# Development of Vehicle-to-Infrastructure Applications Program

## First Annual Report

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**Final Report — August 31, 2015**
**FHWA-JPO-16-263**

U.S. Department of Transportation
**Federal Highway Administration**

Produced by Crash Avoidance Metrics Partners LLC in response to Cooperative Agreement Number DTFH6114H00002

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# Notice

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**16. Abstract**

This report documents the work completed by the Crash Avoidance Metrics Partners LLC (CAMP) Vehicle to Infrastructure (V2I) Consortium during the first year of the "Development of Vehicle-to-Infrastructure Applications (V2I) Program." Participating companies in the V2I Consortium during this period were FCA US LLC, Ford, General Motors, Hyundai-Kia, Honda, Mazda, Mercedes-Benz, Nissan, Subaru, Volvo Truck, and VW/Audi. The period covered by the report is from January 15, 2014 through June 30, 2015. The overall goal of the V2I Program is to develop and test V2I safety, mobility, environmental and automation applications as part of the U.S. Department of Transportation (USDOT) Intelligent Transportation System (ITS) Strategic Plan. Projects active during the reporting period investigated Cooperative Adaptive Cruise Control (CACC), Vehicle-to-Infrastructure Safety Applications, Road Weather Management Connected Vehicle-Infrastructure, and Eco-Approach / Eco Departure at intersections. This report provides a summary of key project activities and accomplishments for the period.

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# Executive Summary

This document represents work carried out under the Development of Vehicle-to –Infrastructure (V2I) Applications Program (V2I Program), through Cooperative Agreement No. DTFH6114H00002, from program inception on January 15, 2014 through June 30, 2015. Annual reports will be delivered through the end of the agreement. The overall goal of the V2I Program is to develop and test V2I safety, mobility, environmental and automation applications as part of the U.S. Department of Transportation (USDOT) Intelligent Transportation System (ITS) Strategic Plan.

The following sections provide a high-level overview of significant activities and key findings for efforts under the various Work Orders that have been awarded under the Cooperative Agreement. The main body of this report (Sections 1 through 7) provides a full account of activities for each of the following Work Orders.

## V2I Program Administration (Work Order 1)

**Project Status:** In Progress
**Project Timeline:** January 2014 – January 2019

The V2I Program Administration work order provides the mechanism to administer the Cooperative Agreement between the Federal Highway Administration (FHWA) and the Crash Avoidance Metrics Partners LLC (CAMP). The purpose of Work Order 1 is to:

- Establish a multi-year research program to address V2I initiatives
- Organize one or more research consortia to conduct the awarded projects
- Establish program management systems to conduct the work

***Significant Activities and Key Findings***

- **Formally organized the V2I Consortium in June 2014:** The consortium consists of FCA US LLC, Ford, GM, Honda, Hyundai-Kia, Mazda, Mercedes-Benz, Nissan, Subaru, VW/Audi, and Volvo Truck. This consortium represents a broad range of automotive perspectives that include both light vehicles and heavy truck as well as global viewpoints that include the U.S., Europe, and Asia.
- **Initiated the following projects:**
  - Cooperative Adaptive Cruise Control (CACC) Project
  - V2I Safety Applications (V2I-SA) Project
  - Road Weather Management Program (RWMP) Connected Vehicle-Infrastructure Research (CVIR) Project
  - Applications for the Environment: Real-Time Information Synthesis (AERIS) Eco-Approach and Eco-Departure Project
  - CACC Small-Scale Test (CACC-SST) Project

These project activities are expected to enhance deployment of driver assistance systems to improve safety and mobility for drivers through improvements in performance made possible by V2I connectivity, while also exploring enhancements to situational awareness possible through improved knowledge of the driving environment. The V2I Consortium considers exploring the potential of V2I communications to improve the performance of vehicle information, warning and control systems to be high value research. In particular, the V2I Consortium believes that cooperative research to explore opportunities to improve safety, sustainability and vehicle control are the highest priority.

# Cooperative Adaptive Cruise Control Project (Work Order 2)

**Project Status:** Complete
**Project Timeline:** August 2014 - March 2015

The overall objective of the Cooperative Adaptive Cruise Control (CACC) Project was to assess the feasibility of prototyping a CACC system by assessing technical and safety issues, gaps and challenges. The CACC Project considered the feasibility of implementing this concept utilizing Dedicated Short Range Communication (DSRC) and framed the future research work needed to move the concept toward potential implementation.

***Significant Activities and Key Findings***

- **Developed a high-level research plan:** The V2I Consortium prepared a research plan to address the unanswered technical and safety questions, information gaps, and deployment challenges regarding potential future development and deployment of CACC. Four broad topic areas were considered during development of the CACC research plan: (1) potential extension of current production ACC using vehicle-to-vehicle (V2V) communication; (2) V2V communication and standards for CACC; (3) CACC vehicles for platooning; and (4) functional and operational safety of the CACC system. A plan and timeline to explore these questions was developed.
- **Assessed the potential for production implementation of CACC in future vehicles:** An analysis was performed to explore the utility of implementing CACC functionality utilizing DSRC-based communication in conjunction with current production ACC systems. Considering CACC as an extension of current ACC systems complemented with V2V communication, the task developed the following:
  - A preliminary look at possible enhancements of production ACC systems by adding Vehicle-to-Vehicle (V2V) communication systems.
  - A working definition of CACC systems for use in future research, including a CACC State Transition Model, for single- and multiple-vehicle look-ahead scenarios and string stability assessment.
  - A preliminary investigation of the use of System-Theoretic Process Analysis (STPA) to conduct a preliminary hazard analysis for CACC systems.
  - A proposed framework for prototyping a reference CACC implementation as a near-term research project.
- **Defined prototype and small-scale test plans:** An outline was developed for conducting recommended research in two sequential phases. Phase 1 (18 months)

includes conducting exploratory tests to collect data from a reference ACC system implementations concurrently with V2V communication to compare the results and to establish baseline performance; establishing a simulation platform to develop and test different CACC algorithms; and development of a concept CACC system specification and conducting a hazard analysis. Phase 2 (14 months) includes evaluation of hardware and software implementation of the CACC algorithms using Hardware-in-the-Loop (HIL) simulations, followed by integration and testing on a small fleet of vehicles.

# Vehicle-to-Infrastructure Safety Applications (Work Order 3)

**Project Status: In Progress**
**Project Timeline: September 2014 - May 2016**

The objective of the Vehicle-to-Infrastructure Safety Applications (V2I-SA) Project is to develop and initially test V2I safety applications for which performance requirements have been completed and sufficient information exists to initiate development. The safety applications considered in the project include: Red Light Violation Warning (RLVW), Emergency Vehicle Priority Warning (EVPW), Curve Speed Warning (CSW), Spot Weather Impact Warning (SWIW), Reduced Speed/Work Zone Warning, and Stop Sign Gap Assist (SSGA).

***Significant Activities and Key Findings***

- **Conducted a technical assessment of V2I Safety applications:** The technical assessment included a review of: (1) common requirements for implementing the V2I applications; (2) Application-specific required infrastructure data elements from the roadside equipment (RSE); (3) application-specific required vehicle data elements from the vehicle data bus; and (4) application operating scenarios and conditions that may produce inconsistent advisory, alert or warning messages to the driver, and possible means to mitigate potential conflicts that might occur.
- **Developed criteria to select V2I safety applications for development:** In cooperation with FHWA, criteria was defined and developed to assess benefits of each application for selection. The selection criteria were developed for selecting a representative cross-section of the V2I safety applications to address intersections, vehicle speed, and localized anomalies in traffic flow. The criteria leveraged the National Connected Vehicle Field Infrastructure Footprint Analysis conducted by AASHTO and focused on various factors such as infrastructure demands, and the cost and timing constraints of the current project.
- **Selected three V2I safety applications for further development:** Based on FHWA's input and agreement, the following three safety applications were selected for further development and field testing within this project:
  - Red Light Violation Warning (RLVW)
  - Curve Speed Warning (CSW)
  - Reduced Speed/Work Zone Warning (RSZW), including Reduced Speed (RS) and Lane Closure (LC) warnings

# Road Weather Management Program Connected Vehicle-Infrastructure Research Project (Work Order 4)

**Project Status: In Progress**
**Project Timeline: May 2015 – May 2016**

This project is directed towards Connected Vehicle-Infrastructure (CVI) research focused on demonstrating how weather, road condition, and related vehicle data may be collected, transmitted, processed, and used in road weather applications and services. This project is a joint effort between the CAMP V2I Consortium and the Virginia Tech Transportation Institute (VTTI).

***Significant Activities and Key Findings***

- **Identified road weather related variables of interest:** The CAMP-VTTI team initiated work with FHWA to develop an understanding of the types of data that may be of interest to road weather research and applications. During this period, background documents on the RWMP provided by FHWA were reviewed. A meeting was held with FHWA and the National Center for Atmospheric Research (NCAR) to discuss the content and functionality of the Vehicle Data Translator (VDT) developed by NCAR, which aggregates and processes weather-related vehicle data. In addition, work was initiated to establish weather data categories for use in assessing the availability of weather-related vehicle data elements on representative high-volume production vehicles.

# AERIS Eco-Approach and Eco-Departure Project (Work Order 5)

**Project Status:** In Progress
**Project Timeline:** June 2015 – February 2016

The objective of the project is to identify information gaps, define technical and safety needs, and propose an evolutionary research plan for developing and evaluating AERIS applications. This project is a joint effort between the CAMP V2I Consortium and the Texas Transportation Institute (TTI) in conjunction with the University of California Riverside and the University of Michigan Transportation Research Institute (UMTRI).

***Significant Accomplishments and Key Findings***

- **Initiated literature review:** The CAMP Team initiated work on examining the technical feasibility of prototyping Eco-Approach and Eco-Departure (Eco-A/D) applications and establishing a research plan to develop and evaluate potential concepts. This included the review of relevant background documents describing prior and ongoing Eco-A/D research, and defining initial research topics in the following categories: (1) Eco-Concepts; (2) Vehicle Technical Issues; (3) Infrastructure Technical Issues; (4) Communications/Standards; (5) Human Factors; and (6) Performance Measures. This work establishes the foundation for future tasks, including refinement of an eco-signal application concept and developing a roadmap for future research.
- **Initiated assessment of transportation related data sharing:** This task examined potential issues associated with sharing transportation data originating from infrastructure operated by public agencies with private owner vehicle systems across jurisdictions. This

research will identify the various forms of data, both current and anticipated, that will require sharing across jurisdictions and investigate shortcomings that may limit the sharing of that data to facilitate advanced operations, including real-time data that will enable connected vehicle operations.

# Cooperative Adaptive Cruise Control Small-Scale Test Project (Work Order 6)

**Project Status:** In Progress
**Project Timeline:** June 2015 – February 2017 (Phase 1 only)

Previous research conducted in the Cooperative Adaptive Cruise Control Project (Work Order 2) considered the feasibility of implementing CACC utilizing DSRC to expand the functionality of Adaptive Cruise Control (ACC). The conclusion of this work recommended a focused research effort to explore the viability and efficacy of this approach through prototyping and small-scale testing of a representative CACC system.

The Cooperative Adaptive Cruise Control – Small-Scale Test (CACC-SST) Project will perform the recommended research using a two-phase approach employing simulation tools and prototype evaluation to explore the feasibility and utility of providing CACC functionality as a DSRC-enabled evolutionary expansion of ACC. Preliminary activities focused on engagement with identified suppliers in order to finalize terms and issue purchase orders. The team also started to create a detailed work plan for the upcoming technical tasks in the project.

# 1 V2I Program Administration (Work Order 1)

This document presents the First Annual Report for the Development of Vehicle-to-Infrastructure (V2I) Applications Program (i.e., the V2I Program). The V2I Program is sponsored by the Federal Highway Administration (FHWA) through Agreement No. DTFH6114H00002. The period covered by the report is from program inception on January 15, 2014 through June 30, 2015. The overall goal of the V2I Program is to develop and test V2I safety, mobility, environmental and automation applications as part of the U.S. Department of Transportation (USDOT) Intelligent Transportation System (ITS) Strategic Plan. The overall program is being administered through the Crash Avoidance Metrics Partners LLC (CAMP) under the Program Administration order (Work Order 1). This Work Order will run throughout the V2I Program. The purpose of Work Order 1 is to:

- Establish a multi-year research program to address V2I initiatives
- Organize one or more research consortia to conduct the awarded projects
- Establish program management systems to conduct the work

During the second quarter of 2014, CAMP management initiated efforts to form a research consortium. Seven original equipment manufacturers (OEMs) from the CAMP Vehicle Safety Communications 3 Consortium agreed to participate in the new V2I Consortium. In addition, several other OEMs were contacted to identify their interest in participating. Eleven organizations ultimately agreed to participate and the V2I Consortium was formally organized in June 2014. The V2I Consortium consists of FCA US LLC, Ford, GM, Honda, Hyundai-Kia, Mazda, Mercedes-Benz, Nissan, Subaru, VW/Audi, and Volvo Truck. This consortium represents a broad range of automotive perspectives from light-vehicle to heavy-truck manufacturers as well as global viewpoints from the U.S., Europe, and Asia. The Consortium Management Committee (CMC) meets on a bi-weekly basis that will continue throughout the Program. These meetings are held to review progress within the individual projects, assess the status of deliverables and milestones, and address strategic items affecting the overall Program.

CAMP initiated development of the V2I research program in parallel with the organization of the V2I Consortium. Through discussion with FHWA personnel, potential research projects and scope were identified in the safety, mobility, environmental and automation areas of FHWA's planned research programs. During the first eighteen months of the V2I Program execution, technical and cost proposals for six projects were prepared by the V2I Consortium and submitted to FHWA. The proposals were for the:

- Cooperative Adaptive Cruise Control (CACC) Project
- V2I Safety Applications (V2I-SA) Project
- Road Weather Management Program (RWMP) Connected Vehicle-Infrastructure Research (CVIR) Project

- Applications for the Environment: Real-Time Information Synthesis (AERIS) Eco-Approach and Eco-Departure Project
- CACC Small-Scale Test (CACC-SST) Project
- Advanced Messaging Concept Development (AMCD) Project

These activities are expected to enhance deployment of driver assistance systems to potentially improve safety and mobility for drivers through improvements in performance made possible by V2I connectivity, while also exploring enhancements to situational awareness possible through improved knowledge of the driving environment. The V2I Consortium considers exploring the potential of V2I communications to improve the performance of vehicle information, warning and control systems to be high value research. In particular, the V2I Consortium believes that cooperative research to explore opportunities to potentially improve safety, sustainability and vehicle control are the highest priority.

Subsequently, FHWA awarded Work Orders for five of the proposed projects, with the AMCD Project Proposal still under discussion at the end of the period covered by this report. Of these projects, the CACC Project was also completed during the reporting period. The material that follows in the sections of this report presents a summary of the five projects listed above. The material includes a summary of key project activities and accomplishments.

In addition to the activities noted above, several deliverables were prepared and submitted to FHWA as part of the work completed in the Program Administration Work Order. These involved the following items:

- Quarterly Status Reports, summarizing progress in all active projects within the V2I Program by calendar quarter. The Quarterly Status Reports were submitted to FHWA on April 30, 2014, July 30, 2014, November 11, 2014, February 26, 2015, and April 30, 2015.
- Quarterly Progress Briefings, providing a presentation to FHWA of the work performed in each active project during the preceding quarter. Quarterly Progress Briefings were completed on April 23, 2014, July 25, 2014, October 30, 2014, January 30, 2015 and May 5, 2015.
- The V2I Risk Log which consolidates the identified risks for each active project into one report along with the proposed mitigation plans. The consolidated Risk Log was initially summited on May 28, 2014 is updated quarterly.
- The First Annual Report for the V2I Program (i.e., this report)

In addition, work in Program Administration also includes bi-weekly FHWA-CAMP program management meetings held to track administrative items related to the preparation and submission of proposals, discuss plans for possible future projects, and identify issues affecting the Program execution. These meetings will continue through the V2I Program.

# 2 Cooperative Adaptive Cruise Control Project (Work Order 2)

The Cooperative Adaptive Cruise Control (CACC) Project for FHWA mobility applications was initiated on August 1, 2014. The overall objective of the CACC Project was to assess the feasibility of prototyping a CACC system by assessing technical and safety issues, gaps and challenges. The CACC Project considered the feasibility of implementing this concept utilizing Dedicated Short Range Communication (DSRC) and to frame the future research work needed to move the concept toward potential implementation. The project identified lessons learned from ongoing advanced research activities sponsored by the USDOT and recommended further research and an immediate follow-on project. The technical work in the CACC Project was concluded on March 31, 2015.

It should be noted that the CACC Project was the first of two projects undertaken by the V2I Consortium in subject topic area during the reporting period. The second project, the CACC Small-Scale Test (CACC SST) Project, is currently underway and is discussed later in this report.

The CACC Project consisted of four tasks. Below is a summary of the tasks and major activities.

## 2.1 Technical Project Management (Task 1)

Task 1 was the project management task that ran throughout the project. Within this task, the Principal Investigator (PI) managed the technical activities involving the Participants under the CACC Project. The CACC Final Report, prepared as part of the Task 1 work, was submitted to FHWA on March 31, 2015. The final report is currently in preparation for release to the public. The finalized report is expected during September 2015.

## 2.2 Develop Research Plan (Task 2)

The purpose of this task was to assess the technical feasibility of prototyping a CACC system by identifying technical challenges, safety issues and research gaps. An evolutionary approach to developing CACC was considered in the project. The approach assumed the use of radar-based production Adaptive Cruise Control (ACC) systems as a starting point for CACC and was taken to address the following topics:

- Potential extension of production ACC using vehicle-to-vehicle (V2V) communication
- V2V communication and standards for CACC
- CACC vehicles for platooning
- Overarching functional and operational safety of CACC system

A literature review was conducted to assess the current body of knowledge about CACC and identify additional research needs. This effort identified a broad spectrum of research questions that have not been addressed. A process for determining an appropriate research methodology for each of the unaddressed research needs was developed in Task 2. Each of the identified research needs was

considered further using this process. The resulting list of research needs and assessment of the research approach needed to address each were then summarized in the final project report. A research timeline was developed based on the assumption that resources required to accomplish the outlined tasks will be available in the future. Clarifications of assumptions, priorities and resource availability will facilitate refinements to the timeline in future work.

The research plan proposed follow-on research in three phases:

1) Preliminary research in Task 3 to examine two key questions:

    a. What are the benefits of adding vehicle communication to current production ACC systems?

    b. For CACC, what are the issues related to reducing the headway gap between vehicles beyond the headway gap in current production ACC systems?

2) A potential short-term project to assess the viability of extending current production ACC systems by adding V2V communication

3) A potential longer-term project to assess the efficacy of V2V/V2I communication for vehicle platooning of CACC vehicles

## 2.3 Assessing the Potential for Production Implementation (Task 3)

The goal of this task was to assess the potential for developing CACC systems for future production vehicles. Considering CACC as an extension of current ACC systems complemented with V2V communication, the task developed the following:

- A preliminary look at possible enhancements of production ACC systems by adding Vehicle-to-Vehicle (V2V) communication systems
- A working definition of CACC systems for use in future research
- A preliminary investigation of the use of System-Theoretic Process Analysis (STPA) to conduct a preliminary hazard analysis for CACC systems
- A proposed framework for prototyping a reference CACC implementation as a near-term research project

## 2.4 Prototyping and Small-Scale Test Plan (Task 4)

The purpose of this task was to develop a plan for testing a prototype CACC system and conducting assessments with a small-scale test fleet of CACC-equipped vehicles. The outline of a follow-on research project was developed to conduct this work in two sequential phases totaling 32 months of effort as follows:

Phase 1 (18 months of technical work):

- Conduct exploratory tests to collect data from a reference ACC system implementations concurrently with V2V communication to compare the results and to establish baseline performance

- Establish a simulation platform to develop and test different CACC algorithms
- Develop a concept CACC system specification and conduct a hazard analysis

Phase 2 (14 months of technical work):

- Evaluate hardware and software implementation of the CACC algorithms using HIL simulations followed by integration and testing on a small fleet of vehicles

# 3 Vehicle-to-Infrastructure Safety Applications (Work Order 3)

The Vehicle-to-Infrastructure Safety Applications (V2I-SA) Project started on September 15, 2014 and is scheduled to run through May 10, 2016. The objective of the V2I-SA Project is to develop and initially test V2I safety applications for which performance requirements have been completed and sufficient information exists to initiate development. The safety applications under initial consideration for further development in the project are: Red Light Violation Warning (RLVW), Emergency Vehicle Priority Warning (EVPW), Curve Speed Warning (CSW), Spot Weather Impact Warning (SWIW), Reduced Speed/Work Zone Warning (RSZW) and Stop Sign Gap Assist (SSGA). Activities in Tasks 3 and 4 will include a technical assessment of these applications and the selection of one or more applications for development and evaluation within the remainder of the project. A summary of the tasks is presented below.

## 3.1 Technical Project Management (Task 1)

Task 1 is the project management task that runs throughout the project. In this task, the PI managed the technical activities involving the project Participants under the V2I-SA Project. Weekly meetings were held by the Technical Management Team (TMT) to coordinate and ensure timely work progress.

## 3.2 Coordination with Stakeholders (Task 2)

The objectives of Task 2 are to identify stakeholders for the safety applications and subsequently conduct future meetings with the identified organizations as needed to support the project tasks. Task 2 is expected to run throughout the project. On December 17, 2014, a Stakeholder Coordination Plan was completed and submitted to FHWA. The plan was developed through discussions with FHWA. The Stakeholder Coordination Plan initially identified the following organizations:

- Battelle
- American Association of State Highway and Transportation Official (AASHTO)
- Institute of Transportation Engineers (ITE)
- USDOT Intelligent Transportation System (ITS) Joint Program Office (JPO) implementing Connected Vehicle Reference Implementation Architecture (CVRIA)
- Michigan Department of Transportation (MDOT)
- Road Commission of Oakland County (RCOC)

In addition to the stakeholders identified above, the Vehicle-Infrastructure Integration Consortium (VIIC) and Iteris, Inc. are being considered for inclusion in the stakeholder list. Other organizations may be added in the future.

During the period, the following meetings were held as part of the stakeholder coordination activities:

- MDOT for regarding infrastructure support for the placement of the Roadside Equipment (RSE) at the selected site to conduct CSW application evaluation
- MDOT for placement of a roadway sensor (Environmental Sensor Station) for detecting roadway surface condition such as dry, wet, icy, etc.
- FHWA/Noblis and SAE for rationale and the need for new Infrastructure-to- Vehicle (I2V) Basic Information Message (BIM) to support current and future V2I Safety Applications.

Interaction with stakeholders will continue throughout the duration of the project.

## 3.3 Technical Assessment and Selection Criteria (Tasks 3 / 4)

With concurrence from FHWA, Task 3, Technical Assessment, and Task 4, Selection Criteria Development for V2I Safety Applications, were combined as a single task for execution in the project. The work in Task 3 / 4 during the reporting period focused on the following:

- Reviewing the Concept of Operations (ConOps), system requirements, and performance requirements documents for the proposed applications of interest in this project
- Conducting working meetings with FHWA and Battelle to discuss the safety applications, and discuss questions emerging from reviews of documents
- Performing technical assessment of proposed safety applications. The assessment included a review of:
  - Common requirements for implementing the V2I applications
  - Application-specific required infrastructure data elements from the roadside equipment (RSE)
  - Application-specific required vehicle data elements from the vehicle data bus
  - Application operating scenarios and conditions that may produce inconsistent advisory, alert or warning messages to the driver, and possible means to mitigate potential conflicts that might occur
- In cooperation with FHWA, defining and developing criteria for assessing benefits of each application for selection
- Selecting applications for use in the project based on the defined criteria

The selection criteria were developed for selecting a representative cross-section of the V2I safety applications to address intersections, vehicle speed, and localized anomalies in traffic flow. The criteria leveraged the National Connected Vehicle Field Infrastructure Footprint Analysis conducted by AASHTO and focused on various factors such as infrastructure demands, and the cost and timing constraints of the current project. Detailed discussions about the criteria were conducted with the FHWA.

Based on FHWA's input and agreement, the following three safety applications were selected for further development and field testing within this project:

- Red Light Violation Warning (RLVW)

- Curve Speed Warning (CSW)
- Reduced Speed/Work Zone Warning (RSZW), including Reduced Speed (RS) and Lane Closure (LC) warnings

Work in Task 3 / 4 was completed on April 23, 2015.

## 3.4 Project Plan Development (Task 5)

In Task 5, a project work plan to design, develop, test and demonstrate prototypes of the applications selected in Task 3 / 4 was developed. The plan included the project timeline, milestones, development deliverables, cost estimates, candidate equipment suppliers, and possible locations (i.e., test track or public road) for testing and demonstrating the applications. Makes and models of the prototype vehicles were also included in the plan. The timeline entailed nine months and included time for hardware/software specification and development, vehicle/infrastructure integration, and iterative rounds of testing for application validation.

The development work plan was presented to FHWA for review and approval prior to starting the actual development work. Task 5 was completed on April 24, 2015.

## 3.5 Application Development (Task 6)

The work in Task 6 initially focused on development of the in-vehicle architecture for the three safety applications identified in Tasks 3 / 4. The architecture consists of the required hardware, software, vehicle data, vehicle data bus communication interface, and the Driver Vehicle Interfaces (DVI) for the applications. The work conducted identified how these architecture elements will work together as a system and what differences may exist across the vehicles anticipated as test vehicles in the project.

Following development of the in-vehicle architecture, development of the algorithms for the applications was initiated. For example, algorithms to determine the relevance of events encountered, the position of the vehicle with respect to the events, and how warnings will be presented to the driver are being developed. Flowcharts of these algorithms are currently being prepared and discussions with the equipment suppliers are underway. This activity will continue in the near future as refinements and improvements to the algorithms are made.

Execution of the Task 6 will continue into the next reporting period and will focus on the continued development of:

- Specifications for the selected applications
- Test scenarios and potential procedures
- Application algorithms
- Messages from the infrastructure to the vehicle for the applications
- Data logging to support application testing and evaluation

## 3.6 Vehicle Build (Task 7)

Task 7 entails building the prototype vehicles for the project. In Task 7, seven of the Participants will be building vehicles and implementing all three selected applications. Two of the Participants will be

conducting the full range of application testing and performance evaluations on behalf of the Consortium. The other five Participants will conduct only the evaluation of the applications. As the reporting period for this report closed, work was underway in this task to:

- Finalize the in-vehicle equipment and select equipment suppliers
- Finalize the in-vehicle communication architecture
- Finalize other equipment needed to support the vehicle build

Work in Task 7 will continue into the coming months of the project.

## 3.7 Infrastructure Build (Task 8)

Task 8 involves building the infrastructure needed to support the applications for testing and demonstrations within the project. It is anticipated that interoperability testing to be conducted later in the project will be performed at public intersections supported by the FHWA Integrated V2I Prototype (IVP). Consequently, work currently underway in Task 8 is currently focused on identifying the required infrastructure equipment and coordinating installation arrangements for the IVP. Discussions are also ongoing regarding the following items:

- Equipment and support for Global Positioning System (GPS) / Radio Technical Commission for Maritime Services (RTCM) correction
- Survey and SAE J2735 MAP data for the selected test locations
- Placement of RSE(s) during evaluation and testing

This activity will continue in the next project quarter to prepare for application testing.

## 3.8 Testing (Task 9)

In Task 9, efforts have been focused on developing the Objective Test Procedures (OTPs) and real-world interoperability evaluations with the infrastructure. It is anticipated that interoperability testing will be conducted at IVP-supported intersections on public roads, while application performance tests will be conducted on a closed-course test track. For each of the selected applications, OTPs are currently under development for the application performance testing. The OTPs will include descriptions of the test scenarios, vehicle approach speeds to the event, successful/unsuccessful criteria, and validity criteria for the individual tests. Both true positive and false positive tests are being developed. Development of the interoperability test scenarios are also underway. Refinement of the OTPs and interoperability tests will continue in the next reporting period.

## 3.9 Map Support (Task 10)

In Task 10, a Request for Proposal (RFP) was sent to four prospective suppliers for their response and quotation to develop and validate an algorithm to automatically generate intersection maps (in SAE J2735 MAP formats) using probe data. The work in Task 10 is expected to run through February 2016. Additional information about this task will be available in future reports.

# 4 Road Weather Management Program Connected Vehicle-Infrastructure Research Project (Work Order 4)

The Road Weather Management Program Connected Vehicle-Infrastructure Research (RWMP-CVIR) Project was initiated on April 20, 2015. Subcontracts were finalized and technical work was initiated May 1, 2015. The objective of the project is to assess how weather, road condition, and related vehicle data may be collected, transmitted, processed and used in road weather applications and services. This project is a joint effort between the CAMP V2I Consortium and the Virginia Tech Transportation Institute (VTTI).

A summary of the major activities and accomplishments for the reporting period are presented below for each task in the project.

## 4.1 Technical Project Management (Task 1)

Task 1 provides management of technical activities by the PI throughout the project. Activities in this task were focused on the holding the project Kickoff Meeting and developing a detailed Work Plan for accomplishing the project.

Weekly coordination calls were held between the PI and VTTI Technical Manager, and bi-weekly meetings were held by the TMT to coordinate work and ensure timely progress was being achieved. The major accomplishments were:

- The Project Work Plan was delivered May 29, 2015
- The Project Kickoff Meeting was held June 12, 2015

The activities associated with these accomplishments are summarized in the material, which follows.

## 4.2 Coordination of Vehicle System Technical Assistance (Task 2)

Task 2 provides technical assistance to the RWMP regarding vehicle systems related to Connected Vehicle-Infrastructure standards and protocols and the definition of parameters of interest.

### 4.2.1 Identification of Road Weather Related Variables of Interest (Task 2.1)

During the period background documents on the RWMP provided by FHWA were reviewed. A meeting was held with FHWA and the National Center for Atmospheric Research (NCAR) to discuss the content and functionality of the Vehicle Data Translator (VDT) developed by NCAR, which

aggregates and processes weather-related vehicle data. In addition, work was initiated to establish weather data categories for use in assessing the availability of weather-related vehicle data elements on representative high-volume production vehicles in the next subtask.

### 4.2.2 Vehicle Data Element Map (Task 2.2)

This task is not scheduled to start until later in the project.

### 4.2.3 Candidate Research Vehicle Identification (Task 2.3)

This task is not scheduled to start until later in the project.

### 4.2.4 Support of Ongoing RWMP Projects (Task 2.4)

This task is not scheduled to start until later in the project.

## 4.3 Technical Support, Reporting, and Pilot Demonstration Proposal (Task 3)

Task 3 reviews the existing ConOps for the RWMP, assesses the potential for available vehicle data to support the applications identified, and if appropriate, will develop a proposal for follow-on research.

### 4.3.1 RWMP ConOps Review (Task 3.1)

During the reporting period, review of the RWMP ConOps documents and supporting information was initiated.

### 4.3.2 Preliminary Follow-On Concept Development (Task 3.2)

This task is not scheduled to start until later in the project.

### 4.3.3 Follow-On Technical and Cost Proposal (Task 3.3)

This task is not scheduled to start until later in the project.

## 4.4 Representation at RWMP Events (Task 4)

Under Task 4, VTTI represents the project team at RWMP stakeholder events and project-related activities to gain exposure to the types of research and discussions taking place between stakeholders and within the industry. An Integrated Mobile Observations (IMO) Program Meeting was held May 28, 2015 in St. Paul, Minnesota and was attended by the project staff.

# 5 AERIS Eco-Approach and Eco-Departure Project (Work Order 5)

The Applications for the Environment: Real-Time Information Synthesis (AERIS) Eco-Approach/Departure Planning Project (AERIS-Planning) was initiated on April 28, 2015. Subcontracts were finalized and project technical work was initiated June 1, 2015. The objective of the project is to identify information gaps, define technical and safety needs, and propose an evolutionary research plan for developing and evaluating AERIS applications. This project is a joint effort between the CAMP V2I Consortium and the Texas Transportation Institute (TTI) in conjunction with the University of California Riverside and the University of Michigan Transportation Research Institute (UMTRI).

A summary of the major activities and accomplishments for the reporting period are presented below for each task in the project.

## 5.1 Technical Project Management (Task 1)

Task 1 provides management of technical activities by the PI throughout the project. Activities since inception were focused on conducting the project Kickoff Meeting, developing a detailed work plan for accomplishing the project, and initiating the literature review task.

Weekly meetings were held by the TMT to coordinate work and ensure timely progress was being achieved. The major accomplishments were the completion of the Project Kickoff Meeting on June 15, 2015.

The activities associated with these accomplishments are summarized in the material, which follows.

## 5.2 Prepare Research and Development Plan (Task 2)

Task 2 examines the technical feasibility of prototyping Eco-Approach and Eco-Departure (Eco-A/D) applications and establishes a research plan to develop and evaluate concepts.

### 5.2.1 Conduct Literature Review (Task 2.1)

During the reporting period relevant background documents were collected describing prior and ongoing Eco-A/D research, research topic categories were defined, and key questions were identified for use in conducting a detailed literature review. A total of 167 reports were identified for consideration. Based on a review of abstracts, 63 documents were selected for further review covering six key categories:

1) Eco Concept

2) Vehicle Technical Issues

3) Infrastructure Technical Issues

4) Communications/Standards

5) Human Factors

6) Performance Measures

Reading assignments were distributed to the technical team and document review will begin in July 2015. Additional documents will be considered for review as they become available.

### 5.2.2 Define / Refine Eco-Signal Application Concept(s), Assumptions and Initial Research Questions (Task 2.2)

In this subtask, a high-level concept for the AERIS applications will be developed or refined based on information obtained from the literature review. Research questions and assumptions resulting from the literature review will be formulated in order to proceed to the next subtask. The initial list of research questions and assumptions will serve as a starting point for discussions in planning the future work.

This subtask is not scheduled to start until later in the project.

### 5.2.3 Identify Road Map to Address Eco-Signal Research Needs (Task 2.3)

Under this subtask, the combined team will develop the plan (or 'road map') to conduct the needed research and fill information gaps for the development and testing of the Eco-Signal applications. The road map will also include the plans for developing and testing the applications in an evolutionary manner such that the initial versions of the applications are subsequently enhanced based on the outcomes of work conducted.

This subtask is not scheduled to start until later in the project.

### 5.2.4 Initial Assessment of Transportation Related Data Sharing (Task 2.4)

This task examines potential issues associated with sharing transportation data originating from infrastructure operated by public agencies with private owner vehicle systems across jurisdictions. Since the project was started, the work plan for executing the subtask was expanded and review questions specific to this subtask were added to the overall literature review to flag reports for separate review of data sharing issues.

This subtask began the first week of June and has been proceeding in conjunction with the literature review.

### 5.2.5 Prepare Final Report (Task 2.5)

This subtask is not scheduled to start until later in the project.

# 6 Cooperative Adaptive Cruise Control Small-Scale Test Project (Work Order 6)

The Cooperative Adaptive Cruise Control – Small-Scale Test (CACC-SST) Project was initiated on June 1, 2015. The overall objective of the CACC-SST Project is to perform the recommended research identified in the preceding CACC Project using a two-phase approach employing simulation tools and prototype evaluation to explore the feasibility and utility of providing CACC functionality as a DSRC-enabled evolutionary expansion of ACC. Only the initial phase of the CACC-SST Project has been awarded. It is scheduled to run 21 months.

A summary of the activities and accomplishments for the first month of project operations are presented below for each task in the project. The activities reported are primarily administrative since there was only one month of project operations during the reporting period for this report.

## 6.1 Technical Project Management (Task 1)

Task 1 is the project management task for the project. Within this task, the PI managed the technical activities involving the Project Participants under the CACC-SST Project. Activities were focused on the engagement with identified suppliers in order to finalize terms and issue purchase orders. Furthermore, the team started to create a detailed work plan for the upcoming technical tasks in the project.

Weekly meetings were held by the TMT to coordinate and ensure timely work progress. The major accomplishment in this period was the completion of the Project Kick-off Meeting on June 15, 2015.

## 6.2 Field Test and Analysis of Empirical Data (Task 2)

This task is not scheduled to start until later in the project.

## 6.3 Algorithm Development, Simulation and Specification (Task 3)

This task is not scheduled to start until later in the project.

## 6.4 Planning for Phase 2 (Task 4)

This task is not scheduled to start until later in the project.

# APPENDIX A. List of Acronyms

| | |
|---|---|
| **AASHTO** | American Association of State Highway and Transportation Officials |
| **AERIS** | Applications for the Environment: Real-Time Information Synthesis |
| **ACC** | Adaptive Cruise Control |
| **AMCD** | Advanced Messaging Concept Development Project |
| **BIM** | Basic Information Message |
| **CACC** | Cooperative Adaptive Cruise Control |
| **CACC-SST** | Cooperative Adaptive Cruise Control – Small-Scale Test |
| **CAMP LLC** | Crash Avoidance Metrics Partners LLC |
| **CMC** | Consortium Management Committee |
| **ConOps** | Concept of Operations |
| **CSW** | Curve Speed Warning |
| **CVIR** | Connected Vehicle-Infrastructure Research |
| **CVRIA** | Connected Vehicle Reference Implementation Architecture |
| **DSRC** | Dedicated Short Range Communication |
| **DVI** | Driver-Vehicle Interface |
| **Eco-A/D** | Eco-Approach and Eco-Departure |
| **EVPW** | Emergency Vehicle Priority Warning |
| **FHWA** | Federal Highway Administration |
| **GPS** | Global Positioning System |
| **IMO** | Integrated Mobile Observations |
| **ITE** | Institute of Transportation Engineers |
| **ITS** | Intelligent Transportation System |
| **IVP** | Integrated V2I Prototype |
| **I2V** | Infrastructure-to-Vehicle |

| | |
|---|---|
| **JPO** | Joint Programs Office |
| **LC** | Lane Closure |
| **MDOT** | Michigan Department of Transportation |
| **NCAR** | National Center for Atmospheric Research |
| **OEMs** | Original Equipment Manufacturers |
| **OTPs** | Objective Test Procedures |
| **PI** | Principal Investigator |
| **RCOC** | Road Commission for Oakland County |
| **RS** | Reduced Speed |
| **RFP** | Request for Proposal |
| **RSE** | Roadside Equipment |
| **RLVW** | Red Light Violation Warning |
| **RSZW** | Reduced Speed/Work Zone Warning |
| **RTCM** | Radio Technical Commission for Maritime Services |
| **RWMP** | Road Weather Management Program |
| **SA** | Safety Applications |
| **SSGA** | Stop Sign Gap Assist |
| **SST** | Small-Scale Test |
| **STPA** | System-Theoretic Process Analysis |
| **SWIW** | Spot Weather Impact Warning |
| **TMT** | Technical Management Team |
| **TTI** | Texas Transportation Institute |
| **UMTRI** | University of Michigan Transportation Research Institute |
| **USDOT** | United States Department of Transportation |
| **VDT** | Vehicle Data Translator |
| **VIIC** | Vehicle Infrastructure Integration Consortium |

| | |
|---|---|
| **VTTI** | Virginia Tech Transportation Institute |
| **V2I** | Vehicle-to-Infrastructure |
| **V2I-SA** | Vehicle-to-Infrastructure Safety Applications Project |
| **V2V** | Vehicle-to-Vehicle |

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