Southeast Michigan Test Bed Advanced Data Capture Field Testing

Task 4: Operational Data Environment – Field Test Plan

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16. Abstract

This document presents the field test plan that was executed in the Southeast Michigan (SEMI) Connected Vehicle (CV) Test Bed to evaluate the performance of the Operational Data Environment (ODE). The ODE's functionalities were evaluated against its ability to provide real-time, real-world data, from the SEMI test bed, to subscribing CV applications to process these data as a part of their operation. A number of CV applications were explored and 4 were selected, and emulated, to support this field test. Details provided throughout this document highlight the protocols and procedures that gave structure to the test bed vehicle drivers to follow specific driving routes and execute specific tasks to produce CV data capable of evaluating the functions of the ODE. The success of this test was evident in applications receiving data, as dictated by their subscription to the ODE, and their issuance of corresponding notifications, alerts and warnings. The results from this field test help to answer key research questions regarding the ODE's ability to support the real-time operations of CV applications.

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CHAPTER 1. INTRODUCTION

This Field Test Plan is a deliverable produced by Booz Allen Hamilton, Inc., under contract to the U.S. DOT for Task 4 of the “Southeast Michigan Test Bed Advanced Data Capture Field Testing” project. Companion documents include the “Operational Data Environment - Concept of Operations” and “Operational Data Environment - System Design Document.” This Test Plan describes how the capabilities and functionality of the data provisioning system (the Operational Data Environment), being developed under this project, was tested in a real-world setting of the Southeast Michigan Connected Vehicle Test Bed (SEMI Test Bed).

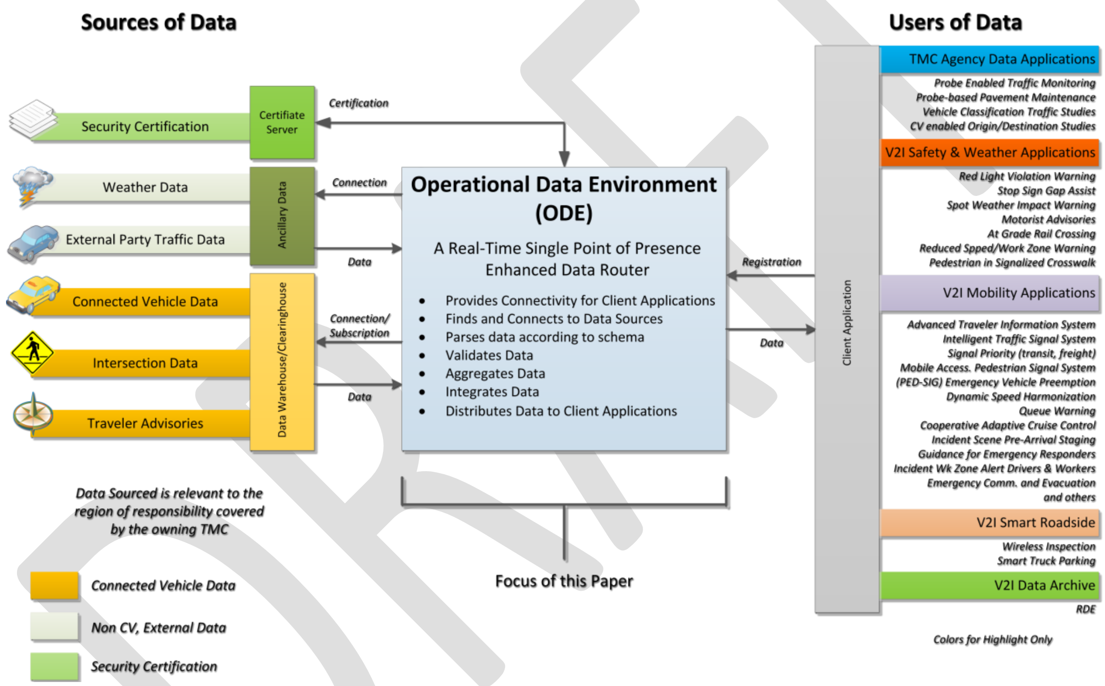
1.1. Overview of the ODE

The Operational Data Environment (ODE) is a real-time data router that processes vehicle and infrastructure data collected from sources such as the Situation Data Clearinghouse (SDC) and the Situation Data Warehouse (SDW), along with other non-connected vehicle sources of data. The ODE offers four core functions to supply tailored and custom-requested data from the SEMI Test Bed to subscribing client software applications. The core functions are: 1) Validation (V), 2) Integration (I), 3) Sanitization (S)[1] and 4) Aggregation (A), which are collectively referred to as the VISA functions. These four functions are particularly critical to the field test plan as they enable subscribing applications to submit tailored data requests to support their operation. These functions also serve to increase the general usability of the data being generated in the SEMI Test Bed. For descriptions of each of these core functions, as well as the other functions of the ODE, readers are directed to the Task 3 White Paper, the ODE Concept of Operation Document, and the System Design Document developed under this task.

The current scope of the ODE’s development is to augment the operation of the SEMI Test Bed with additional data processing functionalities to support real-time quality checking and sanitization of connected vehicle (CV) data, as well as providing data aggregation, and integration capabilities. This in turn will extend the SEMI Test Bed’s ability to support the operation of CV applications while simultaneously bolstering the ODE’s ability to provide enhanced data processing and distribution capabilities. While the ODE built for this project is customized for the SEMI Test Bed environment, it is the intent of U.S. DOT that this ODE will be a model for processing transportation data collected in other locations across the country.

[1] The working definition of this term (Sanitization) is synonymous with de-identification as it is focused a suppressing / removing personally identifiable information, and not the “cleaning” of data which also tends to be associated with data sanitization

On a more granular level, the ODE is a data provisioning entity for client applications that supplies connected vehicle data as well as other available data of interest such as those conveying contextual information about the environment in which the connected vehicle data were obtained. Figure 1 presents a high-level illustration of how the ODE provisions data from various sources to a variety of concurrently subscribed users, i.e., client applications, which will be using these data in a myriad of ways to complete their task objectives. The ODE provides its client applications (shown on the right as a list of connected vehicle applications) with a standardized interface to which they can securely connect and request data. While responding to the request, the ODE will perform additional data processing functions, such as data validation, integration, and data aggregation – as per the request of the subscribing application. (For a summary of the mapping of these additional data processing functions to a subset of connected vehicle applications please see Table 9 in Appendix A.)



Source: Booz Allen Hamilton, 2015

Figure 1. High Level Contextual Representation of the ODE, Connecting Data Source to Data Users

The ODE processes provide the capability to parse its client applications' subscription request, configure connections, and source data to service all requests efficiently. A brief description of how an application interacts with the ODE to receive requested data is provided in Section 2. The ODE has secure mechanisms for connection to data sources and data collection from each source. The components of this system run real-time processes aggregating and integrating data, matching up users and their data, and performing data validation to verify that it is receiving valid data (i.e., the inbound messages come in as expected and the data appears useable).

The ODE will be designed to scale in order to meet the data demands placed upon it by client applications. The design approach of this system will fulfil all client application requests, as defined by the ODE API and given appropriate authorization. The ODE will integrate a collection of technologies, associated with processing *large* volumes of data, in order to ingest and distribute data as rapidly as possible to meet the needs of its client applications.

1.2. Field Test Goals and Objectives

The field test is one testing activity within a testing program to verify the functionalities of the ODE. This testing program is the framework by which software and hardware/system products are sequentially tested and evaluated prior to release. Figure 2 provides an overview of the structure of this testing program and shows the four stages of a product's testing life-cycle: two software tests (unit and integration), and two "sell-off" / system acceptance tests (system and field).

All four test stages were executed during the development and evaluation of the ODE. Normally, in a lightweight (Agile) development, Software Unit and Integration Testing are performed in recurring cycles and are documented only by test logs that show purpose, time, place, and result of tests. Formal sell-off (system acceptance) tests adhere to a more rigorous standard using procedural documentation that maps key functionality to demonstrable steps, either through empirical data or by direct observation. To meet this need, a series of test procedures and scripts are developed, dry run, validated and used during a formal test, with each procedure based upon the maturity and successful evaluation of prior tests in the sequence.

The sell-off / system acceptance test is composed of a "System Test" and a "Field Test". This document will only present the details associated with the Field test. Details of the "System Test" are presented in the "System Test Plan" Document. This document walks through each requirement of the ODE and how it will be evaluated to ensure that these requirements / functions are satisfied.

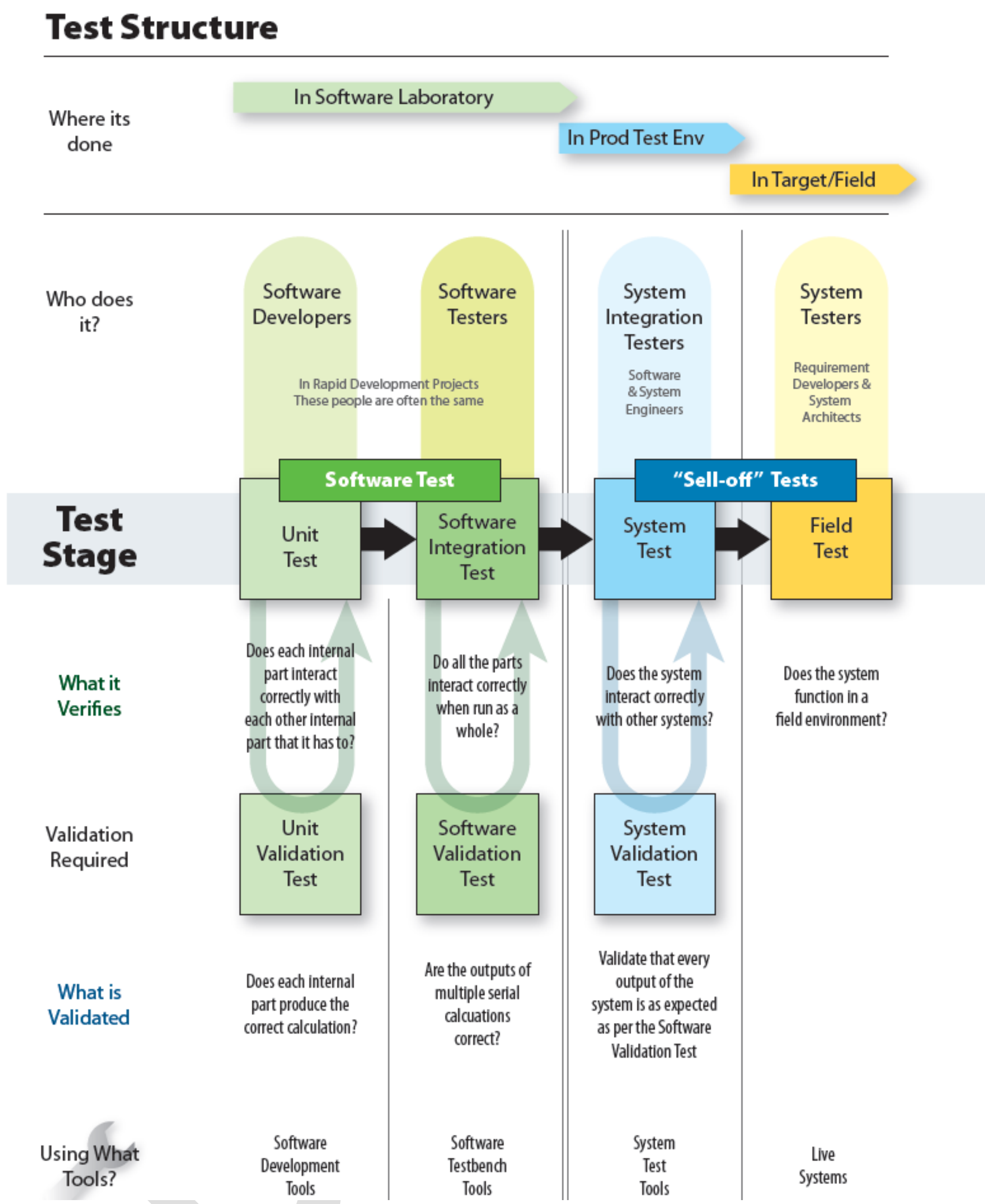


Figure 2 Testing Program's Framework

1.3. The Field Test

The goal of the field test is to evaluate the performance of ODE's functionalities, using real-time, real-world data from the SEMI test bed; and delivering these data to applications that process connected vehicle data as a part of their mode of operation. A suite of these connected vehicle applications were explored and eventually selected to support these field test activities. In selecting these applications, a number of features from each application were examined, in addition to the composite features of the suite of applications that were considered. In evaluating these features, considerations that were taken into account included:

- Effectiveness of the emulated applications, given less than 100% market penetration
- The diversity and volume of data that will be involved throughout the field test
- The interoperability of the ODE and the SDC and SDW of the Southeast Michigan Test Bed
- The sufficiency of the ODE’s real-time capabilities to ingest data from the various data sources and to support the emulated applications
- How well does the ODE’s data validation functionality quality-check the data and rid the data of PII/ proprietary/sensitive information
- The interoperability between the ODE and RDE in being able to provide connected vehicle data to support the research community and application developers

The specifics and execution of the field test largely involve procedures that instruct SEMI Test Bed vehicle drivers to follow specific driving routes and execute specific tasks that produce CV data capable of evaluating CV functions of the ODE. The success of this series of tests will be evident in subscribing applications being able to achieve their various objectives. The results of this field testing will help answer key questions regarding the ODE’s abilities and performance. Examples of questions to be answered include:

- Are the data available from the SEMI Test Bed sufficient to enable operation of subscribing Connected Vehicle (CV) applications?
- How can the ODE efficiently aggregate the data received from the SEMI Test Bed before transmission to the subscribing applications, beyond the functions performed by the SEMI Test Bed’s SDC and SDW?
- How can the ODE efficiently quality check the data received from the SDW and SDC before transmission to the subscribing applications, beyond the functions performed by the SEMI Test Bed’s SDC and SDW?
- How do the data security and privacy procedures established for the SEMI Test Bed carry through to the subscribing applications?
- How do the applications subscribe to the ODE at the same time the ODE subscribes to the SDC?
- How do the CV applications coordinate their requests to the SDW and SDC and/or the ODE to implement data aggregation?
- Is the volume of data from the SEMI Test Bed and the market penetration of the equipped vehicles in the test bed adequate to operate the CV applications?
- Is the time delay before the data are received by the CV applications small enough for the CV applications to operate successfully?

1.4. Connected Vehicle Applications

To support field test activities of the ODE, a series of connected vehicle applications, developed under the auspices of USDOT, were evaluated for integration. These applications were developed under a number of USDOT sponsored programs. A few of these programs include the Dynamic Mobility Applications (DMA) Program, the Road Weather Program and the Applications for the Environment: Real-Time Information Synthesis (AERIS) Program. Each of these application programs was explored to identify CV applications to serve as subscribing applications to request data from the ODE, with the goal of using these data to accomplish the objective(s) of the said application.

Of these application programs, the DMA program supports one of the most diverse set of CV applications. As such the following section provides an overview of the bundles that are a part of the DMA program. This overview not only serves to provide additional context for this field test and its application selection but also for future field tests in different locations and / or with different vehicle fleets. The DMA Program was initiated to create, test, and demonstrate innovative mobility applications exploiting frequently collected and rapidly disseminated multi-source data drawn from connected travelers, vehicles, and the infrastructure.

The DMA Program focuses on vehicle-infrastructure connectivity using Dedicated Short Range Communications (DSRC) and other wireless communications methods. The objective of the DMA program is to develop open source applications that use multi-source ITS data to transform surface transportation management and information. Some of the notable application bundles of the DMA program include:

Enable Advanced Traveler Information System (EnableATIS): represents a framework around a desired end state for a future traveler information network, with a focus on multimodal integration, facilitated sharing of data, end-to-end trip perspectives, and use of analytics and logic to generate predictive information specific to users.

Freight Advanced Traveler Information Systems (FRATIS): seeks to improve the efficiency of freight operations by using several levels of real-time information to guide adaptive and effective decision making. FRATIS seeks to integrate existing data sources in a manner and with a quality that is oriented toward freight's unique operational characteristics that require different data and methods/time frames for information delivery. This suite of applications is being developed in a manner that leverages connected vehicle data. These applications are Freight Specific Dynamic Travel Planning and Performance, and Drayage Optimization.

Integrated Dynamic Transit Operations (IDTO): enables transit systems to provide better information to travelers and increase the quality of service. The IDTO applications significantly alter existing transit services and result in substantial mobility improvements; and leverage the connected transportation environment data. The IDTO applications look to resolve existing gaps and evolve the current state to offer transformative impacts while minimizing risks. The IDTO has three applications: T-Connect (Connection Protection), T-DISP (Dynamic Transit Operations), and D-RIDE (Dynamic Ridesharing).

Intelligent Network Flow Optimization (INFLO): is a collection of high-priority, transformative applications that aim to maximize roadway throughput, reduce crashes, and reduce fuel consumption through the use of frequently collected and rapidly disseminated multisource data drawn from connected vehicles, travelers' mobile devices, and infrastructure. INFLO bundle consists of applications related to queue warning (Q-WARN), Dynamic Speed Harmonization (SPD-HARM), and Cooperative Adaptive Cruise Control (CACC).

Multi-Modal Intelligent Traffic Signal Systems (MMITSS): is the next generation of traffic signal systems that seeks to provide a comprehensive traffic information framework to service all modes of transportation, including general vehicles, transit, emergency vehicles, freight fleets, and pedestrians and bicyclists in a connected vehicle environment. The vision for MMITSS is to provide overarching system optimization that accommodates transit and freight signal priority, preemption for emergency vehicles, and pedestrian movements while maximizing overall arterial network performance. MMITSS incorporates these arterial traffic signal applications: Intelligent Traffic Signal System (I-SIG), Transit Signal Priority (TSP), Mobile Accessible Pedestrian Signal System (PED-SIG), Emergency Vehicle Preemption (PREEMPT), and Freight Signal Priority (FSP).

Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.): are the next generation of applications that transform the response, emergency staging and communications, uniform management, and evacuation process associated with incidents. The vision for R.E.S.C.U.M.E. is to leverage wireless connectivity, center-to-center communications, and center-to-field communications to solve problems faced by emergency management agencies, emergency medical services (EMS), public agencies, and emergency care givers, as well as persons requiring assistance. The R.E.S.C.U.M.E. bundle has the following applications: Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG), Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE), and Emergency Communications and Evacuation (EVAC).

As previously stated, the primary objective of selecting connected vehicle applications is to conduct a series of field tests for real-world evaluation of the ODE's operation and performance. Also, as part of the field test, emulation of three or more connected vehicle applications that subscribe to the ODE is required. Therefore the selected applications, and more importantly the criteria which are used to select these applications, are critical. In order to down select the applications, the team underwent a rigorous application-selection process that started with a comprehensive review of the status of various CV applications within the multiple USDOT programs. The down selection criteria include a few general conditions such as ensuring that there are synergies between selected applications, they complement each other (in that the selected applications use similar but not identical data), while making sure that the applications are sufficiently dissimilar to thoroughly exercise the ODE's ability to support overlapping and divergent data requirements of connected vehicle applications. Additional criteria are given in Appendix A.

1.5. Emulated Applications

While the maturity of these various applications may vary within and across application bundles, and many of these applications were not developed to be operated in conjunction with a system such as the ODE, this field test employed a suite of "emulated" applications to test the functionalities of the ODE.

Emulated applications are applications that are meant to function as stand-ins for applications that were developed under the various application programs. For this field test, emulated applications were either modified from the original application to become compatible with the ODE or developed to mirror function(s) of an original application. These emulated applications, as best as possible, are intended to reflect the primary functions of the originally selected CV applications and their data requirements as they subscribe to the ODE. Upon subscribing to the ODE, the emulated applications sufficiently mimicked the real-time operation of the original applications. Note, these emulated applications are not substitutes for the original applications nor are the configurations used by these emulated application to be considered as recommended configurations. In fact, during the field test, the output from these applications were not supplied to drivers for them to act on as they navigate their vehicles through the Test Bed. The output from these emulated applications were evaluated in a software environment, where a series analyses informed sufficiency of the ODE's operation.

The purpose of this field test is not to verify or validate the applications, but to test the operation of ODE to support the operation of these applications. The operation of ODE is application agnostic, meaning that no matter the objectives of a subscribing application, the ODE shall be able to provide the requested data to the application to support its operation.

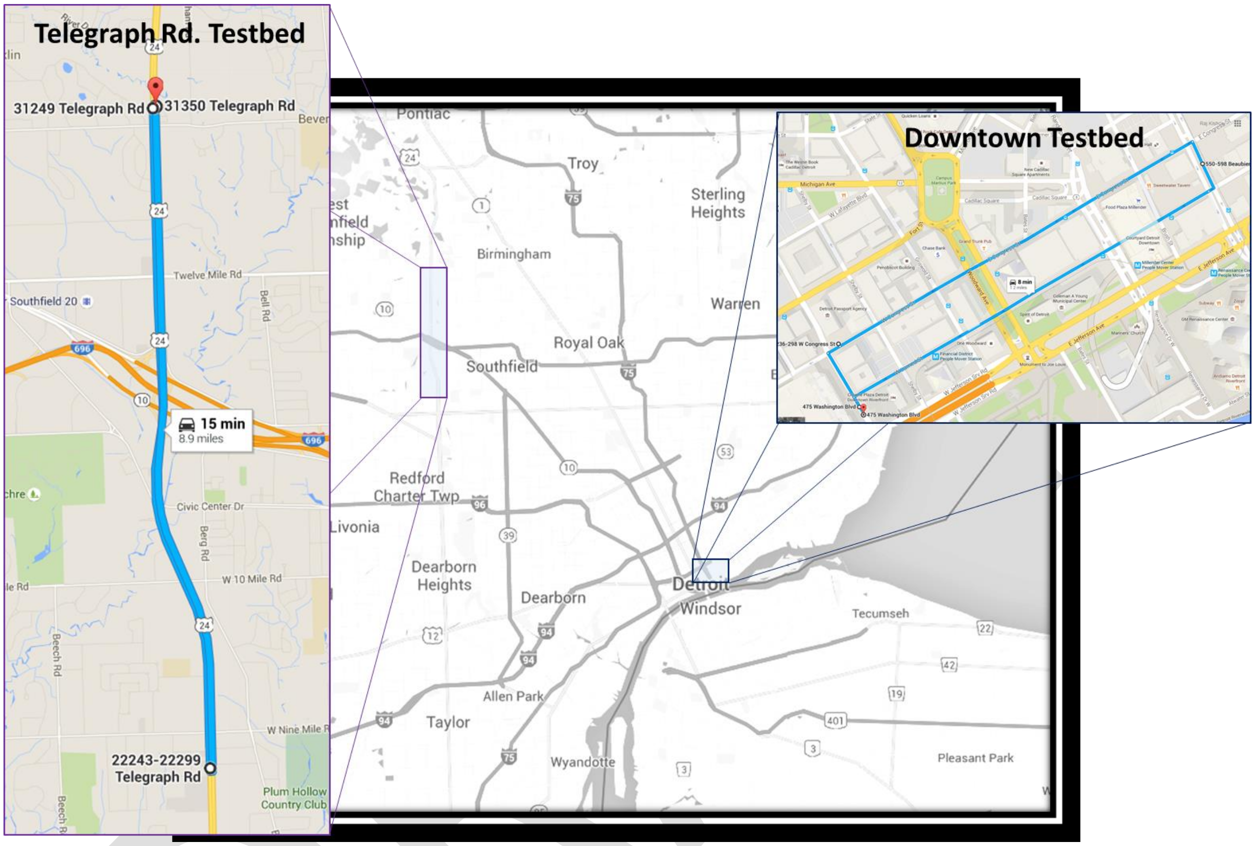
1.6. Geographic Location

The ODE Field Test used two instrumented testbeds from South East Michigan, namely, the downtown Detroit testbed and the Telegraph Road testbed. The Downtown testbed consists of two parallel one-way streets (Congress St. and Larned St.) with a set of signalized intersections at every block. These streets are 0.5 mile long and the total length of the testbed is 1.2 miles. The Telegraph Road, however, is a high-speed rural corridor with a few signalized intersections and several median U-turn alternative intersections. The testbed length is 4.5 miles and the overall loop length is 9 miles. Further details on the testbeds are provided on Table 1.

Table 1: Characteristics of the two Testbeds.

	Downtown Area Testbed	Telegraph Road Testbed
Loop Length	1.2 miles	9 miles
Loop Travel Time	8 minutes free-flow time	15 minutes free-flow time
Speed Limit	25 mph	50 mph
Effective No. of Lanes	2	3

The layouts for the downtown area and telegraph road area are provided in Figure 3. The images provided are screenshots from Google Maps.



Source: Google Maps, Booz Allen Hamilton, 2015

Figure 3. Geographic Scope of the SE Michigan Test Beds.

1.7. Field Test Plan – Document Overview

This document focuses on the plan used to execute the field test of the ODE. From this document, readers will gain high level understanding of all the activities that were conducted to evaluate the performance of the ODE. Step-by-step directives that were executed to evaluate the ODE are also provided in this document.

The remainder of this section provides a high level overview of the remaining sections of this test plan document.

- Section 2 ODE Field Test Plan and Emulated Applications: introduces the intent of the field test plan and the importance of selecting the most appropriate applications to emulate for this field test.
- Section 3 Field Test Preparation: highlights a series of steps and concepts that were undertaken to plan and execute an effective field test
- Section 4 Interaction with the Research Data Exchange: gives a summary of the plan to make appropriate data collected from this field test available on the Research Data Exchange
- Section 5 Risks and Mitigation: is intended to capture possible risks to the field test exercise and measures that may be taken to reduce the risk and its impact on the field test
- Appendix A – CV Application Selection Framework

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ODE Field Test Plan and Emulated Applications

CHAPTER 2. ODE FIELD TEST PLAN AND EMULATED APPLICATIONS

The primary goal of the ODE's field test is to evaluate the ODE's functionalities in a real-world environment using the SEMI testbed and subscribing client applications. The ODE processed incoming data feeds according to the data requests of subscribing applications. Subscribing applications are, therefore, an integral part of the field test. These applications dictate the processes that are to be performed by the ODE in order to provide the data required by the applications. These processes are dictated by the parameters of an application's subscription. These parameters include the data type / source of interest, the geographic area under study and others such as those associated with requesting aggregated data. There are numerous applications to choose from, and selecting the right applications for the downtown Detroit and Telegraph Road field test exercises is also important.

Appendix A provides the application selection framework, which describes the process that was used to select the applications that were a part of this field test. Four Connected Vehicle applications were selected using this framework and are described in the sections below. These sections describe each of the selected applications, their objectives, and the required data input for each of the applications.

2.1. Emulated Applications

For the applications that were selected for this field test, these applications evaluated the core functionalities of the ODE during the field test, in one form or another. For the definition of each of these functions, readers are asked to consult the ODE's Concept of Operations.

The four applications that were selected for emulation to support this field test were:

1) Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) – Incident Scene Work Zone Alerts for Drivers and Workers Application (INC-ZONE)
2) Intelligent Network Flow Optimization (INFLO) – Dynamic Speed Harmonization Application SPD-HARM
3) Applications for the Environment: Real-time Information Synthesis (AERIS) – Eco Approach and Departure at Signalized Intersections
4) Road Weather Program's Motorists Advisories and Warnings (MAW) based Application

ODE Field Test Plan and Emulated Applications

2.1.1. Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) - Incident Scene Work Zone Alerts for Drivers and Workers Application (INC-ZONE)

Application Description

Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E.) is a bundle of three applications under the USDOT's Dynamic Mobility Applications Research Program, one of which is the Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) application. The INC-ZONE application aims to provide oncoming drivers with merging and speed guidance around an incident. In-vehicle alerts and warnings are provided to oncoming drivers in violation of speed and lane closure restrictions, both for the protection of the drivers and incident zone personnel. It includes a warning system for on-scene workers when a vehicle approaching the incident zone is being operated outside of safe parameters for the conditions. See Figure 4 for an operational overview of the prototype INC-ZONE application.

ODE Field Test Plan and Emulated Applications

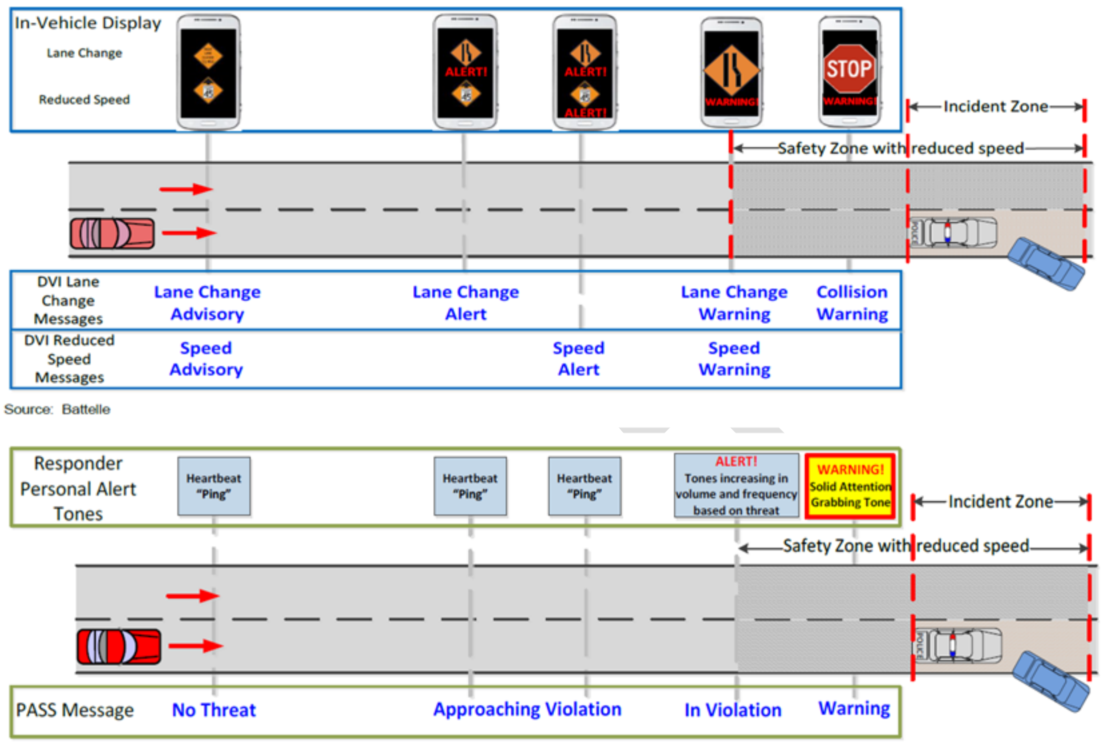


Figure 4: Prototyped INC-ZONE Application (Battelle[2])

Application Objectives
This application has the following primary objectives:

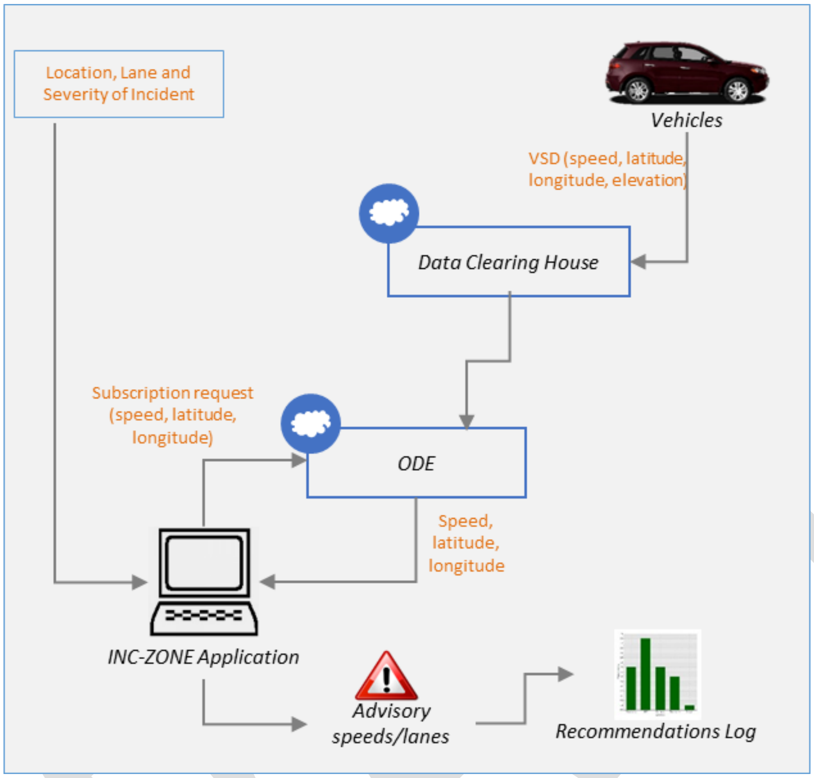
- Warns drivers who are approaching temporary incident response zones at unsafe speeds and/or trajectory;
- Warns public safety personnel and other officials working in the zone through an audible warning system about errant vehicles.

INC-ZONE Emulation Environment
The INC-ZONE application, as developed by the DMA Program's Impact Assessment Team, is currently being modeled with the aid of a microscopic traffic simulation software, Vissim, and its COM (Component Object Model) module. The current plan is to develop a standalone application environment, based in Python, that is a modification of what was developed for the Vissim COM module. This application environment replaced the Vissim data input stream with a tailored data stream from the SEMI Test Bed using ODE Subscriptions. The output of this application was redirected from the Vissim software package to a universal log file which

[2] Battelle, UMD; Prototype Development and Demonstration for R.E.S.C.U.M.E. – System Design Document (dated April 11, 2014)

ODE Field Test Plan and Emulated Applications

includes detailed logs from different components of the applications such as subscription requests, received data, utilized data, computed output etc.



Source: Booz Allen Hamilton, 2015

Figure 5. INC-ZONE Application Field Execution Schema

Figure 5 presents a high level implementation schema for INC-ZONE application and how it was deployed during the field test to help evaluate the functionalities of the ODE. In the figure below, and in similar figures further in this document, it is indicated that advisories and warnings are generated by the various applications. It should be noted that the outputted warnings or advisories from this, and other applications, were not transmitted to the drivers. Instead these outputs were monitored by the field test execution team and logged for post field-tests processing analysis.

The section below presents a high level overview of the execution plan in evaluating the ODE's support of the INC-ZONE application.

Test Case Objective

The primary objectives of this test are to ensure:

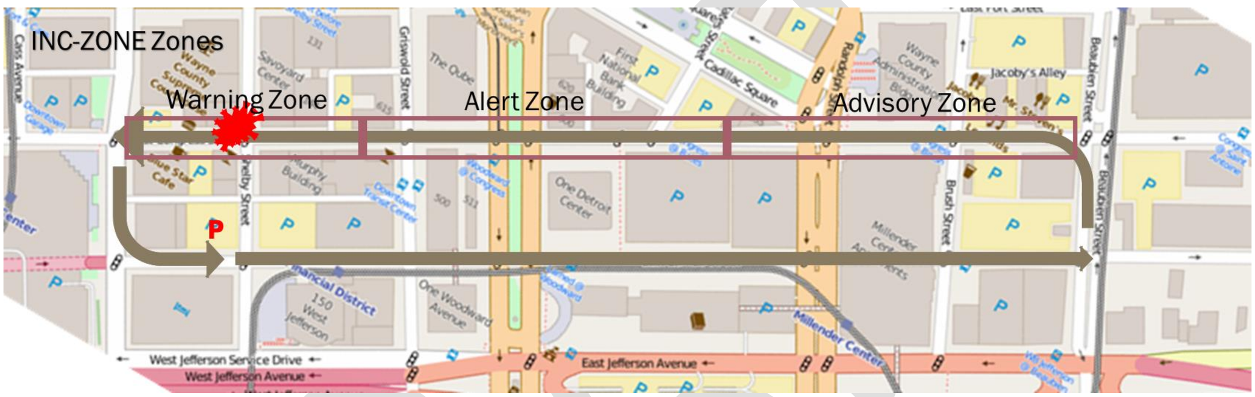
1- The application can initialize ODE-subscriptions on-the-fly to get vehicle and aggregate streams of data.

ODE Field Test Plan and Emulated Applications

2- The ODE can provide the subscribed data at a reliable latency and volume to the INC-ZONE application.
3- The INC-ZONE application generates appropriate advisories and warnings to test vehicles as they approach the incident location.

Test Case Location

The INC-ZONE application was evaluated in both the testbeds with an area designated as an incident location. This incident location was a virtual incident as there was not be an actual incident in the test bed. **Error! Reference source not found.**Figure 6 below presents a snapshot of the downtown area test bed and location of the virtual incident.



Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 6. INC-ZONE Test Path and Incident Zone Location for Downtown Test Area

Vehicles approaching the virtual incident location received Advisories, Alerts, or Warnings based on their distance from the incident. Three zones are created by the application based on work-zone distances derived from the Manual on Uniform Traffic Control Devices (MUTCD). The Warning Zone, Alert Zone, and Advisory Zone are determined as follows:

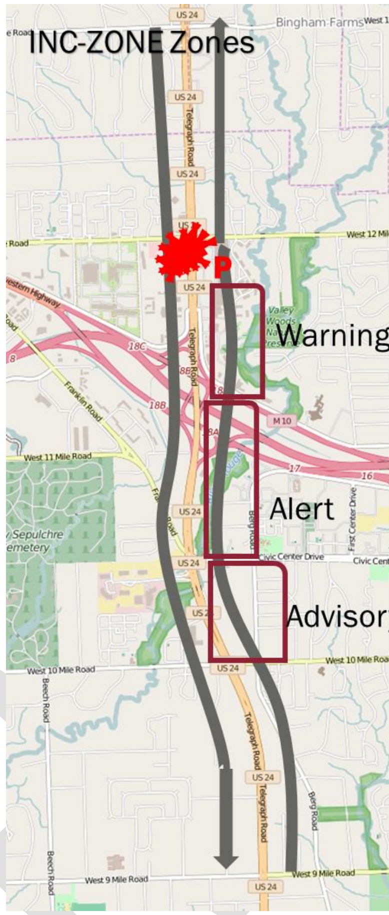
- *Vehicles at or near the virtual incident received Warnings (most critical)*
- *Vehicles approaching the incident from a mid-range distance on Congress St. received Alerts (less critical)*
- *Vehicles approaching the incident long-range distance on Congress St. received Advisories (least critical)*

The INC-ZONE field test was executed at the Telegraph Road testbed with the same objectives and data inputs. The virtual incident is assumed on US-24 North near the intersection of Telegraph Rd. and Twelve Mile Rd. The test path and the incident locations are shown in Figure 7. The three INC-ZONE zones are determined as follows:

- *Vehicles north of I-696 received Warnings (most critical)*

ODE Field Test Plan and Emulated Applications

- *Vehicles north of Civic Center Drive received Alerts (less critical)*
- *Vehicles north of 10-mile Road received Advisory (least critical)*



Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 7. INC-ZONE Test Path for Telegraph Road

Data Input to the Application

The application, as developed by the prototype development team, requires the following inputs:

- Vehicle class (optional), to classify emergency and non-emergency vehicles.
- Instantaneous Vehicle Location, derived from BSM Messages is used to classify vehicles to different zones. Lane data could be computed from latitude and longitude if accuracy permits.
- Vehicle heading, derived from BSM Messages is used for threat determination of whether a vehicle is in the direction of incident or away (applicable to two-way streets).

- Vehicle speed (at least 1 Hz)

Table 2 below presents a mapping of the above application input data to data elements that are generated in the SEMI Test Bed and propagated by the ODE.

Table 2: Mapping INC-ZONE Application Input Data to those Generated by SEMI Test Bed

Data Element #	Application Data Input	SEMI Test Bed Message Bundle | Data Element
1	Vehicle class	Optional
2	Instantaneous vehicle location	VSD | (latitude, longitude, elevation)
3	Vehicle heading	VSD | Heading
4	Vehicle speed (at least 1 Hz)	VSD | Speed

Additional Data Input

In addition to the core data requirement listed above in the "Data Input to the Application" section, the emulated INC-ZONE application requires speed guidance, as if it were generated by incident responder(s), lane closure rules reduced speed limit.

Data Output

In addition to the advisories, alerts and warnings, the emulated application also outputted a series of timestamps, latitude and longitude pairs of on-coming vehicle, heading, and speed as these message are generated.

2.1.2. Intelligent Network Flow Optimization (INFLO) - Dynamic Speed Harmonization Application (SPD-HARM) Application Description

Application Description

The Intelligent Network Flow Optimization bundle is a set of applications being developed under USDOT's Dynamic Mobility Applications Research Program. INFLO consists of applications that enhance the mobility of freeways using Connected Vehicles including queue warning (Q-WARN), Dynamic Speed Harmonization (SPD-HARM), and Cooperative Adaptive Cruise Control (CACC). In this field test, only SPD-HARM application was emulated.

ODE Field Test Plan and Emulated Applications

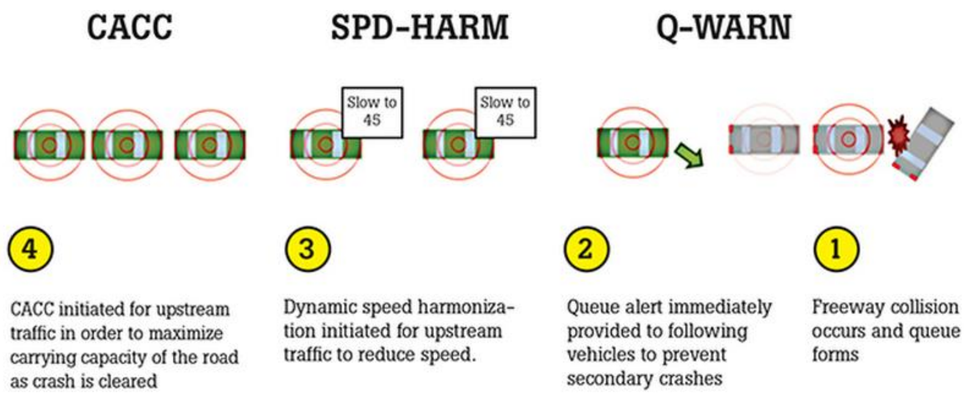


Figure 8: Combined Q-WARN/SPD-HARM/CACC Illustration[3]

SPD-HARM is one of the applications that aim to maximize throughput and reduce crashes by utilizing infrastructure-to-vehicle (I2V) and vehicle-to-vehicle (V2V) communication to detect impending congestion that might necessitate Dynamic Speed Harmonization; generating appropriate target speed recommendation strategies for upstream traffic; and communicating the recommendations to the affected vehicles using either I2V or V2V communication. SPD-HARM is deployed in an operational environment in which speed recommendation decisions are made at a Traffic Management Center (TMC) or a similar infrastructure-based entity, and then communicated to the affected traffic.

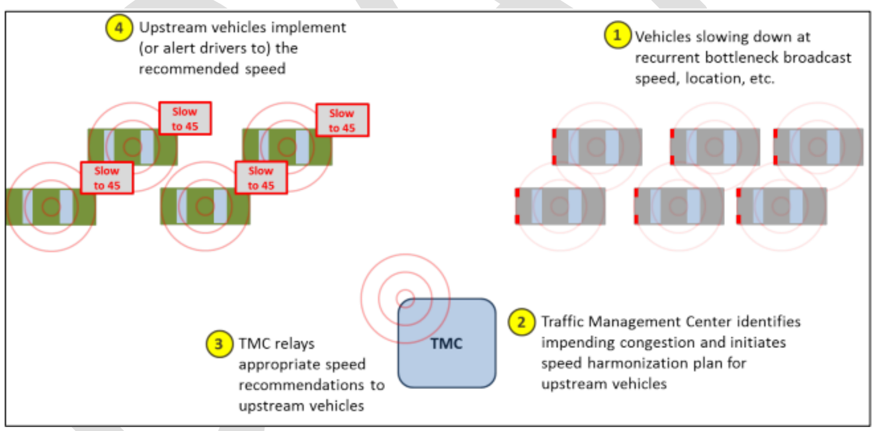


Figure 9: SPD-HARM Application in Operation

The SPD-HARM algorithm is designed to identify, produce, and establish a recommended speed for segments of the corridor. The harmonized travel speeds integrated the recommended travel

[3] While this figure demonstrates the Q-WARN, SPD-HARM, and CACC applications being used in a scenario where a crash is detected, these applications do not rely on a crash occurring for their operation.

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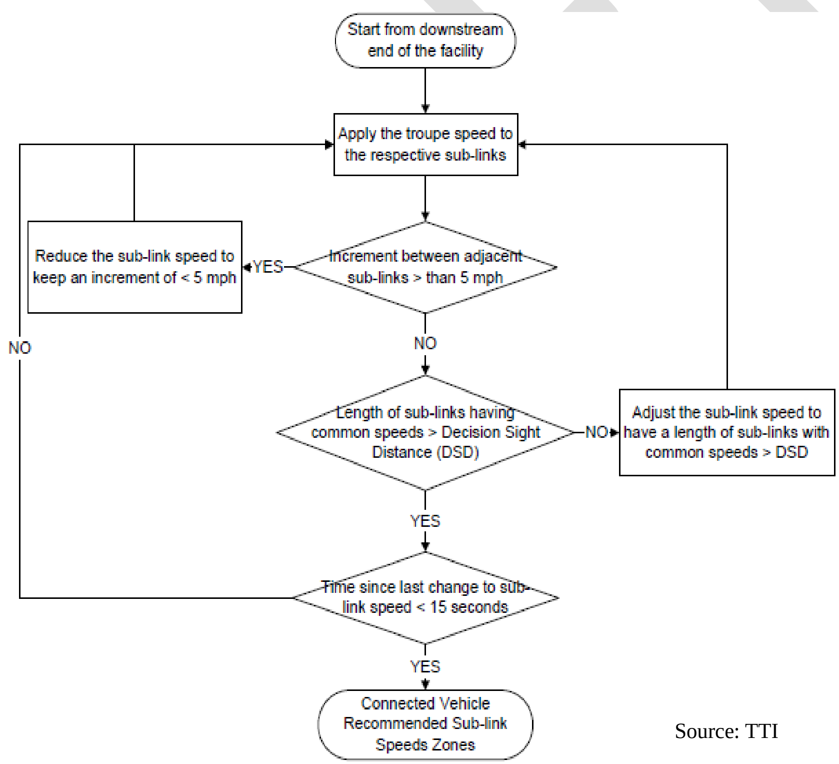
speeds from all the potential sources to produce a final recommended travel speed. The output of this process defined speed zones based on recommended speeds from each of the potential data sources. Figure 10 below summarizes the algorithm used for determining and recommending the harmonized speed. The algorithm uses four steps to determine the CV recommended speeds:

1- Applies the platoon speeds for each segment as the Connected Vehicle Recommended Speeds to each sub-link within the segment starting from the downstream end.
2- Ensures that the change in sub-link speeds between any adjacent sub-links does not exceed a user defined threshold
3- Ensures that a length of the segment of the facility having the same Connected Vehicle Recommended Speed is not shorter than the decision sight distance for that speed
4- Ensures that a change in the Connected Vehicle Recommended Speed for a sub-link does not occur at a frequency of less than 15 seconds.

These steps minimized the work load on the driver by reducing the number of speed changes. It has to be noted that the recommended speeds for each sub-link is logged for this field test and not provided back to the driver as dynamic speed limits.



Source: TTI

Figure 10: Illustration of SPD-HARM Algorithm for SubLink Speed

Application Objectives

The SPD-HARM application aims to harmonize speeds in response to congestion, incidents, and road weather conditions, applicable to freeways, arterials, and rural roads, by:

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- Dynamically adjusting and coordinating maximum appropriate vehicle speeds in response to downstream congestion, incidents, and weather or road conditions in order to maximize traffic throughput and reduce crashes.
- Reducing speed variability among vehicles, especially in near-onset flow breakdown conditions, to improve traffic throughput, delay or eliminate flow breakdown formations, and reduce collisions and severity of collisions
- Utilizing V2V and V2I communication to coordinate vehicle speeds
- Providing recommendations directly to drivers in-vehicle

The Dynamic Speed Harmonization application attempts to fuse data from infrastructure-based sensors with data from connected vehicles, identify sections of the roadway that exhibit common speed characteristics and then develop recommended speeds for various segments in a gradual manner.

INFLO – Dynamic Speed Harmonization Emulated Environment:

The Dynamic Speed Harmonization application as used by the DMA Impact Assessment team is a C#-based executable. Both input and output streams of this application are centered on Microsoft Access database tables. For field test purposes, this approach was retained. However for maximum flexibility, and future test ODE team may replace these database tables with flat files.

While the SEMI Test Bed does not contain any freeway, which is the ideal roadway type for the prototype application upon which the emulated application is based, its use in the Test Bed is only intended to demonstrate its feasibility of being supported by the ODE. The recommended speeds produced by INFLO were not necessarily practical owing to the signalized intersections on the roadways, but this test did assess if the ODE can serve the application with required amount and frequency of data.

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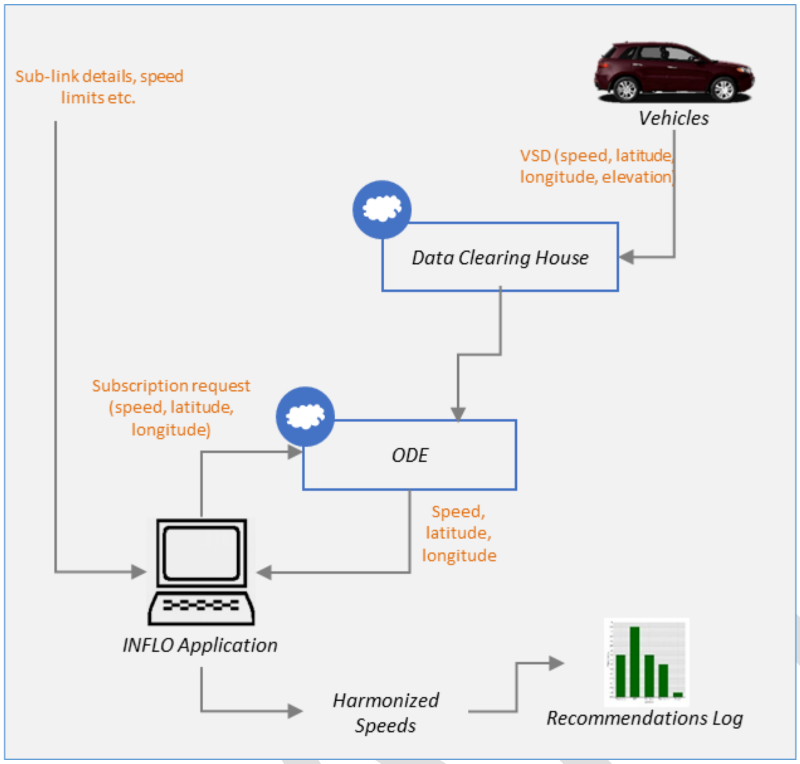

Source: Booz Allen Hamilton, 2015

Figure 11. INFLO Application Execution Schema

Figure 11 presents a high level depiction of the implementation schema for SPD-HARM application and how it was deployed during the field test to help evaluate the performance of the ODE. In the figure above, it is noteworthy that speed recommendations are not provided to drivers but to a recommendations log. This log was monitored by the field test execution team during the field test. The data contained in this log was then used to support post field-test analyses to determine the effectiveness of the ODE in supporting the application.

INFLO – Dynamic Speed Harmonization Field Test Execution Plan

The section below presents a high level overview of the execution plan in evaluating the ODE's support of INFLO's Dynamic Speed Harmonization application.

Test Case Objective

The primary objectives of this test are:

1- Ensure the that requested data from the ODE is provided to the SPD-HARM application for ingestion
2- Evaluate data sufficiency of the ODE to provide the SPD-HARM application with the data required for the application to derive speed recommendations for connected vehicles involved in the field test

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Test Case Location

While the Speed Harmonization application is primarily meant for freeway operation, its feasibility as to whether or not it may be supported by the ODE can be done through evaluating the application on arterial streets. In the case of the SEMI Test Bed, the application was tested on both city streets and on rural high-speed signalized highways. The primary segment of the downtown test bed that was used to evaluate the ODE's support of the SPD-HARM application was along Larned St. and for Telegraph Road would be Telegraph Road South Bound. The goal of the SPD-HARM application was to provide recommended travel speed along the targeted segments shown in the Figures.

For the Downtown Testbed, the total length of the harmonized segment is only 0.5 mile and therefore, the recommendation produced would be at a sublink level (four sublinks of 0.125 mile each). Because Telegraph Road is longer than the Downtown testbed, INFLO can utilize true mile-marker information at this location. The four zones are one mile long with 2x0.5 mile long sublinks in for each. As platoons of vehicles travel south on US-24, their real-time speeds and locations triggered the application to produce speed advisory messages.

Source:Open Street Maps, Booz Allen Hamilton, 2015

Figure 12: INFLO's 4 Target Segments in the Downtown Testbed

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Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 13. INFLO's Target Segments along Telegraph Road

Data Input to the Application

The application, as developed by the prototype development team, requires the following inputs:

- Instantaneous Vehicle Location, derived from BSM Messages.
- Vehicle following distance (assumed if not available at 1 Hz).
- Vehicle speed (at least 1Hz)
- Vehicle acceleration (at least 1 Hz) - to be calculated from instantaneous speeds
- Sub-link descriptors – speed limits, latitude/longitude values etc.

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Table 3 below presents a mapping of the above application input data to data elements that were generated in the SEMI Test Bed and propagated by the ODE.

Table 3: Mapping of SPD-HARM Input Data to those Generated by SEMI Test Bed

Data Element #.	Application Data Input	SEMI Test Bed Message Bundle | Data Element
1	Instantaneous Vehicle Location	VSD | (latitude, longitude, elevation)
2	Vehicle following distance	Can be assumed
3	Vehicle speed	VSD | Speed
4	Vehicle acceleration	VSD | Acceleration
5	Sub-link descriptors – speed limits, lat/long values etc.	Known but not available from the SEMI Test/ODE

Additional Data Input

In addition to the core data requirement listed above in the "Data Input to the Application" section, the key additional data required by the emulated SPD-HARM application is average speeds, computed at the most effective frequency, depending on the number of connected vehicles and operating characteristics of the test bed. Mile Marker Location and direction also served as input to the emulated SPD-HARM app.

Data Output

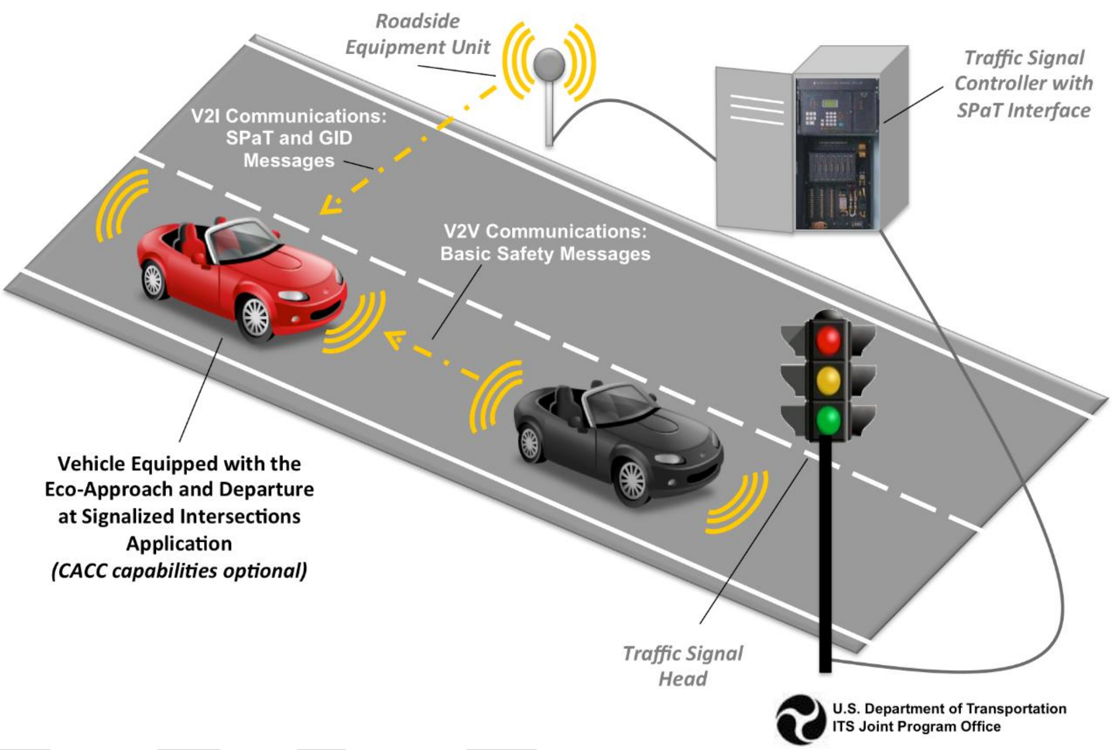
The output data generated by the SPD-HARM application included; date, recommended speed, begin mile marker, end mile marker, justification, and validity duration.

2.1.3. Applications for the Environment: Real-time Information Synthesis (AERIS) - Eco Approach and Departure at Signalized Intersections

Application Description

Eco-Approach and Departure at Signalized Intersections is an application that is part of the Eco-Signal Operations Scenario. The Eco-Signal Operations Scenario is one of the Operational Scenarios (bundles) that were defined as part of the Applications for the Environment: Real-time Information Synthesis (AERIS) program initiated by the US DOT. The Eco-Approach and Departure application makes use of the I2V and V2V communications over DSRC to obtain signal information and information from other vehicles to generate speed advice for vehicles.

This application uses wireless data communications sent from a roadside equipment (RSE) unit to connected vehicles to encourage "green" approaches to signalized intersections. The application, installed in the On-Board Equipment (OBE) in a vehicle, collects signal phase and timing (SPaT) and Geographic Information Description (GID) messages using V2I communications and data from nearby vehicles using V2V communications. Upon receiving these messages, the application performs calculations to determine the vehicle's optimal speed to pass the next traffic signal on a green light or to decelerate to a stop in the most eco-friendly manner. This information is then sent to longitudinal vehicle control capabilities in the vehicle to support partial automation (when longitudinal automation is not available, the vehicles are provided advisory speeds to traverse intersections). The application also determines a vehicle's acceleration as it departs from a signalized intersection and potentially includes engine start-stop technologies. See Figure 14 illustrates the operational concept of the Eco Approach and Departure application.



Source: USDOT, 2012

Figure 14: Eco-Approach and Departure at Signalized Intersections Illustrated

Application objectives

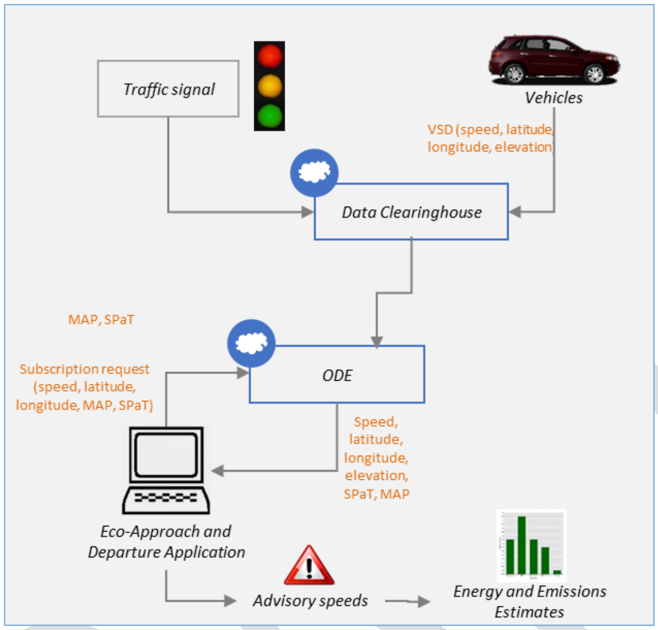
The objective of the application is to help vehicles traverse a signalized intersection in an eco-friendly manner by providing advisory speeds or using longitudinal automation to help vehicles operate in an optimal manner. The application uses the signal information such as "time to red" or "time to green" to determine optimal speeds for accelerating, cruising, or decelerating when approaching an intersection. The application also determines optimal speeds to depart an intersection after coming to a stop.

AERIS - Eco Approach and Departure at Signalized Intersections Emulated Environment

This application is currently implemented in Paramics, with the aid of a C++ module driving the application's algorithm. The ODE team used its access to the inner workings of this application to implement modifications that were needed as SEMI Test Bed was not able to provide all the

ODE Field Test Plan and Emulated Applications

data that a traffic simulation network model can provide. However, the core data elements that were needed by this application were available from the Test Bed. The emulation environment was based in C++ and accepted input from the SEMI Test Bed, and output approach and departure strategies, on a per vehicle basis, to a flat file.



Source: Booz Allen Hamilton, 2015

Figure 15. Eco Approach and Departure Application Execution Schema

As shown in Figure 15, the test environment primarily consisted of the ODE, the Data Clearinghouse, and the testing platform (i.e. a laptop with the test application). As the ODE ingests data from the Clearinghouse, in real-time, the ODE fulfills the data request from the subscribing application. This data request includes the request for SPaT, MAP (which is synonymous with the applications need for GID) and vehicle data consisting of location, speed and heading. The Eco-Approach and Departure application was hosted on a computer for this field test, versus an in-vehicle medium. The computer emulates the behavior of a vehicle's computer requesting information to traverse a signalized intersection using the Eco-Approach and Departure application.

The Eco-Approach and Departure Application used the data from the ODE to generate speed recommendations to traverse the intersection in an eco-friendly manner.

AERIS - Eco Approach and Departure (EAD) at Signalized Intersections Field Test Execution Plan

This section provides an overview of the execution plan that was used to evaluate the ODE's support of the Eco Approach and Departure application.

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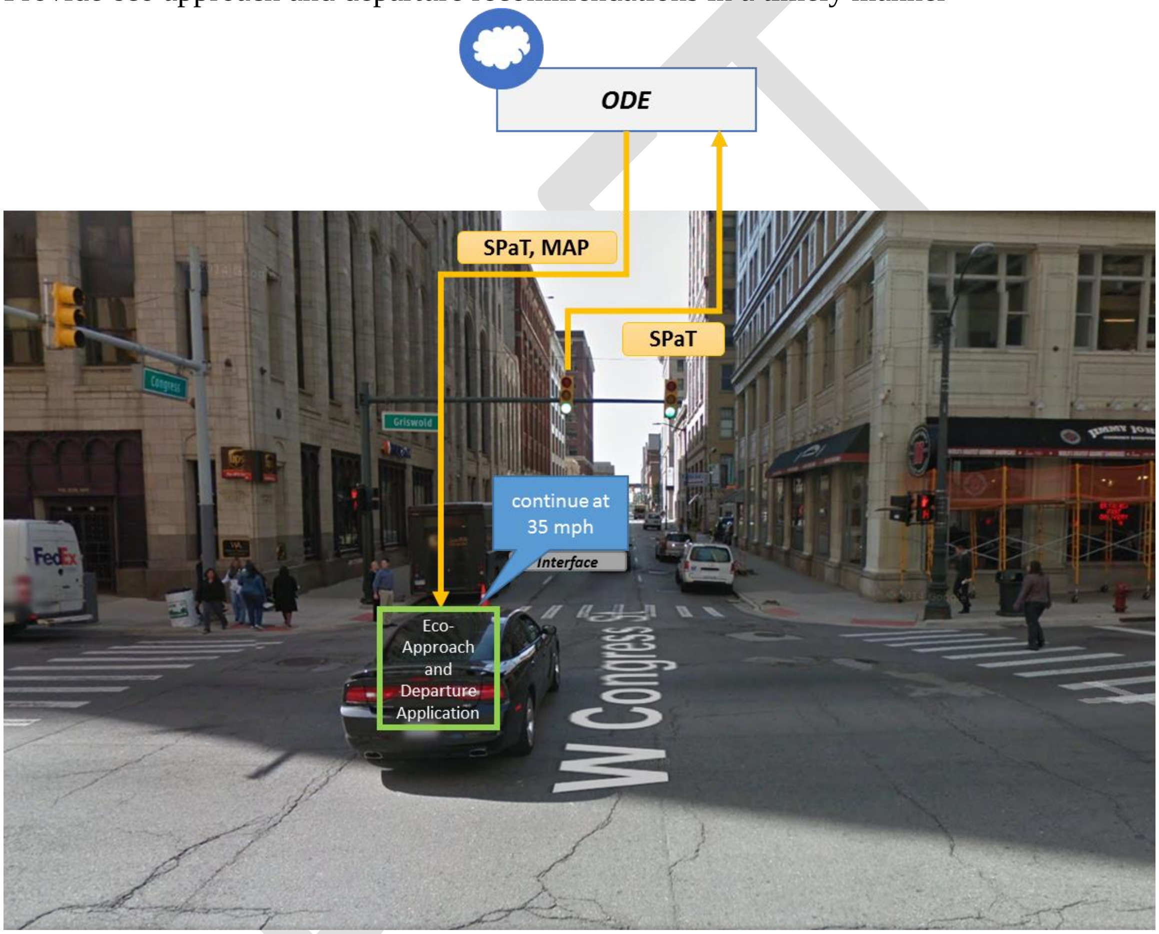
Test Case Objective

The objectives of this test were to:

1- Ensure that the data requested from the ODE, were delivered to the emulated application. This is of particular importance as the ODE provided data from the Clearinghouse to the emulated application.
2- Provide speed recommendations, for both intersection approach and departure based on data received from the ODE
3- Provide eco approach and departure recommendations in a timely manner



Source: Google Maps, Booz Allen Hamilton, 2015

Figure 16: Illustration of Eco-Approach and Departure application using the ODE in the field

Test Case Location

The Eco-Approach and Departure application is intended for use in an arterial transportation network, with signalized intersections. All signalized intersection of the SEMI test bed are equipped with an RSU that is able to capture and communicate the status of the signal.

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To evaluate this application, drivers navigated the test bed as indicated by the arrows shown in Figure 17. Ideally, as vehicles traverse each intersection, the application would have produce eco-approach and departure advisories. However, it should be noted that in the case that an intersection's RSU might be offline, no advisories were generated. While evaluating this application, drivers were not be given any special instructions to exercise the breadth of the Eco Approach and Departure application. However, the field test team ensured that the field test is sufficiently long to facilitate a diverse set of driver interactions with a signalized intersection. Such interactions included drivers being in the position to slow-down, coast, or speed up to navigate a signalized intersection in an eco-friendly manner.

Two intersections were identified to run the EAD application. On US-24 Southbound direction, Telegraph and 10-mile Road intersection (ID# 0C1D) and on US-24 Northbound direction, Telegraph and 12-mile Road intersection (ID# 0C1E) were used. Similarly, for the downtown testbed, intersection of Washington Blvd and Congress St (ID# 0088) was used. The application received simultaneous ISD and VSD streams. For each application the EAD application isolated specific intersection's SPaT and then specific approach's current state and time remaining. VSD's are filtered into unique vehicles in each approach/departure zone. Recommended action is computed based on Distance to Intersection (DTI), Time to Intersection (TTI), current state of the signal (CurrState) and time to change for a given phase (TimeToChange).

Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 17. Downtown Test Path for Eco Approach and Departure Application

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Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 18. Telegraph Road Test Path for Eco Approach and Departure Application

Data Input to the Application

The application required the following minimal information to operate:

- Vehicle position (10Hz)
- Vehicle Current Speed (10Hz)

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- Current speed of the leading vehicle (if any) (10 Hz)
- Current location of the leading vehicle (if any) (10 Hz)
- Current heading vehicle (10 Hz)
- SPaT (10Hz)
- Vehicle type (for the emissions estimator; once per vehicle)
- Vehicle specifications (engine type – diesel or gasoline or hybrid, weight; once per vehicle)
- MAP or GID (once as the vehicle approaches an intersection)
- Road network (once)

Table 4 below presents a mapping of the above application input data to data elements that are generated in the SEMI Test Bed and propagated by the ODE.

Table 4: Mapping of Eco-Approach and Departure at Signalized Application Input Data to those Generated by SEMI Test Bed

Data Element #.	Application Data Input	SEMI Test Bed Message Bundle | Data Element
1	Vehicle position	VSD | (latitude, longitude, elevation)
2	Vehicle Current Speed	VSD | Speed
3	Current speed of the leading vehicle	VSD | Speed
4	Current location of the leading vehicle	VSD | (latitude, longitude, elevation)
5	SPaT	ISD | SPAT
6	Vehicle type	Optional
7	Vehicle specifications	Optional
8	MAP or GID	ISD | MAP
9	Road network (once)	Known

Additional Data Input

In addition to the core data requirements listed above in the "Data Input to the Application" section, an additional data element that is needed by the emulated Eco-Approach and Departure application is the speed of the lead vehicle that is a connected vehicle approaching (or departing) as intersection. While this is speed possible to obtain, assuming that the lead vehicle is also a connected vehicle, cannot be guaranteed. As such the team assumed the speed of the lead vehicle irrespective of whether or not it is a lead vehicle is present.

Data Output

The primary output data generated by the Eco-Approach application were date and time, recommended speed, and signal status and timing.

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2.1.4. P-MAW – *Pseudo* Motorists Advisories and Warnings

Application Description

The Pseudo – Motorist Advisories and Warnings (P-MAW) application is based on USDOT's Motorists Advisories and Warning (MAW) application. The MAW application provides location specific, near real-time road weather information for the travelling public. Incorporating Connected Vehicle data enabled Vehicle Data Translator (VDT) outputs, the MAW provides current inferences for visibility, road condition, and road precipitation. The VDT system ingests and processes mobile data already resident on the vehicle along with ancillary weather data (e.g. radar) to create road and atmospheric hazard products for a variety of users[4]. The MAW application also blends the aforementioned outputs with a forecast engine to provide 12-hour and 24-hour forecasts of road weather conditions. The information may come from either vehicles operated by the general public and commercial entities (including passenger cars and trucks) or specialty vehicles and public fleet vehicles (such as snowplows, maintenance trucks, and other agency pool vehicles). The raw data is processed in a control center to generate data outputs based on road segments. The processing also includes a road weather motorist alerts algorithm to generate short time horizon alerts that is pushed to user systems. In addition, the information collected can be combined with observations and forecasts from other sources to provide medium (next 2-12 hours) or long term (more than 12 hours) advisories through a variety of interfaces including web based and connected vehicle based interfaces. Using the MAW application, drivers will be able to plan routes in advance of their travel, including knowing which way to go and whether to delay travel, based on route-specific road weather conditions. While on the road, a phone application keeps drivers abreast of changing road weather conditions. The phone application provides short term warnings or advisories to individual motorists. The diagram below shows the data flows for the MAW application.

[4]Source: http://ntl.bts.gov/lib/43000/43200/43279/FHWA-JPO-11-127_Final.pdf

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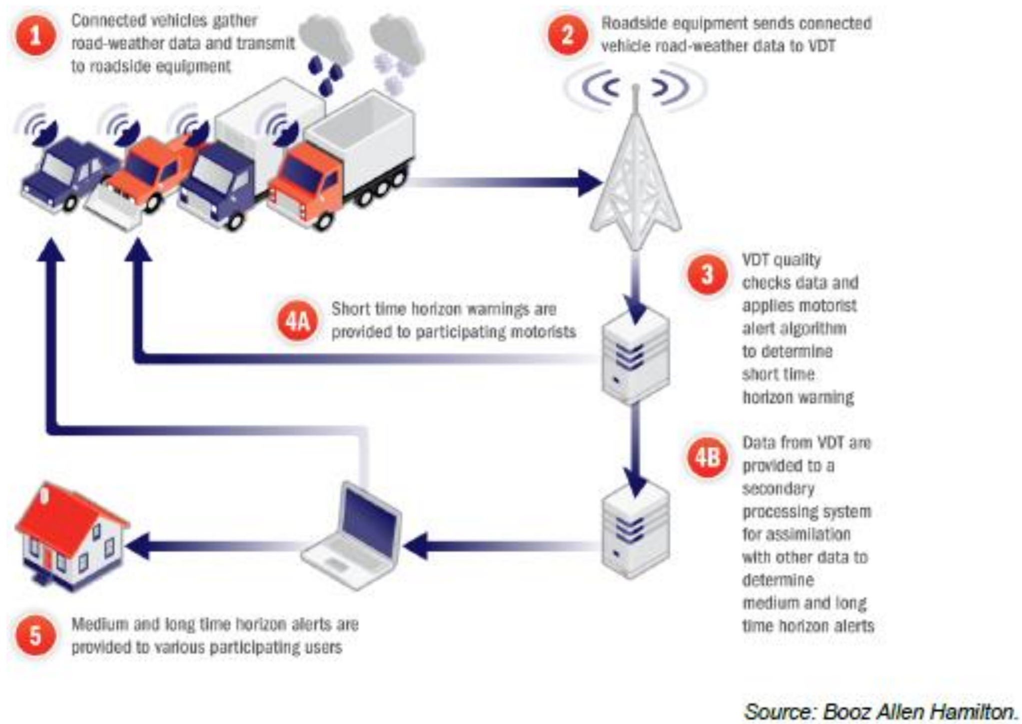

Figure 19: Schematic of the Motorists Advisory and Warning System

The P-MAW application is a lighter version of MAW application, only being able to provide basic road weather based warnings / advisories. The operating concept of the P-MAW application is that it subscribes to Test Bed data, analyze the data in conjunction with data from the Weather Data Environment (WxDE) to determine whether or not to issue a (weather based) warning / alert. Note, the WxDE data that the P-MAW application used was not a real-time stream from the WxDE. Instead the data was archived data from the WxDE that has been transposed to make relevant to the SEMI Test Bed, during field. That original data that is being modified was collected on Belle Isle during a WxDE field test demonstration during the 2014 ITS World Congress. The P-MAW application also did not use data directly from the VDT; instead data that would have been provided by the VDT was a part of the archived WxDE data that was modified for this field test.

Application objectives

The following are the primary objectives of the P-MAW application:

- Create and provide weather and road weather based advisories and warnings

Data Input to the P-MAW application

The application, as developed by the impact assessment team, requires the following inputs:

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- Connected vehicles broadcast position and data that can be used to determine road and weather conditions via roadside equipment to a VDT processor.
- The VDT ingests data, performs quality checks, applies algorithms, and outputs near-real-time road segment data to a Motorist Advisory and Warning System application.
- The Motorist Advisory and Warning System application applies algorithms and outputs short time horizon advisories and warning to in-vehicle systems in participating connected vehicles.
- Environmental Sensor Stations (ESS) and other remote sensor systems send data to the VDT.
- The VDT acquires forecast and other meteorological model output data.
- The VDT ingests additional data, performs quality checks, applies algorithms, and outputs advanced road segment data to the Motorist Advisory and Warning System application in a traffic management entity.
- The Motorist Advisory and Warning System application applies algorithms and outputs medium and long time horizon advisories and warnings to a traffic manager for approval.
- The approved medium and long time horizon advisories and warnings are communicated to participating entities for onward distribution to their users or subscribers.

Since this field test used a lighter version of the MAW application, the main data input that the P-MAW application required were connected vehicle data, largely vehicle position data, from the Test Bed, and weather and road weather data from the modified WxDE data stream, which was obtained from the ODE.

Table 5 below presents a mapping of the above application input data to data elements that are generated in the SEMI Test Bed and propagated by the ODE.

Table 5: Mapping of P-MAW Application Input Data to those Generated by SEMI Test Bed

Data Element #.	Application Data Input	SEMI Test Bed Message Bundle | Data Element
1	Vehicle position	VSD | (latitude, longitude, elevation)
2	Vehicle current speed	VSD | Speed
3	Weather / Road Weather Data	Modified WxDE data stream

Note, the above table references the "*Pseudo*" MAW application and therefore does not need all the data needed by the *real* MAW application

P-MAW Emulated Environment

The P-MAW application was developed using Python. This application was built from the ground up with some of its capabilities informed by those of the mature MAW application. The core logic of this application is to take as input integrated weather data and connected vehicle data, namely VSD, and to generate advisories and warnings to a testbed vehicle approaching an area impacted by a weather event. The weather data that is a part of the application is a transformed WxDE data set which was generated on Belle Isle during a series of simulated weather events. The basics of this transformation was the changing "relocation" of the simulated

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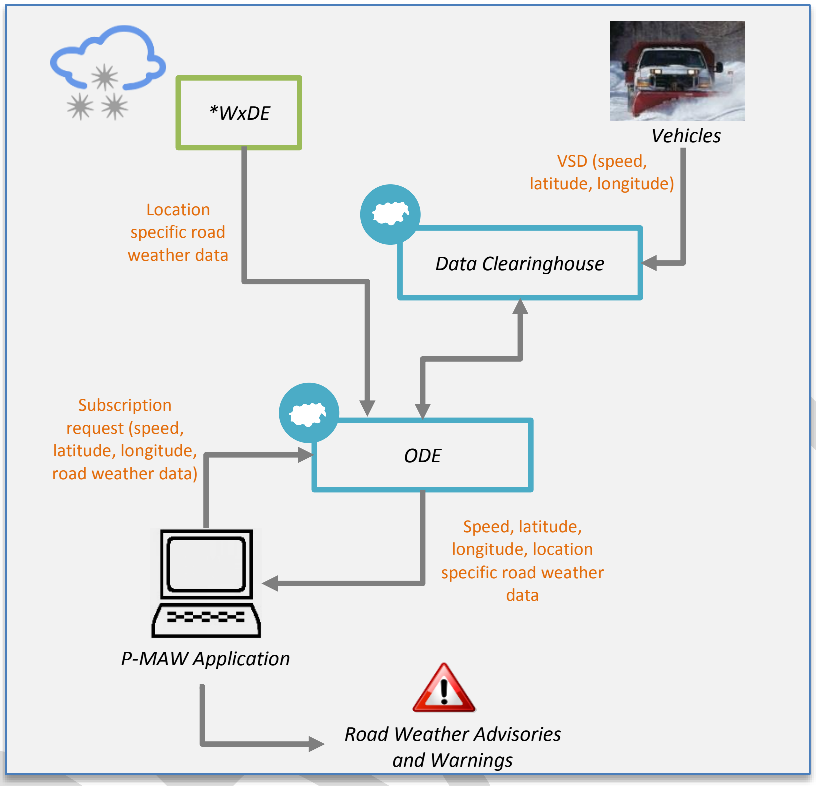
weather events from Belle Isle to the SEMI Test Bed and changing the related timestamp to match that of the test execution window. The relocation of these weather events now enable the P-MAW application to generate location specific warnings and advisories when test bed vehicle approach any of these relocated weather events. See Figure 20**Error! Reference source not found.** for an illustration of the data and information flows that support the P-MAW application



Source: Booz Allen Hamilton, 2015

Figure 20: Data flow for the P-MAW Application Test (*Transformed weather data from the WxDE)

P-MAW Field Test Execution Plan

This section provides an overview of the execution plan to evaluate the ODE's support of the P-MAW application.

Test Case Objective

The objectives of this test are to:

1- Ensure that the data requested from the ODE is delivered to the emulated application. This is of particular importance as ODE provided / integrated data from both the Clearinghouse and an additional data stream (for weather data)

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2- Provide timely advisories and warnings as test bed vehicles approach areas of interest according to the transformed weather data

Test Case Location

For the P-MAW application field testing, the vehicles followed the loop demonstrated in the following figure. This loop is exactly the same loop as with the other test cases. As vehicles traverse these locations, they receive advisories and warnings based on their latitude and longitude. It has to be noted that the weather data is a static file and is not streamed in real-time from any data environment.

Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 21: Downtown Test Bed Path for the P-MAW Application

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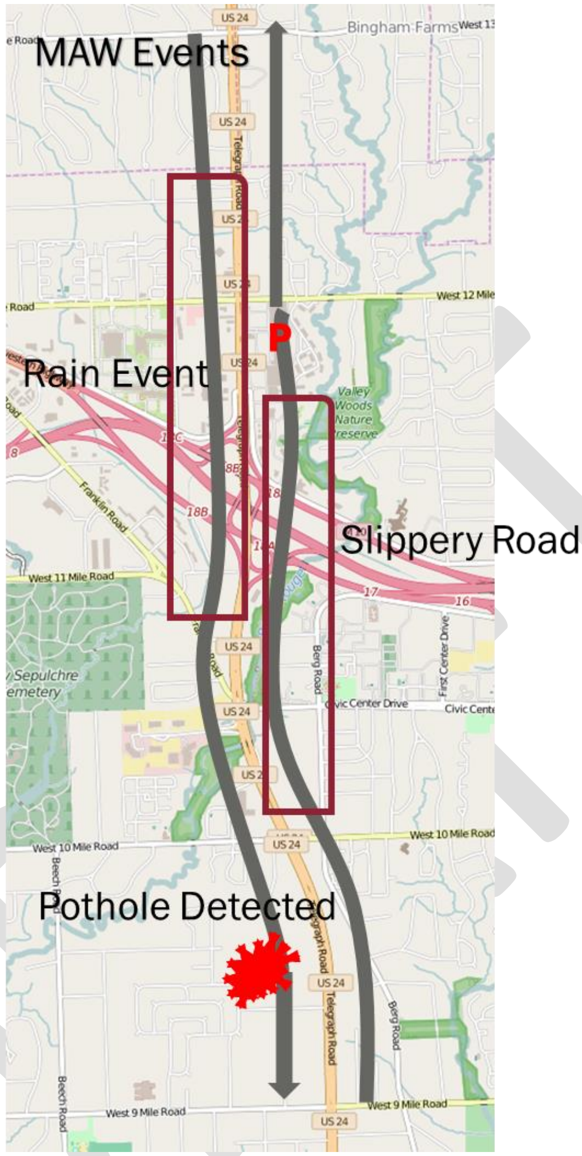

Source: Open Street Maps, Booz Allen Hamilton, 2015

Figure 22: Telegraph Road Test Bed Path for the P-MAW Application

Additional Data Input

In addition to VSD and the simulated WxDE data stream from the Belle Isle demonstration, the test bed team also further transformed the simulated data to include additional weather events that were not simulated on Belle Isle but was of value to this field test.

Data Output

The output data generated by the P-MAW application primarily included advisories and warnings that consist of date, time, weather conditions associated with specific latitude and longitude.

2.2. Summary and Mapping of Emulated Applications and ODE Functionalities

2.2.1. Summary of Emulated Applications

Table 6 below provides a summary of the selected applications, the test objectives, data input, and emulated environment. This table summarizes some of what was presented in the preceding sections.

Table 6: Summary of the Selected CV Applications to Emulate for Evaluating the ODE

Application Objective	Test Objective	Data Input	Emulated Environment
R.E.S.C.U.M.E. – INC-ZONE			
• Warns drivers who are approaching temporary incident response zones at unsafe speeds and/or trajectory; • Warns public safety personnel and other officials working in the zone about errant vehicles.	• Ensure the that requested data from the ODE is provide to the INC-ZONE application for ingestion • The INC-ZONE application outputs appropriate advisories and warnings to test vehicles and responders as vehicles approach an incident location in which responders are working	• Vehicle class • Vehicle location • Vehicle lane • Vehicle speed	• This environment is be based in Python and replaced the VISSIM data input stream with a tailored data stream from the SEMI Test Bed.
INFLO – Dynamic Speed Harmonization			
• Harmonize speeds in response to congestion, incidents, and road weather conditions, applicable to freeways, arterials, and rural roads.	• Ensure the that requested data from the ODE is provided to the SPD-HARM application for ingestion • Evaluate data sufficiency of the ODE to provide the SPD-HARM application with the data required for	• Vehicle Location • Vehicle speed • Vehicle acceleration • Sub-link descriptors	• Both input and output streams of this application are centered on Microsoft Access database tables, As such, a python- based environment was

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	the application to derive speed recommendations for connected vehicles involved in the field test		built to interface with both ODE and these databases
AERIS – Eco Approach and Departure at Signalized Intersection			
• Assist vehicles to traverse a signalized intersection in an eco-friendly manner by providing advisory speeds or using longitudinal acceleration/ deceleration.	• Ensure that the data requested from the ODE is delivered to the emulated application. • Provide speed recommendations for both intersection approach and departure based on data received from the ODE • Provide eco approach and departure recommendations in a timely manner	• Vehicle position • Vehicle Speed • SPaT • Vehicle type • Vehicle specifications • MAP	• Implemented in Paramics, with the aid of a C++ module driving the application's algorithm. • The emulation environment is based in C++ and replaces the Paramics component with input from the SEMI Test Bed (and output approach and departure strategies, on a per vehicle basis, to a flat file).
P-MAW – Pseudo Motorists Advisories and Warnings			
• Create and provide weather and road weather based advisories and warnings	• Ensure that the data requested from the ODE is delivered to the emulated application. This is of particular importance as ODE provided / integrated data from both the Clearinghouse and an additional data stream (for weather data)	• Vehicle position • WxDE weather and road weather	• The algorithm to support the P--MAW is being scripted in Python

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	• Provide timely advisories and warnings as test bed vehicles approach areas of interest according to the transformed weather data		

The four emulated applications were designed to run as simultaneous "instances" and subscribe to VSDs and ISDs in parallel. The overall framework of the application emulation is shown in Figure 23 below.

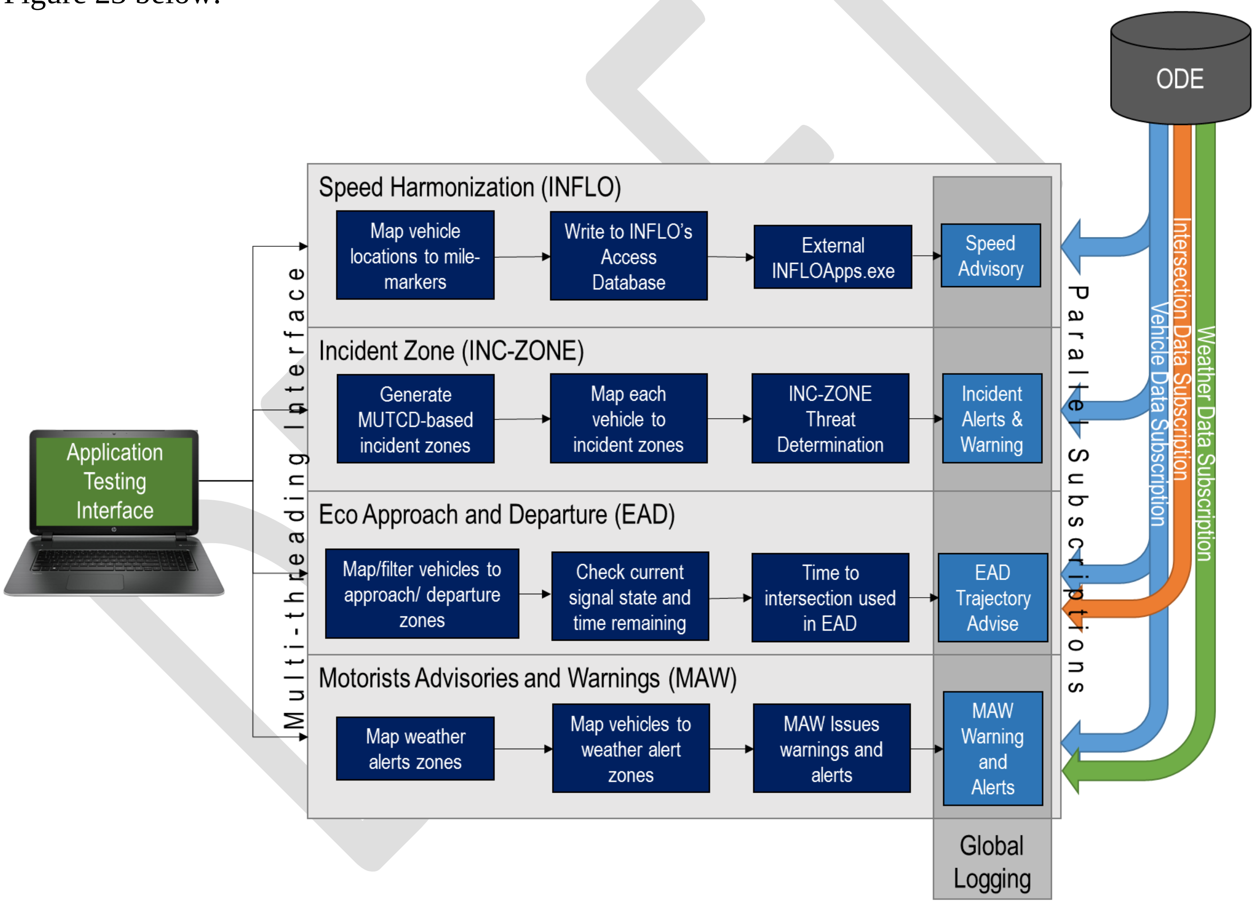

Figure 23: Framework of the application emulation

2.2.2. Mapping of Emulated Applications and ODE Functionalities

The primary goals of this field test is to exercise the core functionalities of the ODE and to evaluate the ODE's ability to support connected vehicle applications in real-time. To this end,

ODE Field Test Plan and Emulated Applications

the four aforementioned emulated applications were selected for involvement in this field test. . Table 7 summarizes the dependencies between the required data input, from the test bed, for each application, and after having the ODE supply those data, the derived output from each application.

Table 7: High level framework for Evaluating ODE Functionalities with Emulated Applications

Emulated Application	Input	Anticipated Output
R.E.S.C.U.M.E. – INC-ZONE	• VSD | (latitude, longitude, elevation) • VSD | Speed	• Lane / speed-alerts around lane-closures due to simulated incident and warnings to responders
INFLO – Dynamic Speed Harmonization	• VSD | (latitude, longitude, elevation) • VSD | Speed • VSD | Acceleration	• Harmonized speed recommendations
AERIS – Eco Approach and Departure at Signalized Intersection	• VSD | (latitude, longitude, elevation) • VSD | Speed • ISD | SPAT • ISD | MAP	• Vehicle approach and departure guidance • Second by second energy and emissions estimates for each vehicle • Energy and emissions benefits for each vehicle
P-MAW – Pseudo Motorists Advisories and Warnings	• VSD | (latitude, longitude, elevation) • VSD | Speed • Modified WxDE data stream	• Advisories and warnings based on vehicle position and WxDE' s weather and road weather data

While the VISA functions are the core, value-added, function of the ODE, these functions are not necessarily central to the operation of the selected applications for this field test. However, each application that subscribes to data from the ODE do receive data that have interacted with the core functions of the ODE. The following sections briefly describes each function and how each of the four selected applications interacted with these functions. Note, for detailed description and the implementation of each of these functions in the ODE, readers are asked to consult the Task 4: Concept of Operation document that was develop under this contract.

Validation is the application of identifiable rules to data to ensure they meet minimum levels of acceptable quality, and are therefore suitable for use in a specific application. When data do not meet the established minimum levels of acceptance, this data were flagged so that subscribing applications are aware of the data's validity. During the field test, all application received data that were processed by the validation function. During the field test, the emulated application

ODE Field Test Plan and Emulated Applications

did not alter their operation upon receiving flagged data from data from the ODE. This is primarily attributable to the fact that these applications did not have the built-in logic to appropriately account for flagged values. However, the log of all the VSD records, from the field test, captured the flags that were assigned to certain values by the Validation function.

Integration is the ability to combine data from multiple sources to provide more complete information to subscribing client. During the field test the integration function was exercised by including a few weather based measure as a part of the VSD. The measures that were included with VSD records were air temperature and air pressure. These measure were obtained from transposed weather data from the WxDE – which is required for the operation of the P-MAW application. The *integration* of these data elements with the VSD can be seen from the log of all the VSD records that were generated during the field test.

Sanitization is the processing of data, in its original form, to prevent the discovery of PII. For the field test, this function was implemented with the use of a geofence so that VSD records from within this area are not propagated by the ODE to subscribing applications. All applications were subject to the output from this function. The evidence of the implementation of this function is the notable absence of data around 28644 Telegraph Rd, Southfield, MI 48034, which was our base location when operating in the Telegraph Road test bed.

Aggregation, as defined in the ODE ConOps document, is the ability to compute summary information from more granular data (e.g., count, average), triggered by client application requests or the ODE's default setting to provide a specific transportation/roadway system performance metric(s). While the original plan was to use this function to support the operation of the SPD-HARM application, with an average speed measure, the core of the application logic did support a feasible integration. However, the effects of this function is documented in the Task 6 Report which presents test procedures and results for *all* the ODE functions.

ODE Field Test Plan and Emulated Applications

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CHAPTER 3. FIELD TEST PREPARATION

This sections presents an overview of a series of preparatory steps that were undertaken in order to successfully execute this field test. These procedures range from identifying the various role and responsibilities for those involved in the field to ensuring that all the various components are in good working order prior to the start of the field test.

3.1. Field Test Schedule

Field test execution for both testbeds was conducted April 4, 2016 – April 7, 2016 in Detroit. For a detailed itinerary of the field test schedule please see Appendix B. During the final stages of development of the ODE team toured the test bed to get a more comprehensive view of the roadway and verify that the test plan was feasible and effectively uses the network to evaluate the ODE. After conducting the walkthrough tour, the team finalized detail test scripts and procedures for field test.

3.1.1. Field Test Dry Run

Before the field test was conducted, a field test dry run was conducted February 22-25, 2016 for both test beds (downtown Detroit and Telegraph Rd.). Drivers navigated the test beds February 23-24. This activity ensured that all testing devices and components, including the communication infrastructure, were operating properly. The dry run activities also served to have all members of the field testing team and the participants in sync on the various testing activities. The dry run also gave the testing team the opportunity to address any issues that may disrupt the final field test.

3.1.2. Simulation Testing

In order to ensure that the emulated applications work with real data, the ODE also featured a “deposit client” through which data files could be streamed to imitate real-time field data. The team used simulated data for this streaming capability and to test the different aspects of applications. The simulated data was generated using a Vissim microsimulation software where the Telegraph Rd and Downtown Testbed networks were replicated. The Vissim output was streamed to TCA (Trajectory Converter Algorithm) Tool (available at USDOT’s Open Source Application Development Portal). The TCA tool generated BSM messages in CSV format which were converted to VSD records using a custom Python-based script. The ODE’s Deposit Client functionality was then used to simultaneously upload this data and stream the subscription to the applications. A demonstration of the simulation testing (for INFLO in this example) is provided below in Figure 24:

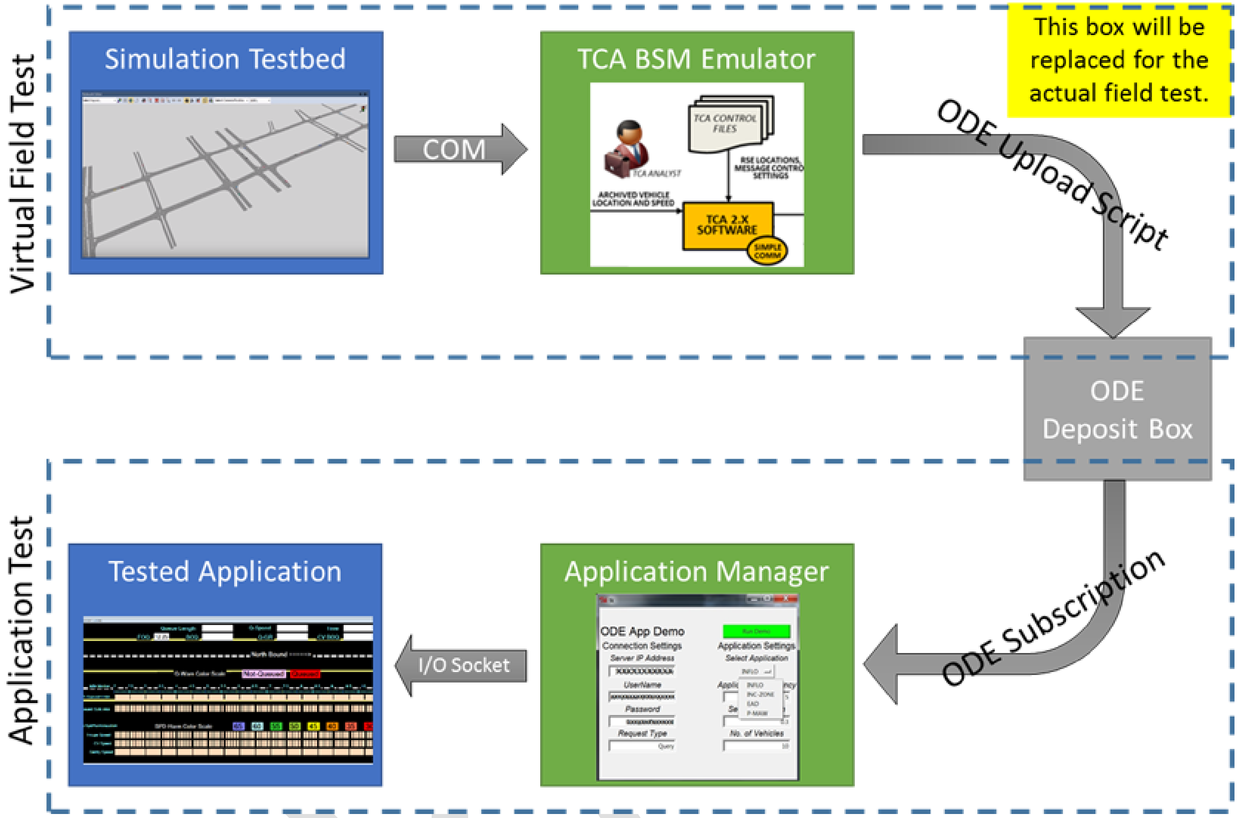

Figure 24: Demonstration of Simulation Testing

3.2. Roles, Responsibility, and Participation

This section highlights the description of a number of participants that were involved with field testing the ODE.

3.2.1. Field Test Team and Lead

The Field Test Team is responsible for designing, developing and coordinating the tests, analyzing the data and reporting the results. This team produced all the test documentation described in the next section, including the Test Procedures / Scripts and Results. The Lead for this team oversaw the execution of duties to be conducted by the Field Test Team.

3.2.2. Field Test Overseer and Approver

The Field Test Overseer is responsible for supervising the experimental design of the Field Test. The Overseer ensures that the Field Test conditions meet the necessary requirements and the data collection is up to the standards. The Overseer confirms that the Field Test design covers all aspects of the ODE to be demonstrated and gives the official approval to kick-off the proceedings for the conduct of the Field Test.

3.2.3. Field Test Observer

The Field Test Observer is in charge of monitoring the data recording, compiling, and transfer during the Field Test. The Observer bears the responsibility for quality control at each stage of the Field Test. The Observer must be present at the field site and evaluate random observations for quality control. The observer must ensure that all steps of the Field Test are being conducted correctly, all the devices are working properly, and the data is being recorded without error.

3.2.4. ODE POC / Lead

The ODE POC/Lead supervises and controls all tests. The ODE Lead reviewed and approved the detailed Test Procedures, and has the authority to direct all test activities. The Test Director notified the relevant stakeholders (US DOT project team and other interested US DOT personnel) representative(s) of the test schedule at least one week in advance of the scheduled start. All stakeholder representatives (including USDOT, Booz Allen Hamilton, SEMI Test Bed, etc.) are welcome to witness any testing.

3.2.5. Emulated Application POC / Lead

The primary function of the emulated application point of contact / lead is to ensure that the emulated applications are in working order and that no further development actions are needed to have these applications functioning during the field test. This individual is also responsible for verifying that all the requisite field test components, per each emulated application, are available and are in good working order for the field test. During the field test, this individual was on hand to ensure that emulated applications are operating accordingly and to troubleshoot any issues that may arise during the field test.

3.2.6. Network and Test Bed Operator

The Network and Test-bed Operator was available at all times during which field tests are executed. The tests was designed to run under default network settings, so the network operator may not be needed. However, the network operator was always be available to make any changes that may become necessary.

3.2.7. Driver Team

The drivers from the Driver Team operated the vehicles during the field test. The field test team worked with the test bed operators to hire drivers for our testing activities. Based on the practice of the test bed operator, the drivers for this field test were contracted from Roush (https://www.roush.com). These drivers followed the explicit instructions in accordance to the test script. Providing two-way means of communication for each driver is currently under consideration. This provided a direct line of communication between the field test team and drivers so that the team can pass instructions as needed and drivers can inform the field test personnel of any incidents or exceptions that they experience.

3.2.8. Field Data Collection Personnel

The field data collection personnel was charged with collecting both directly related field test data elements and contextual data elements – describing the environment in which directly related data elements were collected. Note, both automatic and manual (human-in-the-loop hardware / software mechanism) data recording techniques were a part of this this field test.

3.2.9. Data Analyst POC / Lead

Data analysts are those who will use data available from the field test to evaluate the performance of the ODE in being a data provisioning system, supporting connected vehicle applications. During and after the testing period, they analyzed the recorded data for each test case to determine whether the requirements have been met for a given test case, which requires offline analysis. Data analysts will also participate in preparing the final report, documenting their numerical analyses and providing justifications for their conclusions from the data.

3.3. Testing Documentation

This section describes the development, production, and distribution of the various documents that was used to execute the field test. The core function of these documents was to ensure that all involved were aware of their responsibilities and activities to be undertaken. These documents also supported coordination amongst the participants and various teams that are involved in the field test.

3.3.1. Test Cases/Scenario Description

A test case is a set of vehicular maneuvers and / or scenarios that, when completed, create a data set that was used to support the evaluation of the ODE. For each test case, the test fleet of vehicles moved through the SEMI Test Bed in a scripted way, generating data that t was used to supply the emulated applications with the requisite data to support their operation. As presented above, there were a few test scenarios that were executed for each emulated application. The use of multiple scenarios per application was to ensure that a variety of scenarios are supported by both the application and the ODE.

The above sections provided a detailed overview of the test cases for each application. Section 3.3.2 presents a compact representation of the various scenarios that were a part of the field test.

Section 3.3.2 specifies what vehicular movements and related activities were completed to record the data needed to evaluate the ODE, but does not contain the details necessary for the execution of the test. A preview of those details are provided contained in Appendix B.

Test cases included runs at the downtown Detroit and Telegraph Rd. testbeds for a range vehicle platoon configurations. Each test case run was executed in one continuous block of time, for a specific set of conditions, in order to get sufficient data to verify the operation of the emulated application. However, for test cases with multiple runs, the runs did not need to be executed in a continuous block of time. Because the various runs for a given test case required different traffic conditions, it was often impractical to execute the runs in one block of time. The target duration for each test case run was at least 60 minutes. This, in part, was to ensure that enough data were collected during each run to appropriately evaluate the performance of the application and the ODE, as well as safeguard against brief unusual traffic events did not prevent as overly significant and introduce quality issues with the collected data.

3.3.2. Test Procedures / Script

The Test Procedures / Script describes the general actions that were undertaken by key participants (i.e. drivers) during the execution of the test case runs. Immediately below is a synthesis of the test cases that were executed during the field test. Pairing this synthesis with the schedule presented in Appendix B the full picture as to how the field test was completed is taking form.

In general, the directives that were given to drivers was to loop through each test bed in a particular platoon configuration. The loop through the each test bed is as follows:

The Downtown Detroit Testbed Loop (Figure 25):

- Start from Larned/Shelby Parking onto Larned St.
- Drive East on Larned St. until Beaubien St.
- Turn Left onto Beaubien St.
- Turn Right onto Congress St.
- Drive West on Congress St. until Washington St.
- Turn Left onto Washington St.
- Turn Left onto Larned St.
- If it’s single loop or end of group loops: Turn Left into Parking Lot across Crowne Plaza
- Else: Drive East on Larned St. and repeat the loop.

The Telegraph Road Loop (Figure 26):

- Start from Twelve Mall Parking Lot (Chipotle Parking lot - 28644 Telegraph Rd, Southfield, MI 48034) onto Telegraph Road

- Drive North until the U-turn beyond W 13 Mile Road
- Take a U-turn to SB Telegraph Rd
- Drive South until the U-turn beyond W 9 Mile Road
- Take a U-turn to NB Telegraph Rd
- For last loop in a group: Drive North until Tel Twelve Mall Parking Lot and enter the parking lot from Telegraph Rd
- Else: Drive North towards W13 Mile Road and repeat the loop

–

The general driving directives, platoon configurations and durations are as follows:

- three platoon patterns were selected for the field test
- each pattern last approximately 60 minutes
  - 1 6-car Platoon
  - 2 3-car Platoon
  - 6 1-car Platoon
- Time interval between platoons:
  - Downtown Detroit:
    - 6 1-car Platoon with 3-minute headway
    - 2 3-car Platoon with 6-minute headway
    - 1 6-car Platoon with N/A
  - Telegraph Road:
    - 6 1-car Platoon with 5-minute headway
    - 2 3-car Platoon with 10--minute headway
    - 1 6-car Platoon with N/A

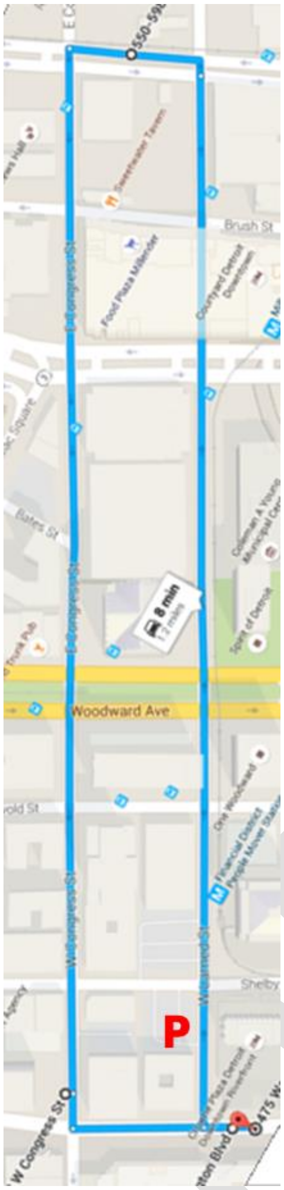

Figure 25. Downtown Testbed Driving Script

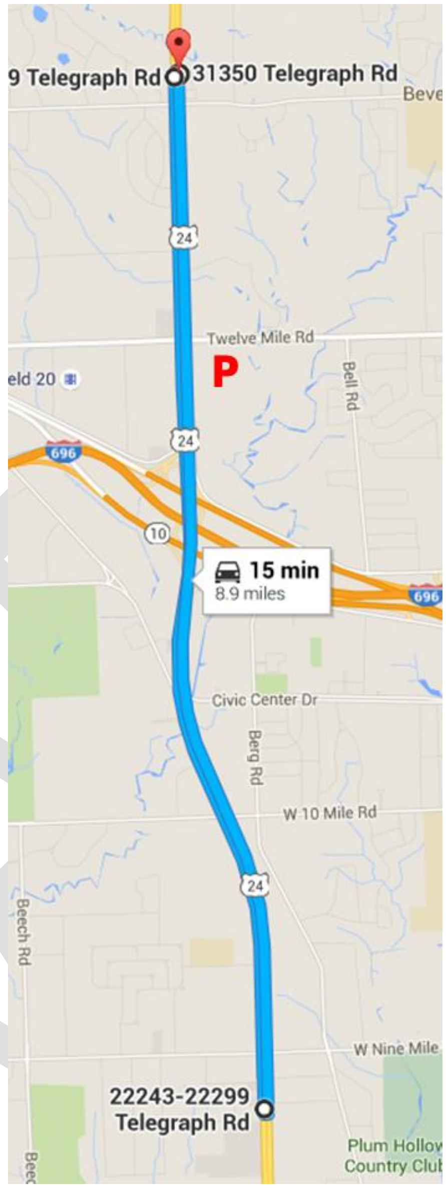

Figure 26. Telegraph Road Driving Script

3.4. Coordination with SEMI Test Bed Contractor

The Southeast Michigan Test Bed is currently operated and maintained by a contractor (Leidos) designated by the USDOT. Booz Allen's field test team coordinated all field test activity with the contractor's operation schedule to minimize any disruption and to establish a base at which to stay during travel.

3.5. Testing Resources

This section describes the various resources that were used / needed to execute this field test. These resources ranged from those affiliated with the environment in which the field test is being conducted, e.g. the road network, to the resources needed by the emulated applications to meet their objectives.

3.5.1. Roadway Network – Southeast Michigan Test Bed

Prior to carrying out field test activities, the SEMI Test Bed contractor was contacted to gather information regarding both the status on the test bed infrastructure and the condition of the roadway network. A significant amount of the RSUs were online and so was the Clearinghouse/Warehouse infrastructure. There were also no significant road work being undertaken during the time that the field test was scheduled. These status updates conducive to the execution of the field test and, as such, the field test proceeded according to plan. .

3.5.2. Vehicles

The test bed contractor has seven equipped, 2007 Jeep Grand Cherokees available to support field test bed activities. This field test used six of the seven equipped vehicles. The seventh vehicle was held in reserve to replace any one if the six in case something were to happen. Each of these vehicles is equipped with an on-board unit that is capable of generating and transmitting basic safety messages (BSMs). These units are either made by Savari or Arada.

3.5.3. Drivers

The field test driving team was acquired through Roush Industries. Our driving team consisted of one driver coordinator and 6 drivers. These driver are professionally trained. Some of these drivers have participated in similar field tests prior to this field test. This was beneficial, as they were familiar with both the network and procedures and goals of conducting such a field test. These experienced drivers were also able to serve as guides for drivers who were participating in such a field experiment for the first time.

3.5.4. Data Collection and Logged Activities

During the field test the data that were generate were automatically stored to support future analyses. The data received by the ODE was captured and stored in its native ASN.1 form as well in log form. Each subscribing emulated application captured and stored all the data they received from the ODE and the data the generated, in the form of alerts, warnings, and guidance. An additional application was created to crosscheck all the VSD records that were transmitted by the ODE. This application captured and logged all VSD records.

3.5.5. Resources Required by Emulated applications

For this field test all emulated applications operated from a single laptop. During the test this configuration worked sufficiently well. However based on preliminary analyses the team began to notice that some of the data were buffered for longer periods than expected. These longer buffering periods occurred when data rate were at the highest and it is discovered that this buffering was a function of the hardware configuration of the laptop. The application that was created to crosscheck VSD records from the ODE was operated on a separate laptop. This was largely due to storage space restrictions.

3.5.6. Additional Equipment

The following is a short list of additional equipment that were used to execute this field test:

- Smart phones (used for coordination calls, picture taking and video recording)
- WebEx and teleconference line
- Mobile chargers for both phones and laptops
- Mobile hotspot (to support internet connectivity in the field)

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CHAPTER 4. INTERACTION WITH THE RESEARCH DATA EXCHANGE

The Research Data Exchange (RDE) is a transportation data sharing system that promotes sharing of both archived and real-time data from multiple sources (including vehicle probes) and multiple modes. This data sharing capability will support the needs of ITS researchers and developers while reducing costs and encouraging innovation.

All pertinent data that were generated and collected during the field test were quality checked, documented and provided to RDE team for review, and posting to the RDE. As a part of the data quality checking process, the team reviewed each data set that was created by the various logging tools, which were in operation during the field test. A significant portion of this exercise was to ensure that the data elements and their values were consistent with the definitions of each element according to the J2735 standard. This quality checking process also included comparing ground truth field data with the data that were logged by the various loggers. The supporting documentation that was provided to the RDE largely comprised of a metadata document, which was developed by the team. This document does not only contain the definition of each data element that is contained in each data set but it also contains contextual data. Contextual data is aimed at communicating some of the conditions under which the data from this field test was generated and collected.

Providing the data to the RDE team is an iterative process. After each data submission, the RDE team will review that submission and provide feedback. The field test team then reviews and address these comments. This process was repeated until the RDE team approves the data, and the necessary documentation that accompanies these data, and post the data to the RDE.

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CHAPTER 5. RISKS AND MITIGATION

A "dry-run" of the field test was carried out prior to the execution of the field test. This dry-run, functioned as the primary means of mitigating against issues that may inhibit the successful execution of the field test. The dry-run not only exercised all the equipment and systems involved in the field test but it also evaluated all the test scenarios and application integration tests. During the dry run a few issue were observed. These issues were either addressed during the dry-run of the field test or resolved at a later data in our development environment. A few of the issues that were observed, from both the test bed and its supporting infrastructure, and the emulated applications, included:

- A few RSUs ran a version of software that resulted in some data lost
- A few RSUs had incorrect clock settings, resulting in data that had future timestamps
- During the dry-run the data clearinghouse crashed of a few occasions
- A 15-minute data transmission outage was observed, followed by a large data dump (presumably the data buffered during the outage, which then resulted in the large data dump)
- Significant latencies were observed when incoming data rates were high
- The issue of significant latencies was exacerbated by duplicate data that were a result of a single record being simultaneously received by the multiple RSUs (up to 6), as the vehicle generating these records are within range of these RSUs
- The Eco Approach and Departure application required ISD and VSD records to be synchronized, which turned out not to be the case during the dry-run. ISD record experienced sub-second latencies while VSD records experienced latencies great the 1 second
- The Road Weather based application also experience synchronization issues as the pre-recorded data was not effectively aligned with timestamps form VSD records, when *replayed*
- Each application could benefit from improved visualization to better validate their operation in real-time

In addition to enabling a successful field test, addressing these observed and other issues informed the lessons learn portion of the final report for this project. As such, for additional information regarding many of these, and other, observations that were made during this project, readers are asked to consult the Task 8 Final Report.

Conducting a full scale dry-run proved to an affect risk mitigation tool as the issued identified, which were addressed prior to returning to the field, facilitated a successful field test and provided a series of troubleshooting steps and go-to solutions if these or similar issues were encountered during the field test. .

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APPENDIX A: CONNECTED VEHICLE APPLICATION SELECTION FRAMEWORK

As previously stated, the primary objective of selecting connected vehicle applications is to conduct a series of field tests for real-world evaluation of the ODE's operation and performance. Also, as part of the field test, emulation of three or more connected vehicle applications that subscribe to the ODE is required. Therefore the selected applications, and more importantly the criteria which are used to select these applications, are critical.

The first step in selecting the most appropriate applications to be emulated is to do a comprehensive review of the status of the various connected vehicle applications within each of the USDOT connected vehicle application program areas. For this review we used resources such as Connected Vehicle Reference Implementation Architecture (CVRIA), V2I and V2V Safety, Road Weather (Road Weather Management), the Environment (Applications for the Environment: Real-Time Information Synthesis (AERIS)), Mobility (Dynamic Mobility Applications), (Transportation) Agency Based applications and Smart Roadside applications. These programs cover a wide range of scenarios that provide key inputs to the ODE for its operation and performance. Upon this review, a series of criteria was used to down-select the application program areas to consider and subsequently the applications to emulate.

These criteria include a few general conditions such as ensuring that there are synergies between selected applications, they complement each other (in that the selected applications use similar but not identical data), while making sure that the applications are sufficiently dissimilar to thoroughly exercise the ODE's ability to support overlapping and divergent data requirements of connected vehicle applications. Additional criteria include:

- Network viability – does the transportation network and the associated CV devices in the Southeast Michigan Test Bed support the operation of a particular application
- Data availability / usability – is the Southeast Michigan Test Bed outputting the necessary data element to support a given application and how much of the data being output is being used by the application
- Algorithm maturity – has the application's algorithm been developed, implemented and valuated
- Algorithm accessibility – can the application's algorithm be shared (with the ODE team and on the OSADP), and what level of access is provided to modify the code as needed
- Real-time emulation – does a given application support archived or real-time operation
- 100% penetration rate required – does this application require 100% connected vehicle penetration rate to operate successfully

- ODE Core functionality - how many, if any, of the core ODE functionalities does the application exercise. Does it exercise the ODE capability to perform:
  - Data Valuation
  - Data Aggregation
  - Data Integration
  - Data Sanitization
  - Data Propagation

While all these criteria influence application selection, they are not of equal importance. Table 8 below details a scoring mechanism that is associated with each criterion and a description as to how scores are assigned. To comprehend the entries in this table, the "Score" column is meant to reflect possible scores for each associated criterion as informed by the score breakdown in the "Description" column. The entries in the "Score" column may take one of two forms 1) a range of values – which is dependent on the sum of the factors impacting the score or 2) a set of possible values – indicating the weight associated with a given criterion.

Table 8: Application Criteria and Assigned Scores

Criteria		Score	Description
Network viability		0, 10	If the network suitable for the application 10, otherwise (0)
Data availability / utility		0-35 [VSD (10), ISD (Map (5), SPAT (5), TSD (5), Other (10)]	For each data element , in the respective bundle the following points are allotted based on whether the data element is available from the considered application: • VSD (10): ○ timestamp (1) ○ position (lat, long, elevation) (1) ○ speed (1) ○ heading (1) ○ steering angle (1) ○ acceleration (lat, long, vertical, yaw) (4) ○ brake (1) • ISD: ○ MAP (5) ▪ service region (1) ▪ name (1) ▪ reference point (1)

			▪ Approach (name, lane) # (2) ○ SPAT (5): ▪ timestamp (1) ▪ intersection name/ID (1) ▪ lane set (1) ▪ current state (1) ▪ time to change (1) • TSD: ○ type (1) ○ timestamp (start, stop) (2) ○ message (2) • Other (for example – weather (10))
Algorithm maturity		0,1	(1) if well tested and validated, otherwise (0)
Algorithm accessibility		0, 1, 2	(2) if the algorithm as well as its inner workings are available, (1) if the algorithm, without its inners working are available, (0) if the algorithm is inaccessible
Real-time emulation		0,1,2	(2) if the application requires real-time data stream, (1) archived, (0) otherwise
100% penetration rate		0-1	(0) if 100% penetration rate is require, (1) otherwise
ODE Core functionality		0-22	• Data Validation (1) • Data Aggregation (10) • Data Integration (10) • Data Propagation (1)
ODE Key functionality		0,5	• Sanitization (5) • Others (…)

Table 9 presents the utilization of the above criteria to a subset of applications from the various application program areas. An exhaustive list of applications is not presented in the table below, as many, for instance those belonging to the V2V safety application domain, were predetermined to be unsuitable for emulation in the SEMI Test Bed[5]. However, a few such applications that were predetermined to be less suitable were included in the table below to demonstrate the functionality of the application selection framework.

While a number of applications are still under development, there are a few that have been developed and sufficiently tested that are suitable for consideration in this effort. Based on the latest assessments of the applications landscape, the list below presents a list of applications that have been tentatively selected for emulation consideration. As seen in Table 9, the use of the selection framework yields a few highest-scoring applications that are the best candidates for emulation as well as offer the requisite diversity of application to evaluate the ODE. These applications include:

- **RESCUME** – Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- **INFLO** – Dynamic Speed Harmonization (SPD-HARM)
- **AERIS** – Eco-Approach and Departure at Signalized Intersections
- **Road Weather** – *Pseudo* Motorist Advisories and Warnings (P-MAW)[6]

As other applications become available, and even more in depth analyses are conducted on the selected applications, it is anticipated that some application maybe be removed and / or added to the list of those to be emulated. This removal and addition of selected application will only be done when deemed appropriate and feasible.

[5] The V2V suite of CV applications were predetermined to be unsuitable for the SEMI Test Bed and this task as these applications require low-latency onboarding processing of the data and not data processing by nor data provisioning from the ODE

[6] The Pseudo-Motorist Advisor and Warning (P-MAW) application is a proxy of the MAW application which was developed under Road Weather Program

Table 9: Application of the Above Criteria and Preliminary Scoring of a Subset of Connected Vehicle Application

Program Area	Applications	Selection Criteria											
		Network viability	Data Utility	Algorithm Maturity	Algorithm Access	Real-time Emulation	100% Penetration	Core Functionality[7]				Key Functionality	Total Score
								V	A	I	P	Sanitization	
V2I Safety	Red Light Violation Warning	0	5	1	0	2	1	1	0	0	1	0	11
	Spot Weather Impact Warning	0	10	1	0	2	1	1	0	0	1	0	15
	Reduce Speed/Work Zone Warning	0	4	1	0	1	1	1	0	10	1	0	19
V2V Safety	Emergency Electronic Brake Lights (EEBL)	0	0	1	0	2	1	1	0	0	1	0	6
	Forward Collision Warning (FCW)	0	0	1	0	2	1	1	0	0	1	0	6
Road Weather	*Pseudo* Motorist Advisories and Warnings (P-MAW)	10	13	1	0	2	1	1	10	10	1	0	**48**
	Enhanced MDSS	0	0	1	0	2	1	1	0	0	1	0	6
	Weather Response Traffic Information WxTINFO	0	0	1	0	2	1	1	0	0	1	0	6
Environment (AERIS)	Eco-Approach / Departure at Signalized Intersection	10	11	1	2	2	1	1	10	10	1	0	**49**

[7] V- Data Valuation, A – Data Aggregation, I – Data Integration, P – Data Propagation

	Eco-Traffic Signal Timing	0	11	1	2	2	1	1	10	10	1	0	39
	Eco-Traffic Signal Priority	0	11	1	2	2	1	1	0	10	1	0	29
Mobility (MMITSS)	Intelligent Traffic Signal System (I-SIG)	10	11	0	0	2	1	1	0	0	1	0	26
(INFLO)	Dynamic Speed Harmonization (SPD-HARM)	0	6	1	1	2	0	1	10	0	1	0	**22**
(R.E.S.C.U.M.E.)	Incident Scene Work Zone Alerts (INC-ZONE)	0	10	1	2	2	0	1	10	0	1	0	**27**

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APPENDIX B: FIELD TEST SCHEDULE

The following presents the itinerary that we used to structure the execution of the April 4-7, 2016 Field Test.

5.1. Monday – April 4, 2016

Time	Activity	Location	Personnel
7:00	• Travel • DTW to Leidos office: 25 minutes	• BOS/BWI/IAD-DTW	• All
8:00			
9:00			
10:00			
11:00			
12:00			
13:00			
14:00	• Preparation and Coordination with Leidos	• Novi, MI	• All
15:00			
16:00			
17:00	• Travel • Leidos office to hotel	• Novi, MI – Southfield, MI	• All
19:00	• Dinner	• TBD	• All

5.3. Tuesday – April 5, 2016

Time	Activity	Location	Personnel
7:30	• Travel • Hotel to Leidos office	• Southfield – Novi	• All
8:00	• Travel/Prepare the command center • Field Test Orientation • Leidos office to Telegraph Rd. testbed: 15 minutes	• On the road (land mark – Chipotle 28644 Telegraph Rd., Southfield MI 48034) • Leidos' Office / Conference Room	• Driving team • CI, Raj @ Command Center • AB, DH @ Field
9:00	• Gradual Testbed Loading and Evaluation	• Leidos Office / Command Center • Telegraph Road	• BAH & Driving Team
10:30	• 6 1-Car Platoon • (5-minute intervals will be used for all testing)		• BAH & Driving Team
12:00	• Lunch	• Chipotle	• BAH & Driving Team
12:30	• Travel/Field Orientation • Telegraph Rd. testbed to downtown testbed: 19 minutes	•	• BAH & Driving Team
13:00	• Gradual Testbed Loading and Evaluation	• Command Center • Downtown Det.	• BAH & Driving Team
14:30	• 6 1-Car Platoon • Headway 3-minutes		• BAH & Driving Team
16:00	• 2 3-Car Platoon • Headway 6-minutes		• BAH & Driving Team
17:30	• Test Wrap-up, Debrief		• BAH & Driving Team

5.4. Wednesday – April 6, 2016

Time	Activity	Location	Personnel
7:30	• Travel • Hotel to Leidos office	• Southfield – Novi	• All
8:00	• Prepare the command center • Travel Leidos office to downtown Detroit testbed: 25 minutes	• On the road (land mark – Crowne plaza) • Leidos' Office / Conference Room	• Driving team • CI, Raj @ Command Center • AB, DH in Field
9:00	• Gradual Testbed Loading and (Brief) Evaluation	• Command Center • Downtown Detroit	• BAH & Driving Team
9:30	• 1 6-Car Platoon • Headway NA		• BAH & Driving Team
11:00	• Lunch	• Restaurant in Crowne Plaza	• BAH & Driving Team
11:30	• Travel to Telegraph Rd. testbed • Downtown testbed to Telegraph Rd. testbed: 21 minutes		• BAH & Driving Team
12:00	• Gradual Testbed Loading and (Brief) Evaluation	• Command Center • Telegraph Rd.	• BAH & Driving Team
12:30	• 2 3-Car Platoon • 10-min headway		• BAH & Driving Team
14:30	• 1 6-Car Platoon • Headway NA		• BAH & Driving Team
16:30	• Test Wrap-up		• BAH & Driving Team
17:00	• Travel • Telegraph Rd. to hotel		
19:00	• Debrief		• All

5.5. Thursday – April 7, 2016

Time	Activity	Location	Personnel
7:30	• Travel • Hotel to Leidos office	• Southfield – Novi	• All
8:00	• Prepare the command center / Orientation • Leidos office to Telegraph Rd. testbed: 15 minutes	• On the road (land mark - Chipotle) • Leidos' Office / Conference Room	• Driving team • CI, RK @ Command Center • AB, DH in Field
8:30	• 1 3-car platoon will navigate in Downtown Detroit • 1 3-car platoon will navigate Telegraph Rd.		• BAH & Driving Team
12:00	• Travel	• DTW – BOS/IAD/BWI	• All
12:00			
13:00			
14:00			
14:00			
16:00			
17:00			
18:00			

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