSRC unit		A sequence number within a stream of messages with the same DSRCmsgID and sender. Value from 0 to 127. Required by J2735.2009 standard.
rsaTypeEvent.ITIS.ITISCodes	Event Type			Uses a standard ITIS code to explain the level of hazard, danger, alert involved. Required by J2735.2009 standard.
rsaMsg.position.lat	Latitude of emergency vehicle	Arada Systems DSRC unit	Basic Threat Algorithm Input	Used to determine basic threat level of an oncoming vehicle. Also used for management of incident zone broadcast.
rsaMsg.position.long	Longitude of emergency vehicle	Arada Systems DSRC unit	Basic Threat Algorithm Input	Used to determine basic threat level of an oncoming vehicle. Also used for management of incident zone broadcast.
rsaMsg.position.elevation	Elevation of emergency vehicle	Arada Systems DSRC unit	Basic Threat Algorithm Input	Used to determine basic threat level of an oncoming vehicle. Also used for management of incident zone broadcast. Elevation is used to aid disambiguation of location of vehicles parked on or below overpasses.

Source: Battelle

Table B-2. Traveler Information Message (TIM) Field Descriptions and Usage

Data Item	Description	Source of Data	Usage	Comments
msgID	Message Type	"16"		Required by J2735.2009 standard
dataFrameCount	Number of frames in message	"3"		Required by J2735.2009 standard
dataFrames(1).frameType	Frame type = "advisory"	"1"		Frame 1 describes the extent of the incident zone advisory region.
dataFrames(1).msgID	links to ATIS msg	"0"		Required by J2735.2009 standard. "0" if ATIS message not present or unknown.
dataFrames(1).startTime	Start time of incident	CapWIN	Incident Zone Description	INTEGER (0..525960), indicates time the incident began
dataFrames(1).durationTime	Duration of incident	"3200"	Incident Zone Description	The duration, in units of whole minutes, that an object persists for. A value of 32000 means that the object persists forever, i.e. until the TIM message ceases to be transmitted.
dataFrames(1).SignPriority	Relative importance of this sign	"7"	Incident Zone Description	The relative importance of the sign, a scale from zero (least important) to seven (most important).
dataFrames(1).commonAnchor.lat	Latitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(1).commonAnchor.long	Longitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.

Table B-2. Traveler Information Message (TIM) Field Descriptions and Usage (Continued)

Data Item	Description	Source of Data	Usage	Comments
dataFrames(1).commonAnchor.elevation	Elevation of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(1).commonLaneWidth	Lane width at start of incident	Map repository	Incident Zone Description	(0..32767) -- units of 1 cm
dataFrames(1).commonDirectionality	Direction	Map repository	Incident Zone Description	forward (0), -- direction of travel follows node ordering reverse (1), -- direction of travel is the reverse of node ordering both (2), -- direction of travel allowed in both directions
dataFrames(1).regions(1).direction	The range of allowed directions	Map repository	Incident Zone Description	OCTET STRING (SIZE(2))
dataFrames(1).regions(1).area.NodeList.Offsets(n).xOffset	X offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(1).regions(1).area.NodeList.Offsets(n).yOffset	Y offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(1).regions(1).area.NodeList.Offsets(n).zOffset	Z offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(1).regions(1).area.NodeList.Offsets(n).width	Optional lane width	Map repository	Incident Zone Description	INTEGER (0..32767) -- units of 1 cm
dataFrames(1).content.advisory	ITIS code = "Incident"	"531"	Incident Zone Description	
dataFrames(2).frameType	Frame type = "advisory"	"1"	Incident Zone Description	Frame 2 will describe the incident zone lane closures
dataFrames(2).msgID	links to ATIS msg	"0"		Required by J2735.2009 standard. "0" if ATIS message not present or unknown.
dataFrames(2).startTime	Start time of incident	CapWIN	Incident Zone Description	INTEGER (0..525960), indicates time the incident began
dataFrames(2).durationTime	Duration of incident	"3200"	Incident Zone Description	The duration, in units of whole minutes, that an object persists for. A value of 32000 means that the object persists forever, i.e. until the TIM message ceases to be transmitted.
dataFrames(2).SignPriority	Relative importance of this sign	"7"	Incident Zone Description	The relative importance of the sign, a scale from zero (least important) to seven (most important).

Table B-2. Traveler Information Message (TIM) Field Descriptions and Usage (Continued)

Data Item	Description	Source of Data	Usage	Comments
dataFrames(2).commonAnchor.lat	Latitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(2).commonAnchor.long	Longitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(2).commonAnchor.elevation	Elevation of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(2).commonLaneWidth	Lane width at start of incident	Map repository	Incident Zone Description	(0..32767) -- units of 1 cm
dataFrames(2).commonDirectionality	Direction	Map repository	Incident Zone Description	forward (0), -- direction of travel follows node ordering reverse (1), -- direction of travel is the reverse of node ordering both (2), – direction of travel allowed in both directions
dataFrames(2).regions(1).direction	The range of allowed directions	Map repository	Incident Zone Description	OCTET STRING (SIZE(2))
dataFrames(2).regions(1).area.NodeList.Offsets(n).xOffset	X offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(2).regions(1).area.NodeList.Offsets(n).yOffset	Y offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(2).regions(1).area.NodeList.Offsets(n).zOffset	Z offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(2).regions(1).area.NodeList.Offsets(n).width	Optional lane width	Map repository	Incident Zone Description	INTEGER (0..32767) -- units of 1 cm
dataFrames(2).content.advisory	ITIS code = "closed to traffic"	"769"	Incident Zone Description	
dataFrames(3).frameType	Frame type = "advisory"	"1"	Incident Zone Description	Frame 3 will describe the incident zone speed restrictions

Table B-2. Traveler Information Message (TIM) Field Descriptions and Usage (Continued)

Data Item	Description	Source of Data	Usage	Comments
dataFrames(3).msgID	links to ATIS msg	"0"		Required by J2735.2009 standard. "0" if ATIS message not present or unknown.
dataFrames(3).startTime	Start time of incident	CapWIN	Incident Zone Description	INTEGER (0..525960), indicates time the incident began
dataFrames(3).durationTime	Duration of incident	"3200"	Incident Zone Description	The duration, in units of whole minutes, that a object persists for. A value of 32000 means that the object persists forever, i.e. until the TIM message ceases to be transmitted.
dataFrames(3).SignPriority	Relative importance of this sign	"7"	Incident Zone Description	The relative importance of the sign, a scale from zero (least important) to seven (most important).
dataFrames(3).commonAnchor.lat	Latitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(3).commonAnchor.long	Longitude of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(3).commonAnchor.elevation	Elevation of start of incident	Map repository	Incident Zone Description	The anchor of the incident zone is defined as the point furthest "upstream" and "outside" or on the right side of the oncoming vehicles to the incident that advice is presented to the oncoming vehicles.
dataFrames(3).commonLaneWidth	Lane width at start of incident	Map repository	Incident Zone Description	(0..32767) -- units of 1 cm
dataFrames(3).commonDirectionality	Direction	Map repository	Incident Zone Description	forward (0), -- direction of travel follows node ordering reverse (1), -- direction of travel is the reverse of node ordering both (2), -- direction of travel allowed in both directions
dataFrames(3).regions(1).direction	The range of allowed directions	Map repository	Incident Zone Description	OCTET STRING (SIZE(2))
dataFrames(3).regions(1).area.NodeList.Offsets(n).xOffset	X offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm

Table B-2. Traveler Information Message (TIM) Field Descriptions and Usage (Continued)

Data Item	Description	Source of Data	Usage	Comments
dataFrames(3).regions(1).area.NodeList.Offsets(n).yOffset	Y offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(3).regions(1).area.NodeList.Offsets(n).zOffset	Z offset of lane segment	Map repository	Incident Zone Description	INTEGER (-32767..32767) signed value where the LSB is in units of 1.0 cm
dataFrames(3).regions(1).area.NodeList.Offsets(n).width	Optional lane width	Map repository	Incident Zone Description	INTEGER (0..32767) -- units of 1 cm
dataFrames(3).content.speedLimit	ITIS.ITIScodes = "mandatory speed limit in force"	"6933"	Incident Zone Description	Represents a specific value for the desired speed limit temporarily being enforced for the incident zone.

Source: Battelle

Table B-3. A la Carte Message (ACM) Field Descriptions and Usage

Data Item	Description	Source of Data	Usage	Comments
msgID	Message Type	"1"		Required by J2735.2006 standard
data.oncomingID	Oncoming Vehicle ID	Arada Systems DSRC unit	Threat Communication	A 4 byte random device identifier
data.responderID	Responder Vehicle ID	EVA message	Threat Communication	Only used for highest threat level. The vehicle ID from an EVA message of the responder vehicle being threatened
data.secMark	DSRC millisecond mark	Arada Systems DSRC unit	Threat Communication	Milliseconds within a minute, Value from 0 to 60999, or 65534 if unknown. Probably will be based on GPS Timestamp.
local.tCategory	Threat Category	Calculated	Threat Communication	Optional. Integer identifying the manner of threat (for debug purposes; not used in alarm)
local.tLevel	Threat level	Calculated	Threat Communication	Local data item defining four levels of alarm. Something like 0. No alarm or alarm reset 1. Oncoming traffic in the area of the Incident Zone 2. Oncoming traffic in the area of the Incident Zone with Lane or Speed Violations 3. Imminent Collision with responder vehicle identified by optional responderID field.

Source: Battelle

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