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Cooperative Intersection Collision Avoidance System Limited to Stop Sign And Traffic Signal Violations

Midterm Phase I Report
May 2006 – April 2007

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16. Abstract

This report presents the Midterm Phase I Report for the Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICASV) project. The report covers the period from project inception on May 1, 2006, through April 30, 2007, and contains a summary of the tasks that were active during the first year of the project. These tasks, collectively, address four major elements of the research needed to develop an FOT-ready system by the end of Phase I. These elements are: (a) human factors research to identify a driver-vehicle interface (DVI) for the CICAS-V system and the operational parameters for the driver warning algorithm; (b) systems engineering activities to design the CICAS-V system; (c) system development and validation tasks to build and test a prototype FOT system; and (d) project management and coordination with outside organizations. The progress made during the period and the accomplishments achieved are also described in the report.

The CICAS-V project is a four-year project to develop a cooperative intersection collision avoidance system to assist drivers in avoiding crashes in the intersection by warning the driver of an impending violation of a traffic signal or a stop sign. The Vehicle Safety Communications 2 Consortium (VSC2) is executing the project. Members of VSC2 are Ford Motor Company, General Motors Corporation, Honda R & D Americas, Inc., Mercedes-Benz Research and Development North America, Inc., and Toyota Motor Engineering & Manufacturing North America, Inc.

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List of Acronyms

CICAS-SLTA	Cooperative Intersection Collision Avoidance System for Signalized Left Turn Assistance
CICAS-SSA	Cooperative Intersection Collision Avoidance System for Stop Sign Assistance
CICAS-V	Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations
ConOps	Concept of operations
DAS	Data acquisition system
DSP	Digital signal processor
DSRC	Dedicated short range communications
DVI	Driver-vehicle interface
DVR	Digital video recorder
FHWA	Federal Highway Administration
FOT	Field operational test
GID	Geometric intersection description
GPS	Global positioning system
GPSC	Global positioning system correction
IEEE	Institute of Electrical and Electronics Engineers
IRB	Internal review board
ITE	Institute of Transportation Engineers
MCNU	Multiband Configurable Networking Unit
NHTSA	National Highway Traffic Safety Administration
OBE	On-board equipment
OEM	Original equipment manufacturer
PBA	Panic brake assist
PMRs	Project management reviews
POC	Proof of concept
RSE	Roadside equipment
SAE	Society of Automotive Engineers
SPaT	Signal phase and timing
U.S. DOT, DOT	United States Department of Transportation
VII	Vehicle Infrastructure Integration
VIIC	Vehicle Infrastructure Integration Consortium
VNTSC	Volpe National Transportation Systems Center

VSC2	Vehicle Safety Communications 2 Consortium
VTTI	Virginia Tech Transportation Institute
WAVE	Wireless access in vehicular environments
WSM	WAVE short messages

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Executive Summary

This report presents the Midterm Phase I Report for the Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V) project. The report covers the period from project inception on May 1, 2006, through April 30, 2007.

The CICAS-V project is a four-year project to develop a cooperative intersection collision avoidance system to assist drivers in avoiding crashes in the intersection by warning the driver of an impending violation of a traffic signal or a stop sign. The Vehicle Safety Communications 2 Consortium (VSC2) is executing the project under Federal Highway Administration (FHWA) Cooperative Agreement No. DTFH61-01-X-00014, Work Order W-05-001. Members of VSC2 include Ford Motor Company, General Motors Corporation, Honda R & D Americas, Inc., Mercedes-Benz Research and Development North America, Inc., and Toyota Motor Engineering & Manufacturing North America, Inc. Funding for this project is provided from the Joint Program Office of the United States Department of Transportation. The project is also supported by Virginia Tech Transportation Institute (VTTI), which plays a major role in the human factors research to define and evaluate the CICAS-V warning system.

The project was initiated in May 2006 and is divided into two phases. Phase I will develop and test a prototype of a CICAS-V system that will be ready for testing with naïve users. Phase I is scheduled to run through July 31, 2008. At the end of Phase I, the U.S. DOT and VSC2 will jointly determine if the system will be tested in a field operational test (FOT) in Phase II of the project. If a “go” decision is made by the two organizations, Phase II is scheduled to run for two additional years.

Phase I of the project consists of 14 tasks of which 12 were active during the first year of the project. These tasks, collectively, address four major elements of the research needed to develop an FOT-ready system by the end of Phase I. These elements are:

- Human factors research to identify a driver-vehicle interface (DVI) for the CICAS-V system and the operational parameters for the driver warning algorithm;
- Systems engineering activities to design the CICAS-V system;
- System development and validation tasks to build and test a prototype FOT system. This includes both software and hardware components for the intersection and the vehicle; and
- Project management and coordination with outside organizations.

In the first year of the project, significant progress was made toward the objectives of this phase. Highlights of the accomplishments include:

- Completed mining of the VTTI 100-Car Naturalistic Driving Study database to determine the conditions under which drivers commit violations of traffic control devices (Task 3);

- Initiated naturalistic data collection at stop-controlled and signalized intersections in Blacksburg, Virginia, to identify how drivers make approaches to intersections and identifying what warning algorithm might be effective in preventing the violations observed at these sites (Task 3);
- Initiated a series of test-track driving studies to identify the DVI for the CICAS-V system (Task 3);
- Developed the systems engineering process that will be used for the CICAS-V project (Task 9);
- Developed the concept of operations for the CICAS-V system (Task 4);
- Defined the message formats for system operation, such as those for transmission of the traffic signal phase and timing information, positioning corrections, and the geometric intersection description, a type of electronic map (Task 8);
- Selected intersections in California, Michigan, and Virginia to support Phase I system testing; selected the test vehicles that are expected to be used in the remainder of the project (Task 8);
- Completed installation of CICAS-V developmental prototype equipment at one intersection in California and one intersection in Michigan. Both intersections are operational and transmitting initial prototype CICAS-V messages via radio to a test vehicle equipped with specially developed test software (Task 8);
- Initiated FOT software development activities (Task 10);
- Completed the design for the vehicle data acquisition system that will be used in the Phase I Pilot FOT as well as the Phase II full FOT (Task 12); and
- Completed an assessment of three FOT designs under consideration and estimated the expected number of system warnings associated with each (Task 13).

Activities planned for the second year of the project include:

- Completing the systems engineering effort to design the system;
- Completing the human factors research and selecting a DVI for use in the CICAS-V system;
- Installing the FOT prototype equipment at the intersections and in the test vehicles;
- Initiating objective tests of the intersection and vehicle components to verify that the system design meets the needed requirements;
- Initiating a Pilot FOT to evaluate the prototype system using naïve drivers; and
- Continuing the project management and external coordination activities.

1 Introduction

This document presents the Midterm Phase I Report for the Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations project. The period covered by the report is from May 1, 2006, through April 30, 2007.

1.1 Project Description

The CICAS-V project is a four-year project to develop a cooperative intersection collision avoidance system to assist drivers in avoiding crashes in the intersection by warning the driver of an impending violation of a traffic signal or a stop sign. “Cooperative” means that the system involves both infrastructure and in-vehicle elements working together. The Vehicle Safety Communications 2 Consortium is executing the project under Federal Highway Administration Cooperative Agreement No. DTFH61-01-X-00014, Work Order W-05-001. Members of the VSC2 Consortium include Ford Motor Company, General Motors Corporation, Honda R & D Americas, Inc., Mercedes-Benz Research and Development North America, Inc. and Toyota Motor Engineering & Manufacturing North America, Inc. Funding for this project is provided from the Joint Program Office of the United States Department of Transportation. The project is also supported by Virginia Tech University, which plays a major role in the human factors research to define and evaluate the CICAS-V warning system. The work at Virginia Tech is being conducted through its research group at the Virginia Tech Transportation Institute.

The project was initiated in May 2006 and is divided into two phases. Phase I will develop and test a prototype of a CICAS-V system that will be ready for testing with naïve users. Phase I is scheduled to run through July 31, 2008. At the end of Phase I, the U.S. DOT and VSC2 will jointly determine if the system will be tested in a field operational test (FOT) in Phase II of the project. If a “go” decision is made by the two organizations, Phase II is scheduled to run for two additional years.

1.2 Purpose for Implementing the System

The purpose of implementing CICAS-V is to reduce crashes due to violation of traffic control devices (both traffic signals and stop signs).

When deployed, this system is intended to:

- Reduce fatalities at controlled intersections;
- Reduce the number of injuries at controlled intersections;
- Reduce the severity of injuries at controlled intersections;
- Reduce property damage associated with collisions at controlled intersections; and
- Create an enabling environment that additional technologies can leverage to further extend safety benefits.

Each year about 5,000 fatal crashes occur in intersections with traffic signals or stop signs (NHTSA, 2005). About 44 percent occur at traffic signals and 56 percent at stop signs. About 400,000 injury crashes occur at those intersections each year. About 600,000 property damage crashes also occur at those intersections annually.

An initial analysis of relevant NHTSA crash databases shows that violation crashes have a variety of causal factors. The CICAS-V system is intended to address the causal factors that include driver distraction (a frequent factor [Campbell, Smith, & Najm, 2004, p. 65]), obstructed/limited visibility due to weather or intersection geometry or other vehicles, the presence of a new control device not previously known to the driver, and driver judgment errors. Driver warnings, such as those planned for CICAS-V, may prevent many violation-related crashes by alerting the distracted driver, thus increasing the likelihood that the driver will stop the vehicle and avoid the crash.

1.3 Goals and Objectives

CICAS-V is intended to provide a cooperative vehicle and infrastructure system that assists drivers in avoiding crashes at intersections by warning the vehicle driver that a violation, at an intersection controlled by a stop sign or by traffic signal, is predicted to occur. The basic concept of CICAS-V is illustrated at a high level in Figure 1 for a signalized intersection. In the figure, a CICAS-V equipped vehicle approaching a CICAS-V equipped intersection receives messages about the intersection geometry and status of the traffic signal. The driver is issued a warning if the equipment in the vehicle determines that, given current operating conditions, the driver is predicted to violate the signal in a manner which is likely to result in the vehicle entering the intersection. While the system may not prevent all crashes through such warnings, it is expected that, with an effective warning, the number of traffic control device violations will decrease, and result in a decrease in the number and severity of crashes at controlled intersections.

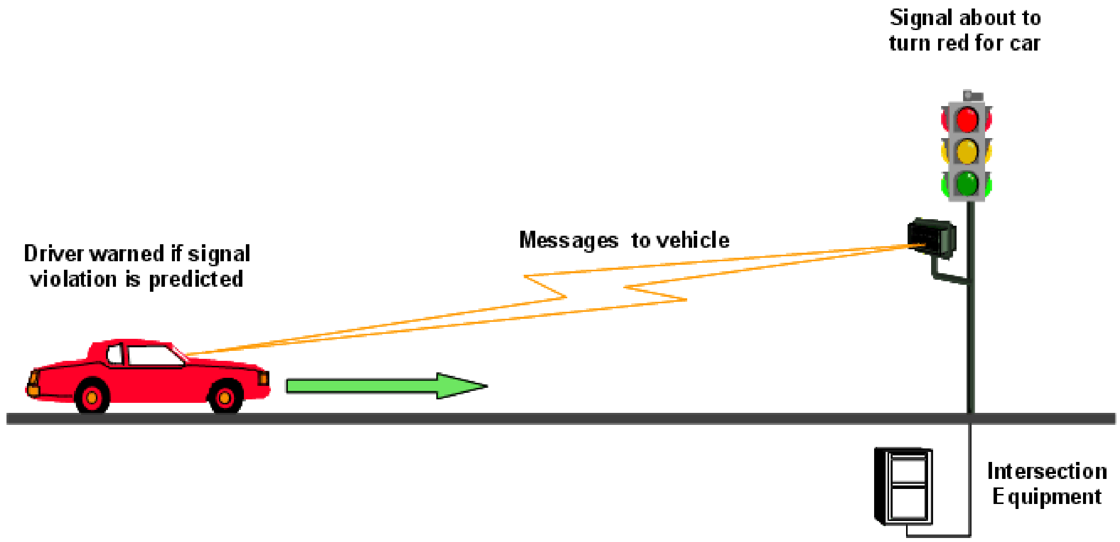


Figure 1. Basic concept of the CICAS-V system at a signalized intersection.

Specific goals of CICAS-V include the establishment of:

- A warning system that will be effective at reducing the number of fatal crashes, the severity of injuries, and property damage at CICAS-V intersections;
- A warning system that is acceptable to users;
- A vehicle-infrastructure cooperative system that helps vehicle drivers avoid crashes due to violations of traffic signals or stop signs; and
- A system that is deployable throughout the United States.

1.4 Project Summary

The project consists of 14 tasks as shown in Table 1. The tasks are summarized in the material following the table.

Table 1. Project Tasks

Task No.	Task Name	Task Active During First Project Year?	
		Yes	No
1	Project Management	√	
2	Coordinate With Standards Development Activities	√	
3	Human Factors Research	√	
4	Concepts of Operations and Systems Requirements	√	
5	System Architecture and System Design	√	
6	Development of Performance Specifications	√	
7	Development of Test Plans and Objective Test Procedures		√
8	Prototype Building and Testing	√	
9	System Development Plan	√	
10	Integration of Subsystems, Building of Prototype Vehicles, and Outfitting of Intersections	√	
11	Vehicle and Intersection Objective Testing		√
12	FOT Data Acquisition Systems	√	
13	Prepare for Field Operational Test	√	
14	Human Use Approval	√	

Task 1 provides the overall project oversight to ensure that the project achieves its technical objectives within the timeframe and resources allocated for the effort. This task will run throughout the entire project.

Task 2 provides the support activities needed to define and incorporate CICAS-V requirements into the standards established by standards-setting organizations such as the Society of Automotive Engineers (SAE), Institute of Electrical and Electronics Engineers, Inc. (IEEE) and Institute of Transportation Engineers (ITE). These activities are intended to facilitate the future deployment of the CICAS-V system by having needed standards in place when suppliers begin developing production equipment. It is expected that activities in this task will run throughout the entire project.

The driver-vehicle interface (DVI) and the alert timing warning algorithm that will activate the CICAS-V warning in the vehicle will be developed and evaluated in Task 3. In addition, data generated from this task will be provided to the U.S. DOT's independent evaluator to aid in system benefits estimation. The task will culminate in a Pilot FOT to evaluate the prototype DVI in a small on-road test with naïve drivers prior to the onset of the project's Phase II activities. Task 3 consists of four major subtasks that will be listed for clarity.

- In Subtask 3.1, the VTTI 100-Car Naturalistic Driving Database will be mined to determine the factors associated with violations and near violations of signalized and stop-controlled intersections.
- Subtask 3.2 will focus on the collection of naturalistic intersection approach data for signalized and stop sign controlled intersections to optimize the warning timing.
- In Subtask 3.3, three alternative DVIs will be examined in a series of studies conducted on a closed-course test track in order to determine the preferred DVI for the CICAS-V system.
- A pilot study with the prototype CICAS-V system will be conducted in Subtask 3.4 using a small sample of drivers recruited from the population of drivers at large to assess the overall readiness of the prototype for the larger FOT planned for Phase II of the project.

In Task 4, the Concept of Operations (ConOps) for the CICAS-V system will be prepared and a set of high-level system requirements will be developed.

Following the work in Task 4, Task 5 will feature development of the system architecture and the detailed system requirements.

The system performance requirements will be developed in Task 6. These will be presented in two documents: one addressing the performance requirements for the vehicle portion of the system and the other addressing the performance requirements for the infrastructure portion of the system.

Objective test procedures that can be used to verify the correct functioning of the system before it is placed into a field test will be developed in Task 7. The actual verification testing of the CICAS-V system will be conducted in Task 11, described below.

In Task 8, a prototype system to test the various system elements will be developed. Work in this task includes development of both the vehicle and intersection system components.

Task 9 contains the activities associated with the development of the systems engineering process and the system engineering oversight that will be used in Tasks 4 through 7, above, to design the CICAS-V system and the verification procedures.

Task 10 features the building of the final vehicle and intersection prototype that is ready for a field evaluation in an unattended setting with naïve users. The prototype will subsequently be validated in Task 11 and evaluated in an on-road pilot test in Subtask 3.4.

Task 11 involves the verification of the CICAS-V system design using the objective test procedures developed in Task 7 and the prototype system built in Task 10. The test results would also serve as benchmarks that manufacturers could use to verify their system implementation.

Development of the vehicle and intersection data acquisition systems that will be used in the pilot FOT and the full FOT in Phase II to collect data to assess system benefits, user acceptance and potential unintended consequences will be done in Task 12.

Task 13 will feature the development and evaluation of various testing strategies intended to obtain data about user acceptance, unintended consequences and safety benefit of the CICAS-V system.

In Task 14, approval to conduct any of the tests in this project involving human participants will be obtained from an established internal review board (IRB). This process is required of the project in order to safeguard the rights of naïve participants.

1.5 Organization of the Report

Section 2 of the report presents a summary of the activities that occurred within each active task during the first year of the project. Some tasks, such as Tasks 7 and 11, did not have any activities during the initial year of the project, as activities in these tasks are not scheduled to begin until the second year of operations. The reporting period is May 1, 2006, through April 30, 2007.

Section 3 contains the references for reports cited in the document.

Section 4 presents the project schedule as a Gantt chart.

2 Summary of First Year Activities

2.1 Task 1 – Project Management

The objective of the Project Management task is to provide the administrative and technical oversight to keep the project on track from a schedule and budget perspective and to ensure that the project objectives are fulfilled. The Project Management task is an on-going task that will run from project inception through completion of Phase I. Included in the scope of activities in this task are:

- Leadership over all work within the CICAS-V project;
- Maintenance of a project plan;
- Risk identification and management throughout the project;
- Project progress reporting; and
- Coordination with other related programs such as the Vehicle Infrastructure Integration Consortium (VIIC), Vehicle Infrastructure Integration (VII) Program, the Cooperative Intersection Collision Avoidance System projects for Signalized Left Turn Assistance (CICAS-SLTA) and Stop Sign Assist (CICAS-SSA), and the various state or local departments of transportation supporting the project.

To support these activities a project plan was developed early in the project as was a risk management plan that outlined the risks associated with project execution and plans to mitigate the more significant of those. The Gantt chart for the project is presented in Section 4. This material depicts the schedule for the remainder of Phase I. To facilitate project progress reporting, a quarterly report format was developed in conjunction with the U.S. DOT. This report format was subsequently used to provide quarterly progress and financial reports to the U.S. DOT. Quarterly progress briefings were also provided to U.S. DOT during the first year of the project as were weekly updates delivered during teleconferences with VSC2 and U.S. DOT managers.

Coordination activities with the VIIC and VII Program were conducted during the year to support on-going exchange of status information among the three programs and to support planning of the VIIC's proof-of-concept (POC) tests planned for late 2007. Activities undertaken in these efforts included participation in the VII Program Management Reviews (PMRs) and participation in teleconferences and meetings with both the VIIC and VII Program to plan the POC testing. These latter meetings facilitated defining the tests that will be conducted, identifying CICAS-V's role in the POC tests and formulating a timeline for CICAS-V POC preparations. A Concept of Operations document and a Requirements document, specifically directed toward the CICAS-V participation in the POC, were prepared and provided to the VII Program for their use in planning the POC tests.

Progress briefings were also provided to the U.S. DOT in August and December 2006 and February and May 2007.

As this task is on-going, the activities outlined above are expected to continue through the remainder of Phase I of the project.

2.2 Task 2 – Coordinate With Standards Development Activities

The objective of this task is to foster the inclusion of CICAS-V application requirements in the standards established by the various standards-setting organizations both within the United States and world-wide. Such standards will facilitate the future deployment of the CICAS-V system following successful completion of the field testing planned for Phase II of the project. During the first year of the project, work in Task 2 focused on the three standards areas listed below:

- Communications;
- Message formats for transmission of information from the infrastructure to the vehicles approaching equipped intersections; and
- A geometric intersection description, a specialized digital map of a CICAS-V equipped intersection.

The communications standards are currently under development by the Institute of Electrical and Electronics Engineers, Inc. (IEEE), where working groups are in the process of writing and evaluating the IEEE 802.11p and IEEE 1609.x family of standards. These standards describe the Dedicated Short Range Communication (DSRC) system, which is one of the enabling technologies of the CICAS-V system. DSRC allows vehicles to communicate with other vehicles and the infrastructure, wirelessly, using a 5.9-GHz-based radio. Standardizing this communication system is essential to the successful development and interoperability of any communication-based system, such as CICAS-V. The specific details of these standards are highly technical in nature and are, consequently, beyond the scope of this report. However to aid reader understanding, it is worth noting that the IEEE 802.11p standard addresses how messages are sent over the wireless channel, while the IEEE 1609.x family of standards defines an architecture and networking services referred to as Wireless Access in Vehicular Environments (WAVE). These standards are interrelated, as IEEE 1609.x is a higher-layer standard which builds upon the IEEE 802.11p lower-layer standard.

The standards related to the message formats and the geometric intersection description (GID) are under development within the SAE’s DSRC Data Dictionary and Message Set Technical Committee (J2735). Efforts within this group will initially define a Recommended Practice, and later a Standard Practice, covering data elements, data frames and message sets. Such efforts are needed to produce interoperable applications in the future. Currently, formats for the message that will transmit traffic signal status information (referred to as the signal phase and timing information) and the message that will contain the information about the GID are being considered by J2735.

In the Task 2 work performed through the first year of the project, CICAS-V project team members participated in the working groups of IEEE 80211p, IEEE 1609.x, and SAE J2735 and worked to include the requirements needed by CICAS-V in the documents currently being drafted. In addition, the project team members assisted with answering questions, resolving technical issues and addressing comments received on the draft standards that have been developed to date. Several member of the project team are also voting members of the standards working groups and will affect passage of a standard though the voting processes defined by each of the respective standards organization.

As the year ended, the third draft of the IEEE 802.11p standard was being prepared. It is expected that this draft will move to a letter ballot during the second half of 2007. The IEEE 1609.x standards are nearly complete. All of the IEEE 1609.x standards have passed sponsor ballot for trial use. It is anticipated that the IEEE 1609.x trial use series will be revised during 2008 based on collected field experience, and then subsequently balloted as full IEEE standards. IEEE 1609.0 is also being prepared to address the overall communications architecture. Additionally, the SAE J2735 technical committee continues discussion of the message formats and the contents of the GID. It is expected that a second version of J2735 will be published in 2008.

In the coming year, the project team will continue to support the standards development work in IEEE and SAE.

2.3 Task 3 – Human Factors Research

The human factors research in the project plays a key role in helping to ensure that the CICAS-V system developed is effective from both a safety and customer acceptance perspective. The scope of this task includes four subtasks, as shown below:

- Subtask 3.1 – Mine the 100-Car Database;
- Subtask 3.2 – Collect Naturalistic (No Alert) Infrastructure-based Driving Data;
- Subtask 3.3 – Test Alternative Driver-Vehicle Interfaces (DVIs) on the Smart Road; and
- Subtask 3.4 – Conduct Pilot FOT Human Factors Assessments.

Subtasks 3.1 through 3.3 are intended to aid in the design of the CICAS-V DVI through examination of experimental data to help define the type of warning the driver receives and the timing of the warnings during an approach to an intersection. These subtasks were initiated at the outset of the project and continued through the first year of project operations. Efforts in these subtasks are interrelated. Subtask 3.4 will be undertaken during the second year of the project and will focus on evaluation of the prototype CICAS-V system using a small group of drivers from the general public. The following material summarizes the accomplishments within Subtasks 3.1 through 3.3.

2.3.1 Subtask 3.1 – Mine the 100-Car Database

The objective of Subtask 3.1 is to examine the 100-Car Database to identify the conditions under which drivers commit violations of traffic signals and stop signs at intersections. The 100-Car Database is a dataset that was previously generated during the 100-Car Naturalistic Driving Study (Dingus et al., 2006) conducted by VTTI for NHTSA. In this study, 109 primary drivers and 132 secondary drivers drove an instrumented car during normal driving, while data about their behavior and vehicle operations were unobtrusively recorded. The data included vehicle operating parameters as well as video recordings of the road scene and driver's eye movements. As such, the database represents a rich source of information that can be mined to identify driver behaviors related to stop-controlled and signalized intersection approaches and the factors associated with violations of traffic control devices. In addition, it can be used to establish exposure-based estimates, which will be useful for design of the FOT and crash benefits estimation elsewhere in the project.

The work in this subtask focused on a subset of the 100-Car primary drivers that included 54 male and 23 female drivers that drove at least 1,000 miles in the 100-Car Study. The ages of the driver selected for study ranged from 18 to more than 55 years.

During the first year of the project, the primary effort in the subtask centered on creating a subset of the 100-Car Database that included intersection approaches made by the 77 selected drivers through both stop-controlled (i.e., non-signalized intersections where at least one approach was controlled by a stop sign) and signalized intersections. The intersections involved with these crossings were located in Northern Virginia in the Washington, DC metropolitan area. The process to accomplish this involved developing computer-based procedures to identify the events of interest in the 100-Car Dataset and extracting those into a new database. In addition, the video recordings associated with these events were examined by a trained analyst to obtain relevant driver, environmental and road scene information and add it into the database of parametric data.

The crossings were subsequently classified with respect to whether a violation or near violation of a traffic control device occurred during approach. To accomplish this, definitions of violations and near violations were established. For example, in this study, a stop sign violation was defined as an intersection crossing in which the driver does not come to a stop and the estimated stop-bar speed exceeds five mph. For signalized intersections, a violation was defined as crossings in which the driver proceeds through the intersection when the observed signal phase at the stop-bar is red. The stop-bar is the designated stopping location at an intersection and is frequently marked on the pavement with a white transverse line.

The resulting database contained information on over 123,500 signalized intersection approaches and more than 1,500 approaches to stop-controlled intersections.

As the reporting period closed, the analysis of this data was still in-process. The principal analyses underway consist of specifying and categorizing relevant driver behavior and the environmental factors observed during intersection violations. Analysis of signalized intersections is being conducted separately from the stop sign controlled intersections. Some of the analyses that will be conducted include identifying the following:

- Frequency of violations and near violations in the sample;
- Stop bar speed at the time of violation or near violation;
- Violations and near violations by age and gender of driver;
- Time after red phase onset for signalized intersection violations;

- Driver turning intent for violations or near violations;
- Role of driver inattention during violations, including in-vehicle distractions, driving-related inattention or impairment;
- Driver eye glance behavior and classification of avoidance maneuvers or crossing errors;
- Assessment of environmental conditions such as time of day, weather, road surface condition and presence of other vehicles; and
- Other, including driver hand placement on steering wheel, seat belt usage and visual obstructions associated with violations and near violations.

It is expected that the analysis in Subtask 3.1 will continue through May 2007 when the results will be available. These will subsequently be included in the comprehensive report covering Task 3 that will be prepared at the end of Phase I of the project.

2.3.2 Subtask 3.2 – Collect Naturalistic (No Alert) Infrastructure-Based Driving Data

Subtask 3.2 involves naturalistic observation of drivers' intersection approach behavior at both stop-controlled and signalized intersections. The intersections used during this data collection effort have been equipped with data acquisition systems that will enable data from all approaches to be recorded as drivers naturally drive toward the intersection. The data consists of radar-based measurement of vehicle range and range rate as well as video recordings of the traffic approaching the intersection. The purpose of this subtask is to obtain information that can be incorporated into the warning algorithm for the CICAS-V system. The algorithm will be subsequently evaluated in Subtask 3.4 during the second year of the project.

Work performed in this subtask focused on the following items during the first year of the project:

- Intersection selection;
- Development of data acquisition systems for stop-controlled and signalized intersections;
- Installation of data collection equipment and collecting observational data; and
- Development of computer-based methods for data reduction and analysis.

The initial work in this subtask focused on the selection of the intersections to be studied. To accomplish this, the project team worked in conjunction with the DOT staff to define the set of characteristics desired for the intersections that would be used in the study. The set of characteristics included such things as:

- Traffic volume;
- Accident experience;
- Intersection geometry, including the number of lanes at the intersection, obstructions to drivers' lines of sight, presence of left turn lanes and the number of intersection approach legs;

- Global positioning system (GPS) satellite coverage;
- Posted speed limits;
- Support from the local department of transportation having jurisdiction over the intersection; and
- Logistical considerations, such as the availability of electrical power and accessibility by the project team.

Using the intersection selection criteria defined in this step, project team members then located and photographed candidate intersections that could be used as data collection sites. These were reviewed with the DOT. Five stop-controlled and three signalized intersections in the Blacksburg area were then selected from the candidate sites for use in this subtask. The list of Virginia intersections studied in this effort is presented below.

<u>Stop-Controlled Intersections</u>

- Clubhouse and Luster's Gate
- Plank and Luster's Gate
- Nellie's Cave and Woodland Hills
- Fairview Church and Highway 8
- Meadow Creek and Childress (Eastbound and Westbound)

<u>Signalized Intersections</u>

- Franklin, Elm, and Independence
- Depot and Franklin Streets
- US 460 Business and Virginia Route 114

The second effort undertaken in the subtask was the development of data acquisition systems for both stop-controlled and signalized intersections. Because stop-controlled intersections do not typically have electrical power or communication lines available, the data acquisition systems used for these locations were designed to be self-contained, self-powered units that could easily be deployed in the field. The stop-controlled intersection DASs that were developed consisted of a video camera, radar unit, a custom digital signal processor (DSP) circuit board, a digital video recorder (DVR), and an enclosure with a battery power source. The stop-controlled intersection DAS is depicted in Figure 2. The sensing network measured raw inputs (such as approaching vehicle position and speed) and provided the measures to the DSP. The DSP pre-processed the inputs and assembled the dataset while archiving digital data files on the DVR. These parametric data were accompanied by a video stream obtained from a camera focused in the same direction as the radar. The DAS was packaged in a housing intended to be inconspicuous to drivers and positioned next to the roadway at an intersection. One stop-controlled DAS unit was used to acquire data from a single approach leg to the intersection. The datasets obtained from the individual DAS units were subsequently combined into a single dataset for analysis.

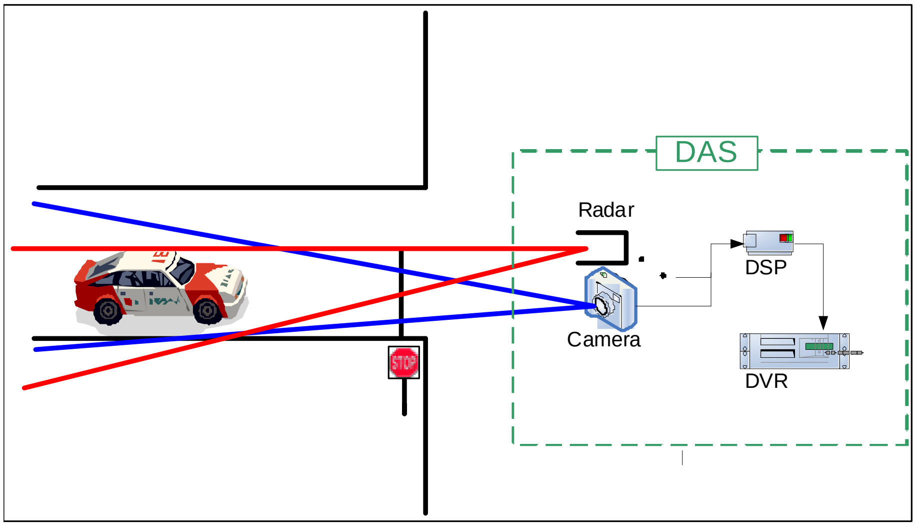


Figure 2. Diagram of data acquisition system for stop-controlled intersections.

The availability of power at signalized intersections means that a more sophisticated DAS design could be employed at these locations. The DAS developed for the signalized intersections consisted of a sensing network, data processor, hardware enclosures and mounting brackets. The DAS is presented in Figure 3. The sensing network was a distributed subsystem of components that provided raw inputs to the data processor and data management system. The sensing network included: (1) four customized radar units for providing vehicle position and speed data, (2) a phase-sniffer to unobtrusively collect the signal phase and timing information from the traffic signal, (3) a GPS antenna for accurately obtaining time and weather station information, and (4) four video cameras for recording the visual scene along each of the approaches to the intersection. The data processing and management unit in the DAS pre-processed these inputs and then assembled and archived the dataset in real-time. This system was completely contained at the intersection site and unnoticeable to drivers. A typical installation of this DAS is shown in Figure 4.

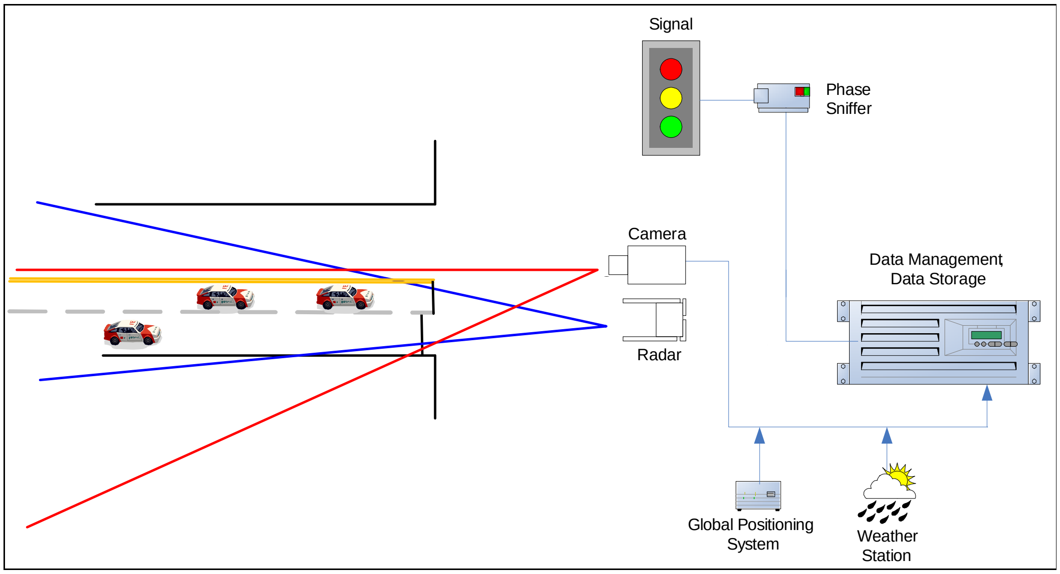


Figure 3. Diagram of signalized intersection data acquisition system.

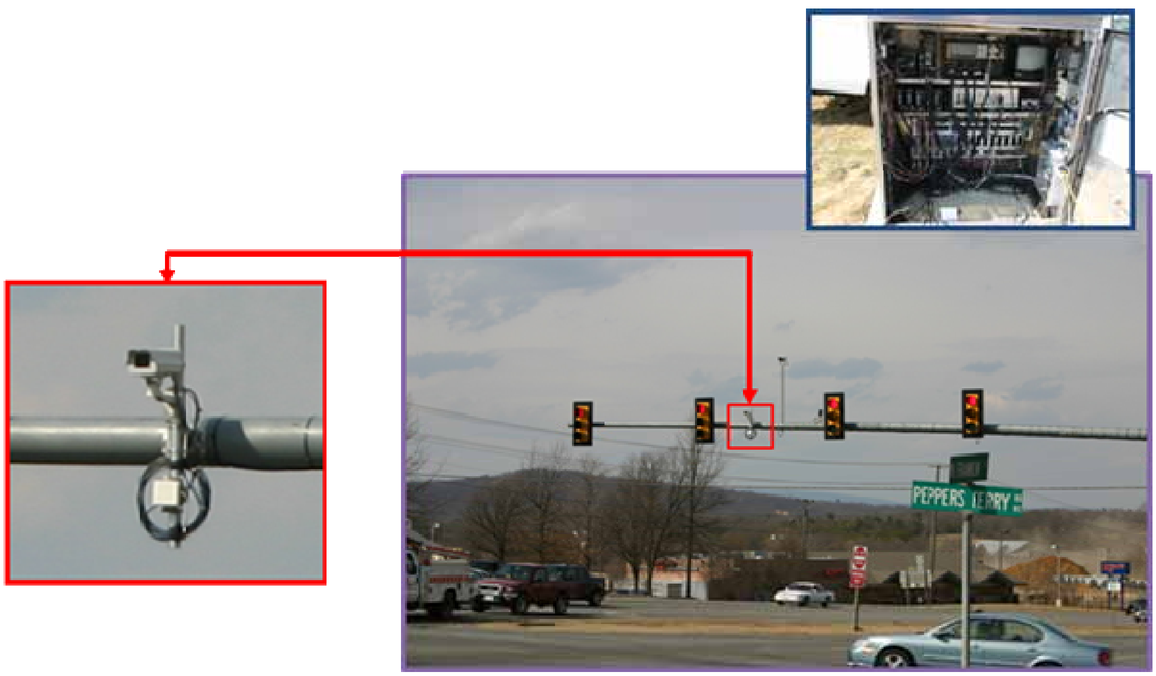


Figure 4. Data acquisition system installed at a signalized intersection In Virginia.

During the first year of the project, the data collection effort at the stop-controlled intersections was completed. Currently, the data is being prepared for analysis and computer-based analysis programs are being developed. These two activities are expected to continue into the second year of the project when analysis of this data will be performed. In addition, data collection is currently underway at the three signalized intersections. This activity is expected to conclude at the end of July 2007. Data reduction and preparation of the analysis algorithms for the signalized intersection data will then follow. The analysis of the approach data from both the stop-controlled and signalized intersections is expected to continue through March 2008.

2.3.3 Subtask 3.3 – Test Alternative DVIs on the Smart Road

One of the primary goals of the project is to identify a driver-vehicle interface and warning scheme that is effective at preventing crashes by reducing violations of traffic control devices. The system also must be acceptable to the users. To address this objective, a series of studies was planned for the Smart Road at VTTI in which alternative DVIs could be evaluated using naïve drivers recruited from the public at large. The Smart Road is a closed-course test track operated by VTTI in Blacksburg. It includes an operating signalized intersection that was outfitted with the equipment needed to support CICAS-V testing in this subtask. Two test vehicles were also equipped with data recording equipment to support this research.

The overall goal of the initial evaluation was to identify a testing methodology that created an efficient, repeatable, visual distraction for the driver so that evaluation of the DVIs could take place. The testing scenario developed for Subtask 3.3 was that, while the driver was approaching the Smart Road intersection, he or she would be distracted and the traffic signal cycled from green to red, creating a situation where the driver was "surprised" by the sudden changing of the traffic light when they returned their attention to the road ahead. The timing of the light change was specifically selected for the travel speed of the vehicle, 35 mph, so that the DVI being investigated would issue its warning to the driver. The driver's response to the signal change and CICAS-V system warning was then recorded to provide data on which comparisons across the DVIs could be made. The test participants were free to either stop for the traffic signal or continue through the intersection at their discretion. Because a test participant could be "surprised" only once, it was important that the technique selected to create the distraction be effective in creating the surprise trial needed to assess the DVIs.

The first studies conducted in this subtask examined two experimental techniques for their appropriateness in comparing candidate DVIs. The two techniques are referred to as the *visual occlusion technique* and the *naturalistic technique*. In the visual occlusion technique, the participating drivers wore special computer-controlled spectacles with electronic "shutters" that could be closed to prevent the driver from seeing the road scene ahead. The spectacles are shown in Figure 5 with the shutters closed. When the shutters are open, the driver has normal visibility through the spectacles. This technique was used to simulate a two-second "eyes-off-the-road distraction" by the driver. A ride-along experimenter accompanied the participant on every test run. The experimenter operated the data recording equipment installed in the car. The experimenter also had access to a second brake pedal mounted on the passenger's side of the vehicle and served as a safety observer during the periods when the driver's view was occluded. Following the period of occlusion, the driver's normal view of the road scene was restored and the driver then proceeded to respond to the signal change and CICAS-V warning with whatever action was deemed most appropriate to the driver.

Figure 5. Occlusion spectacles with "shutters" closed.

In the naturalistic technique, the ride-along experimenter gave the driver an in-vehicle task to perform while driving. Tasks like operating the entertainment system or adjusting the heating and ventilating system were used as the in-vehicle tasks as they are representative of tasks typically performed by drivers in their own vehicles while driving. While the driver's eyes were directed inside the vehicle and attending to the secondary task, the ride-along experimenter cycled the light to red so that the evaluation of the DVI could be conducted. Unlike in the visual occlusion technique where the driver's view to the road scene was physically restricted for a two-second interval, in the naturalistic technique the driver could regain their view to the road scene at any time by simply looking back outside the vehicle. As was the case in the visual occlusion technique, the driver was free to choose the appropriate response.

The DVI examined during the first two studies featured a visual warning coupled with an auditory tone issued at the appropriate distance from the intersection when a stop was required by the driver at a traffic control device ahead. The visual warning was implemented in an icon mounted on top of the instrument panel of the test car at the center of the vehicle. This is depicted in Figure 6. When the vehicle is not near a CICAS-V-equipped intersection, the icon is normally off. When the vehicle comes within range of the intersection, the icon illuminates in a steady, blue color. When the CICAS-V warning is issued, the icon changes color to red and flashes.

Figure 6. Experimental warning icon mounted in test vehicle.

Data collected in the DVI studies included whether the driver stopped or continued through the intersection; the vehicle speed, acceleration and stopping location; measurements related to the driver's eye glancing patterns; driver foot position with respect to the brake and accelerator pedals; reaction times to the CICAS-V warning; and timing of the warnings from the traffic signal. Subjective assessments of the DVIs by the test participants were also collected through a structured interview process at the end of the test session. Eighteen subjects were run in each study conducted within Subtask 3.3. The sample of drivers was balanced by gender and age group (young, middle-aged, older).

Based on an analysis of the data collected and an evaluation of the testing efficiency of the two experimental techniques, it was decided that the naturalistic technique was the more appropriate of the two techniques examined and that it would be used for the remainder of testing in Subtask 3.3.

The final work in Subtask 3.3 will focus on the evaluation of alternative DVIs that have different characteristics and warning timings. Of interest to the project is to identify a suitable DVI for the CICAS-V system that will be further evaluated in a small pilot test that will be conducted in Subtask 3.4 during the second year of the project. This pilot test will be the first evaluation of the CICAS-V DVI by naïve drivers that is conducted on public highways. If this evaluation is successful, the DVI would likely be used as the DVI in the full FOT planned for Phase II of the project.

To address the above need, a series of five additional studies were then developed to examine the following questions:

- Whether a tone alert or a speech warning should be used as an auditory component in the DVI? The speech warning investigated was the message “Stop Light.”
- Whether the addition of a brake pulse feature would increase DVI warning effectiveness? A brake pulse is a haptic cue in which the car’s brakes are momentarily applied and released in a rapid manner to create a vehicle “jerk.” The activation of the brake pulse would coincide with the onset of the auditory and visual warnings examined.
- Whether adding a brake assist feature to the DVI would benefit the driver, when a stop maneuver is performed in a situation where a violation of a traffic control device is imminent? A brake assist feature uses sensing technology on-board the vehicle to help the driver achieve higher levels of braking in emergency situations as compared to a driver’s typical braking ability. This could potentially reduce the occurrence of false alarms for the CICAS-V system by permitting the warning to be issued later in the approach to the intersection, since the driver could potentially use the benefits of the brake assist feature to stop in a shorter distance.
- When should the warning be issued (i.e., at what time or distance from the intersection) to minimize false alarms?

In addition, a sixth study was also planned to record “baseline” driving in which the drivers executed the surprise approach to the intersection but did not have the experimental CICAS-V system operating in the vehicle. The study provided comparison data recorded under “normal” driving without the CICAS-V warning system.

Table 2 summarizes the series of studies planned for Subtask 3.3. Shown are the initial two studies to evaluate the experimental method along with the remaining six studies to complete the DVI evaluation and baseline driving study.

Table 2. Summary of DVI Evaluation Studies Planned for Subtask 3.3

Study	Experimental Method	Experimental Driver-Vehicle Interface
A	Visual Occlusion	Visual Icon + Auditory Tone
B	Naturalistic	Visual Icon + Auditory Tone
Studies that follow the decision to use the Naturalist experimental method.		
C	Naturalistic	Visual Icon + Speech Warning
D	Naturalistic	Visual icon + Auditory Tone + Haptic Brake Pulse
E	Naturalistic	Visual Icon + Speech Warning + Haptic Brake Pulse
F	Naturalistic	Visual icon + Auditory Tone + Haptic Brake Pulse + Panic Brake Assist Feature
G	Naturalistic	Visual Icon + Speech Warning + Haptic Brake Pulse + Panic Brake Assist Feature
H	Naturalistic	Baseline Driving Condition. No Experimental DVI Used; No Driver Warnings Issued in This Study.

As the reporting period closed, testing of the alternative DVIs was in-process and expected to continue through September 2007. Additional information about these studies will be available during the second year of the project.

2.4 Task 4 – Concept of Operations and System Requirements

The systems engineering activities represent the second major thrust of the research in Phase I of the project. Activities in Tasks 4, 5, 6, and 9 will define the system concepts and requirements, the architecture, the performance specifications and the processes for reviewing, testing and revising the proposed CICAS-V design. Task 4 focused on the development of the Concept of Operations (ConOps) document and the definition of the High-Level System Requirements, while Task 9 focused on defining the processes needed to review, test, and revise the system design. Task 5 featured the development of the system architecture and the detailed system requirements and Task 6 features the preparation of performance specifications.

In the first year of project operations, a joint DOT/VSC2 writing team was formed to cooperatively prepare the ConOps and to identify the revisions needed to the document based on the comments received during the various stakeholder reviews that were conducted. A ConOps is a document that describes the system's overall quantitative and qualitative characteristics to the user, buyer, developer and other organizational elements (e.g., training, facilities, staffing, and maintenance).

The preliminary version of the ConOps document was prepared by the joint writing team and released in October 2006. The document that resulted from these efforts contained the following general categories of information:

- System purpose;
- Assumptions, constraints and system boundaries;
- Operational description and operational needs;
- System overview;
- Operational and support environment; and
- Description of operational scenarios.

The preliminary version of the ConOps was then presented to CICAS-V stakeholders from the signal controller manufacturing industry at a meeting held in Austin, TX in November 2006. Comments received during the meeting were subsequently incorporated into the ConOps document along with others received during internal team reviews conducted during the first year of the project. As the first year of project operations concluded, the interim version of the ConOps document was being prepared and is expected to be released at the end of June 2007. One additional update to the ConOps document is expected at the end of Phase I of the project so that the lessons learned from the Pilot FOT (Subtask 3.4, discussed above) and the Objective Testing (Task 11) can be incorporated into the system design.

As the work on the interim ConOps document neared completion, work on the High-Level Requirements document was initiated. The High-Level Requirements is a document that will describe what the users expect the CICAS-V system to do for them, detail the system's expected environment and the system's usage profile, and present the system requirements (including the functional, physical, external, interface, etc. requirements) from a high-level perspective. The preliminary version of the High-Level Requirements is expected to be released in August 2007.

2.5 Task 5 – System Architecture and System Design

The principal activities in Task 5 are associated with the preparation of two systems engineering documents: the System Architecture Description and the System Requirements Specification. The System Architecture Description will define how the CICAS-V system is organized and show its decomposition into functional blocks that work together to satisfy the high-level requirements developed in Task 4. The functional blocks will include both hardware and software components. The System Requirements Specification will contain the detailed requirements for the CICAS-V system such as the functional, design, performance, interface and quality requirements. The requirements contained in the Systems Requirements Specification will be cross-referenced to the requirements contained in the High-Level Requirements Specification through a traceability matrix that will be developed by the technical team during the second year of the project.

Although work in Task 5 was initially started during the first year of the project and drafts of the two documents were prepared, further activities were subsequently deferred to the second year of the project at the request of the DOT. This action was taken to provide sufficient time for the DOT and VSC2 to jointly refine the systems engineering process in Task 9 as well as permit additional reviews to the ConOps document that was developed in Task 4. Development of the documents in this task before the ConOps was stable could lead to unnecessary revisions as the requirements in the ConOps changed in newer versions of that document. It is anticipated that activities in Task 5 will resume in June 2007 and that the preliminary versions of the System Architecture Description and System Requirements Specification documents will be completed by the end of 2007.

2.6 Task 6 – Development of Performance Specifications

Work in Task 6 will develop the performance specifications for the system based on the ConOps developed in Task 4 and the System Requirements Specification prepared in Task 5. The performance specifications will be presented in two documents. One document will present the specifications for the vehicle, while the second document will present the specifications for the infrastructure portion of the system. This document structure is expected to provide compatibility with the design processes for the automotive and intersection equipment manufacturers, which have distinct differences between them.

As was the case with Task 5, work was initially started in Tasks 6 during the first year of the project and draft performance specifications were prepared by the VSC2 technical team. However, following these initial efforts, the DOT requested that further activities in Task 6 be deferred until later in the project. This action was taken to provide sufficient time for the DOT and VSC2 to jointly refine the systems engineering process in Task 9 as well as permit the systems engineering documents that preceded the performance specifications to reach a nominal level of stability. It is expected that work on the performance specifications will resume during the second year of the project and that preliminary specifications will be developed by spring 2008.

2.7 Task 8 – Prototype Build and Testing

Work in Task 8 developed the technology basis for the Phase I prototype that will be used in the Phase II FOT and tested the elements that make up the overall system. This work included:

- Vehicle selection and purchase;
- Intersection selection, equipment installation and functional tests;
- Intersection map development and verification; and
- Application design and testing.

2.7.1 Vehicle Selection

The vehicle selection was based on the requirement that brake pulse and panic brake assist (PBA) would be possible to implement as a user interface on those vehicles and that those vehicles would be available for an FOT (platform stability) two years after the project start. The interface implementation required the presence of panic brake assist and electronic stability system in the vehicle since retrofitting them would be prohibitively expensive and would raise potential safety issues. The vehicles chosen were

- Mercedes-Benz ML350;
- Volvo S80;
- Cadillac STS;
- Acura RL; and
- Toyota Prius.

The vehicles were instrumented with the VSC1 WAVE radio modules produced by DENSO Corporation, OEM-V GPS receivers from NovAtel, Inc., and laptop computers on which the application modules ran.

2.7.2 Intersection Selection

In a joint decision with the U.S. DOT, three intersections each in California and Michigan and four intersections in Blacksburg, Virginia, were selected for CICAS-V installation and testing. The criteria for the intersection selection were that one intersection should be:

- A simple intersection, without protected turn lanes at least in one direction;
- A complex intersection with protected left turn lanes; and
- A stop-sign-controlled intersection.

The intersections selected in Michigan were:

- West 10 Mile and Orchard Lake Roads (simple);
- West 12 Mile and Farmington Roads (complex); and
- West 10 Mile and Drake Roads (stop sign).

The intersections identified in California were:

- El Camino Real and 5th Ave in Redwood City/Atherton (complex);
- Hillview and Hanover in Palo Alto (simple); and
- Peter Coutts Road and Raimundo Way in Palo Alto (stop sign).

The intersections chosen for Virginia were in the Christiansburg/Blacksburg area and included:

- US 460 Business and Virginia Route 114 (complex);
- Depot and N. Franklin Sts. (simple); and
- N. Franklin St. and Independence Blvd. (simple).

A stop-controlled intersection will also be selected in Virginia. However, the selection of this site will be made closer to the start of the Subtask 3.4 Pilot FOT so that the site selected can be situated in the regular travel routes of the drivers participating in the pilot FOT.

Because of institutional issues, the Hillview and Hanover intersection in Palo Alto was replaced with El Camino Real and 12th Avenue in San Mateo.

2.7.3 Intersection Instrumentation

The intersection instrumentation included the first multiband configurable networking unit (MCNU) from TechnoCom Corporation that was compatible with the WAVE radios from DENSO as the roadside equipment. Also installed were a NovAtel OEM-4 receiver that functioned as the base station for the local GPS correction and miscellaneous hardware that was dependent on the local intersection. The intersection instrumentation differed between California and Michigan, due to the different types of cabinets and cabinet locations.

The intersection of El Camino Real and 5th Avenue in Redwood City/Atherton (Figure 7) was the first intersection instrumented in California. This intersection came online in February 2007 and has been working almost without interruption since then.

Figure 7. Intersection at El Camino Real and 5th Avenue in Redwood City, CA.

The setup of this intersection was complex due to the constraints by the environment, such as optimal antenna placement, controller cabinet location and the presence of high-voltage power lines that made the antenna placement challenging. The block diagram in Figure 8 shows the components and the connections for the intersections.

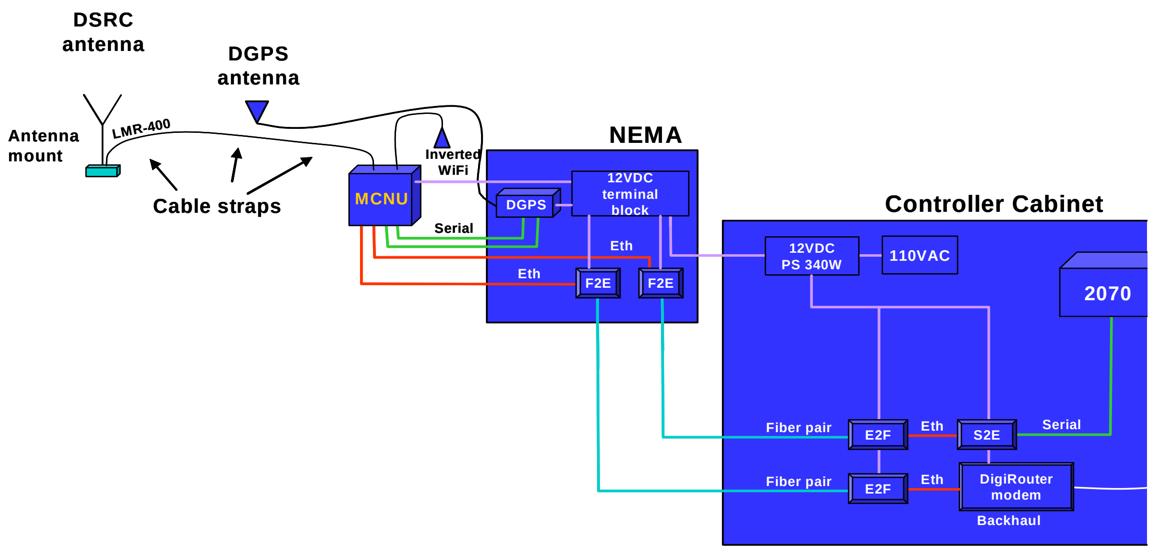


Figure 8. Block diagram of the intersection equipment and connections.

Figure 9 shows a picture of the installation of the equipment in the intersection. The MCNU can be seen on the top of the metal plate and the cabinet at the bottom holds the GPS receiver and the fiber optic to ethernet converters.

Figure 9. Roadside equipment installation at the first California intersection.

The intersection signal controller is an Econolite 2070 that can export signal phase and timing from the controller through a serial port. The protocol that is used to transmit the information is the AB3418a protocol, which is not optimal for CICAS-V purposes. The primary concern about the protocol involves the fact that the information that the controller exports for each signal indication is limited to whether or not the light is green. No information about the red phases is available. However, the length of the yellow phase is known for the intersection and, from this information, a state machine was constructed that accurately determined the phases for each of the signal indications for all the movements in the intersection. In addition, the protocol is a query-and-response type of protocol and has response latencies that are longer than desired for the CICAS-V application.

The first intersection in Michigan to come online was the intersection at West 10 Mile and Orchard Lake Roads (Figure 10).

Figure 10. Intersection at West 10 Mile and Orchard Lake Roads in Michigan.

The CICAS-V intersection installation for West 10 Mile and Orchard Lake Roads is shown in Figure 11.

Figure 11. CICAS-V intersection equipment.

The installation in Michigan was more straightforward than the installation in California, due to the signal controller being located in a cabinet on the mast itself and the possibility to install the antennas on the same mast as the intersection controller.

2.7.4 Message Set Definition

The CICAS-V project defined three message sets that communicate the necessary information from the intersection to the vehicle so that the vehicle can warn of an impending red-light violation:

- Geometric Intersection Description (GID);
- GPS correction (GPSC); and
- Signal Phase and Timing (SPaT).

Those messages were designed to be sent as WAVE Short Message (WSM) packets over DSRC, the standard way in which safety messages are conveyed. The project also developed a unifying framework for those messages that made them both compact and easily extensible.

2.7.4.1 GID Definition and Intersection Mapping

The CICAS-V application requires that the vehicle can determine which traffic signal applies to its path through the intersection. In the CICAS-V application, this is achieved by giving the vehicle a lane-level accurate map of the intersection where necessary (called a GID) and associate the lanes with the correct signal. The vehicle, using its GPS and assisted by the GPSC signal from the intersection, matches itself to the correct lane and can determine the correct signal. Those lane-level accurate maps are sent from the intersection to the vehicle, also in a WSM packet. Since the size of the packet is limited to about 1.4K bytes of information, it was necessary to develop a map format that would allow the transmission of even complex intersections within this byte size. In addition to the precise lane geometry (accurate to 30 cm or better), the GID also contains for each lane the information which traffic signal applies to the lane.

The mapping data for the GIDs were obtained by aerial survey of the intersections and accurate GPS survey of selected points to ortho-rectify the image.

2.7.4.2 GPS Correction

The CICAS-V application requires accurate lane matching in the cases where protected left turn lanes and signals are present so that the vehicle can correctly determine the applicable traffic signal indication. This requires that the GPS positioning in the vehicle is aided by differential corrections. The intersection is generating the differential correction through a GPS base station at the intersection and sends the differential correction to the vehicle via the GPSC message in the RTCM 104 format.

2.7.4.3 Signal Phase and Timing

The CICAS-V system in the intersection generates the Signal Phase and Timing (SPaT) message from information received from the intersection controller. The SPaT message contains all the information for all the signal indications in the intersection (more precisely: all the movements in the intersection). The information in the SPaT message contains at a minimum the current phase for all the movements and, if a movement is in the yellow phase, how much time is left in that phase. In Michigan, the Siemens Eagle controller exported the information about the phases directly. In California, the controller protocol required an added state machine to obtain the correct phase information

2.7.5 Application Development

The CICAS-V project developed prototype applications to test the individual elements that together comprise the CICAS-V application. All the application components were tested successfully and shown to the U.S. DOT during the quarterly briefings. The focus of Task 8 was the definition and testing of the individual modules that would comprise the CICAS-V system. The applications were not integrated into an overall CICAS-V prototype system in Task 8 since this was the objective of Task 10. The application development also led to the development of the specifications for the software development for the CICAS-V FOT prototype system in Task 10. The individual components that were developed are discussed below.

2.7.5.1 Map Matching

The project developed a map matching algorithm that was based on the GID. The positioning augmented by the GPSC message was able to reliably match the vehicle to the correct lane

2.7.5.2 Warning Algorithm

The project developed the basic warning algorithm logic that will be used as a starting point for the FOT warning algorithm development.

2.7.5.3 GPS Correction

The project developed a GPSC methodology based on locally generated differential corrections that are sent to the vehicle via the GPSC message set. The positioning accuracy achieved with this correction was around 50 cm.

2.7.5.4 Message Parsing

The project developed the message generators in the intersection and the message parsing software on the vehicle side.

2.7.5.5 System Specification

The project developed the system specifications for the Task 10 FOT system development. The specifications were reviewed by DENSO and resulted in the overall statement of work and system specifications for the system that DENSO is implementing in Task 10.

2.8 Task 9 – System Development Plan

The main focus of Task 9 is to define the systems engineering process that will govern the CICAS-V design activities and development work conducted during Phase I of the project. A second focus of the task is to provide the systems engineering oversight to ensure that activities adhere to the process and that the system's requirements are met by the design that emerges from the Phase I efforts.

The first activity undertaken in this task was to define the specific design documents needed for the project and the organization of each. To accomplish this, the technical team worked in conjunction with the U.S. DOT and identified an initial set of documents for inclusion into the development process along with the IEEE standard that would define the organization of each document. The set of documents was subsequently refined during additional discussions with the DOT that took place in the second quarter of 2007. The list that resulted for the project is presented below. It includes:

- Concept of Operations (Task 4);
- High-Level Requirements (Task 4);
- System Architecture Description (Task 5);

- System Requirements Specification (Task 5);
- System Performance Specification – Vehicle (Task 6);
- System Design Specification – Infrastructure (Task 6);
- System Test Plan (Task 7); and
- System Test Procedures (Task 7).

In addition, it was also decided that three public workshops would be held during Phase I to review elements of the system design with CICAS-V stakeholders and obtain feedback. The workshops planned include:

- Concept of Operations Workshop (Task 4);
- Preliminary Design Review; and
- Critical Design Review.

The ConOps Technical Workshop was held in November 2006, as previously mentioned in the summary for Task 4. The Preliminary Design Review and the Critical Design Review have not yet been held and are planned for October 2007 and January 2008, respectively.

2.9 Task 10 – Integration of Subsystems, Building of Prototype Vehicles and Outfitting of Intersections

The goal of Task 10 is to upgrade the vehicles and intersections to the final FOT hardware and software. During this task, the vehicles will be shipped to VTTI for installation and testing of the vehicle DAS that has been developed by VTTI. The FOT vehicle build will include the final results from Subtask 3.2 (warning timing) and from Subtask 3.3 (effective DVI) and all the components, including the DVI will be tested for functionality.

The task selected the on-board equipment (OBE) that will be used as the computing platform for the FOT. This process took longer than expected and eventually led to a project extension of three months that was approved by the U.S. DOT. The selected unit was the DENSO WSU on which DENSO, as the contractor for the development of the FOT system, will develop the necessary software. During the reporting period, the kickoff meeting with DENSO took place where the initial specifications were discussed.

The vehicle build was initiated during the first year of the project. The first of the test vehicles were sent to VTTI to be outfitted with the DAS. The DAS system is comprised of in-vehicle cameras to monitor the driver, the interior of the car and the forward direction as well as forward and rearward facing 24 GHz radars to detect vehicles surrounding the CICAS vehicle. The DAS will also record vehicle operating parameters, vehicle position and the messages the vehicle receives from the intersection. More information on the development of the DAS is presented in the Task 12 summary, below.

The project also held regular meetings with Booz Allen Hamilton to discuss the migration of the CICAS-V intersection software to the roadside equipment that is expected from the VII Program later in Phase I of the project.

2.10 Task 12 – FOT Data Acquisition Systems

During the FOT planned for Phase II, it will be necessary to collect data on the functioning and performance of the CICAS-V system. Such data will be used by the VSC2 consortium and the U.S. DOT to estimate the system's safety benefits, examine potential unintended consequences of system use and assess the users' acceptance of the system. This effort will require that data from the traffic signal system, CICAS-V intersection equipment, CICAS-V vehicle equipment, the vehicle and the driver be obtained using data acquisition systems designed specifically for this purpose. The objectives of Task 12 are to plan, build and test both an intersection-based and a vehicle-based DAS for use in the FOT. The output from the task will be prototype DAS systems for the intersection and the vehicle that will subsequently be tested in a Phase I Pilot FOT and deployed later in the Phase II FOT, once the decision to conduct Phase II is made.

Work in Task 12 during the first year of the project focused on development of the vehicle DAS. Development of the intersection DAS will be undertaken during the second year of the project.

Work in developing the vehicle DAS was contained in three activities:

1. Develop the list of vehicle and driver variables that will be recorded;
2. Build an engineering prototype and conduct initial testing; and
3. Install the vehicle DAS into test vehicles and test with the CICAS-V on-board equipment.

The first two of these activities were completed during the year. The third activity in developing the vehicle DAS, installation into test vehicles and testing, will be completed during the second year of the project.

Work on the vehicle DAS began in January 2007 when a working group composed of CICAS-V team representatives from the VSC2 consortium, VTTI, U.S. DOT and the Volpe National Transportation Systems Center (VNTSC) was convened to formulate the list of variables that would be collected by the vehicle DAS. VNTSC is the independent evaluator for the project and will assist in planning CICAS-V field tests and assessing safety benefits of the CICAS-V system during Phase II of the project. Over the course of several meeting held through February 2007, the group completed the list of items that would be collected by the vehicle DAS. The list included such things as:

- Vehicle operating parameters like vehicle speed, acceleration, yaw rate, brake system pressure, etc.;
- Brake, accelerator, and steering wheel use by the driver;
- Status of seat belts, wipers, turn signals, horn, and lights;
- Status of the CICAS-V DVI and driver warning algorithm;

- Intersection information received from the infrastructure, such as GID version number, number of intersection approaches, current phase of traffic signal, and time to next phase;
- Current lane occupied by the vehicle;
- GPS information, including vehicle latitude and longitude, number of GPS satellites;
- Video recordings of the driver's face, instrument panel, and forward and rearward views of the road scene; and
- Leading and following vehicle information obtained through forward and rearward looking radars.

Based on this information list, VTTI next assembled an engineering prototype of the vehicle DAS and conducted testing to verify the system's operation. This work was completed at the end of April 2007.

During the next year of the project, the vehicle DAS will be installed into the test cars of the five automotive partners participating in the project. Further DAS testing will be conducted in the fall of 2007 as software for the CICAS-V on-board equipment becomes available. Final refinements to the DAS will follow the completion of tests with the on-board equipment.

2.11 Task 13 – Prepare for Field Operational Test

The CICAS-V project has been, from its inception, divided into two phases. The goal of Phase I is to develop a CICAS-V prototype system consisting of the intersection and the vehicle portions. In Phase II, the system will be evaluated in an FOT using naïve drivers. Preparing for the FOT in Task 13 entails identifying the number of vehicles, drivers and intersections that need to be deployed for a successful test. A successful Phase II FOT is intended to gain insight into three main questions:

- User Acceptance;
- Unintended Consequences; and
- Safety Benefit Estimation.

The purpose of Task 13 is to identify the FOT design necessary to address these questions. Specifically, Task 13 will focus on developing:

- The size of the FOT needed, including the number intersections and the number of vehicles in the test, and the number of drivers involved.
- The cost of the FOT.
- The location of the FOT. and
- Additional tests that should be run to support the evaluations (e.g., on a test track).

The task is being conducted jointly by VSC2, the VNTSC (the independent evaluator for the project), U.S. DOT and VTTI. During the first year of the project, work centered predominantly in identifying the size of the FOT and involved the following three areas:

1. Defining alternative FOT designs for further consideration
2. Evaluating FOT alternatives and estimating the number of CICAS-V alerts expected in each
3. Formulating the working assumptions that are needed to estimate the cost of the FOT

The work to define the alternative FOT designs was conducted by the VNTSC. Three designs were proposed that spanned the size spectrum in terms of the number of intersections, number of drivers and vehicles, and length of data collection involved. See Table 3. For each FOT alternative, the experimental design process estimated the number of drivers needed to study the effect of the CICAS-V system on a key performance measure (e.g., number of violations for the large FOT) based on initial assumptions about system effectiveness and driver exposure to events during the FOT. For example, the large FOT design was based on the ability to detect a 50 percent change in violations between baseline (without CICAS-V assistance) and treatment (with CICAS-V assistance) with a 95 percent confidence level and 80 percent statistical power. The sample size was then used to estimate the number of test vehicles and test duration per subject using the stated number of signalized intersections and an overall test duration of 52 weeks. Designs of varying sizes were deemed necessary to provide testing options with regard to funding requirements.

Table 3. FOT Designs Investigated

FOT	No. of Subjects	Individual Subject Data Collection	No. of Signalized Intersections	No. of Cars	Overall Duration of Data Collection
Small	90	5 wks	20	10	52 wks
Medium	108	12 wks	20	27	52 wks
Large	204	12 wks	24	51	52 wks

Next, VSC2 estimated how many alerts (i.e., CICAS-V system warnings issued to the driver) could be expected from the individual designs, and what additional efforts would be needed to arrive at meaningful conclusions about the three main questions. Estimating the number of alerts is important when assessing user acceptance with a completely new warning system, as the drivers participating in the FOT would need to experience a number of bona fide alerts (warnings) in order to meaningfully provide feedback on the operation and performance of the system. Without experiencing such alerts, drivers would have little basis on which to provide feedback to the research team.

In this project, estimating the number of alerts was based on the assumption that a CICAS-V system would issue alerts when a driver commits a violation or a near violation of a traffic control device. Estimation of violation rates can be found in the literature and the rates published differ substantially. The report, *Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras* (Yang and Najm, 2006), for example, arrives at violation rates between 6 and 29 violations per 100,000 intersection crossings. This report also lists the rates that earlier studies determined. Given the wide range of violation rates, it was decided to analyze the number of expected violations in the form of a minimum / maximum description of the expected alerts.

The minimum number of violations was chosen to be 5 per 100,000 crossings; the maximum number was chosen to be 50 per 100,000 crossings. Since the number of expected alerts is the number of expected violations plus the number of expected near violations, estimating the latter is important. The ratio of near violations to violations was determined from the analysis of the VTTI 100-Car Study in Subtask 3.1. In Subtask 3.1 it was found that the ratio is approximately 10:1 for near violations to violations.

The VSC2 then analyzed the three designs and concluded that the number of expected alerts for the small FOT was considered too small to determine an answer to the FOT questions.

The analysis also showed that if the number of alerts generated is near the high end of the estimates, most drivers, if not all, in the medium and large FOT alternatives will experience at least one alert. See Table 4. If the number of alerts is at the low end of estimated alerts, the medium FOT would not generate enough data since only about half of the drivers would experience an alert, assuming alerts are evenly distributed across drivers. This would probably require extensive modeling to determine the safety benefit, and there would not be enough data to answer the questions about user acceptance. For those reasons, it was determined that the large FOT was the best choice for giving the answers to the FOT questions with the smallest risk of generating insufficient data for the analysis.

Table 4. Expected Alert Rates for the Medium and Large FOT

FOT Size	Intersection Crossings	Violations High Estimate	Violations Low Estimate	Near Violations High Estimate	Near Violations Low Estimate	Total Alerts High Estimate	Total Alerts Low Estimate
Medium	129,600	65	6	684	65	713	71
Large	293,760	147	15	1,469	147	1,616	162

In addition to determining the size of the FOT, future efforts in Task 13 will also determine the FOT methodology, the FOT location, and the FOT cost. This work is planned for the second year of Phase I. However, to facilitate this work, the following assumptions and constraints affecting the FOT were identified during the Task 13 working group meetings:

1. The timeframe for the entire FOT will not exceed 24 months.
2. The FOT will include an extended pilot test, with CICAS-V enabled throughout the period of the test.
3. The FOT will use a naturalistic data collection methodology in which data is collected while participants drive normally.
4. The intersection equipment will include the VII roadside equipment. A backend network will not be used.
5. No intersection DAS will be used in the FOT.
6. Up to 24 signalized intersections and a to-be-defined number of stop-sign-controlled intersections will be used in the FOT.
7. The FOT location requires the active support from a local DOT agency.
8. Cost estimates for the medium or large FOT will assume use of a limited number of vehicle types, where the vehicle class is mid-size or smaller.

2.12 Task 14 – Human Use Approval

The CICAS-V project must comply with Federal regulations contained in 49 CFR Part 11 regarding any testing work that involves the use of human subjects. The Federal regulations are intended to protect the rights and safety of individuals from the public at large who participate in testing for research purposes. To comply with the Federal regulations, a proposed test plan must be submitted to an established institutional review board (IRB) for examination and approval prior to conducting any test with human subjects. In Phase I of the project, such tests are underway in Task 3 – Human Factors Research – to define the driver-vehicle interface, warning algorithm and evaluate the CICAS-V system performance.

Task 14 is the project task in which the activities needed to support the IRB review process take place. This task was initiated at the start of the project and will run throughout Phase I as studies are conducted in which an IRB review is required. The project uses the established IRB at Virginia Tech, a partner in the CICAS-V project, to perform the reviews. Through the first year of the project, the following studies were submitted to and approved by the Virginia Tech IRB:

- Subtask 3.1 – Mine the VTTI 100-Car Database;
- Subtask 3.2 – Collect Naturalistic (No Alert) Infrastructure-based Driving Data;
- Subtask 3.3 – Test Alternative DVIs on Smart Road, including:
  - Study 1 – Evaluate Warning Tone DVI with Occlusion Testing Method;
  - Study 2 – Evaluate Warning Tone DVI with Naturalistic Testing Method;
  - Study 3 – Evaluate Speech Warning DVI with Naturalistic Testing Method; and
  - Study 4 – Conduct Baseline Driving without CICAS-V Warning.

During the second year of the project, several additional studies will be submitted to the IRB for review and approval. These include:

- Subtask 3.3 – Test Alternative DVIs on Smart Road;
  - Study 5 – Evaluate Warning Tone DVI with a Brake Pulse Feature;
  - Study 6 – Evaluate Speech Warning DVI with a Brake Pulse Feature;
  - Study 7 – Evaluate Warning Tone DVI with Brake Pulse and Panic Brake Assist Feature;
  - Study 8 – Evaluate Speech Warning DVI with a Brake Pulse and Panic Brake Assist Feature; and
- Subtask 3.4 – Conduct Pilot Field Operation Test.

3 References

Campbell, B., Smith, J., & Najm, W. (2004). *Analysis of Fatal Crashes Due to Signal and Stop Sign Violations*. Report No. DOT HS 809 779. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www-nrd.nhtsa.dot.gov/departments/nrd-12/809-779/pages/TOC.htm

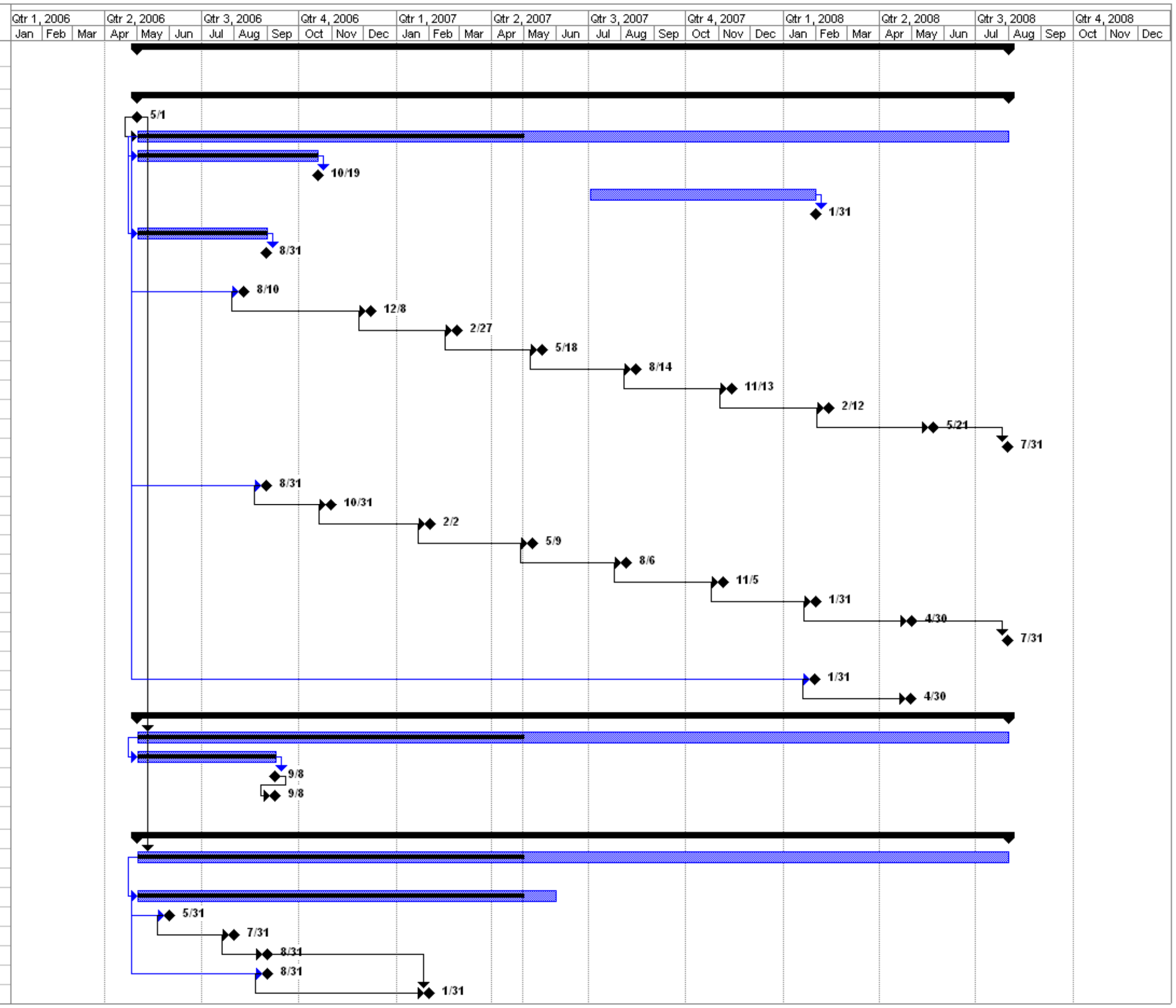
Dingus, T.A., et al. (April 2006). *The 100-car naturalistic driving study, Phase II – Results of the 100-car field experiment.* Report No. DOT HS 810 593. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/14302_files/PDFs/14302.pdf

NHTSA. (2005). Traffic Safety Facts 2005. Report No. DOT HS 810 631. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2005.pdf

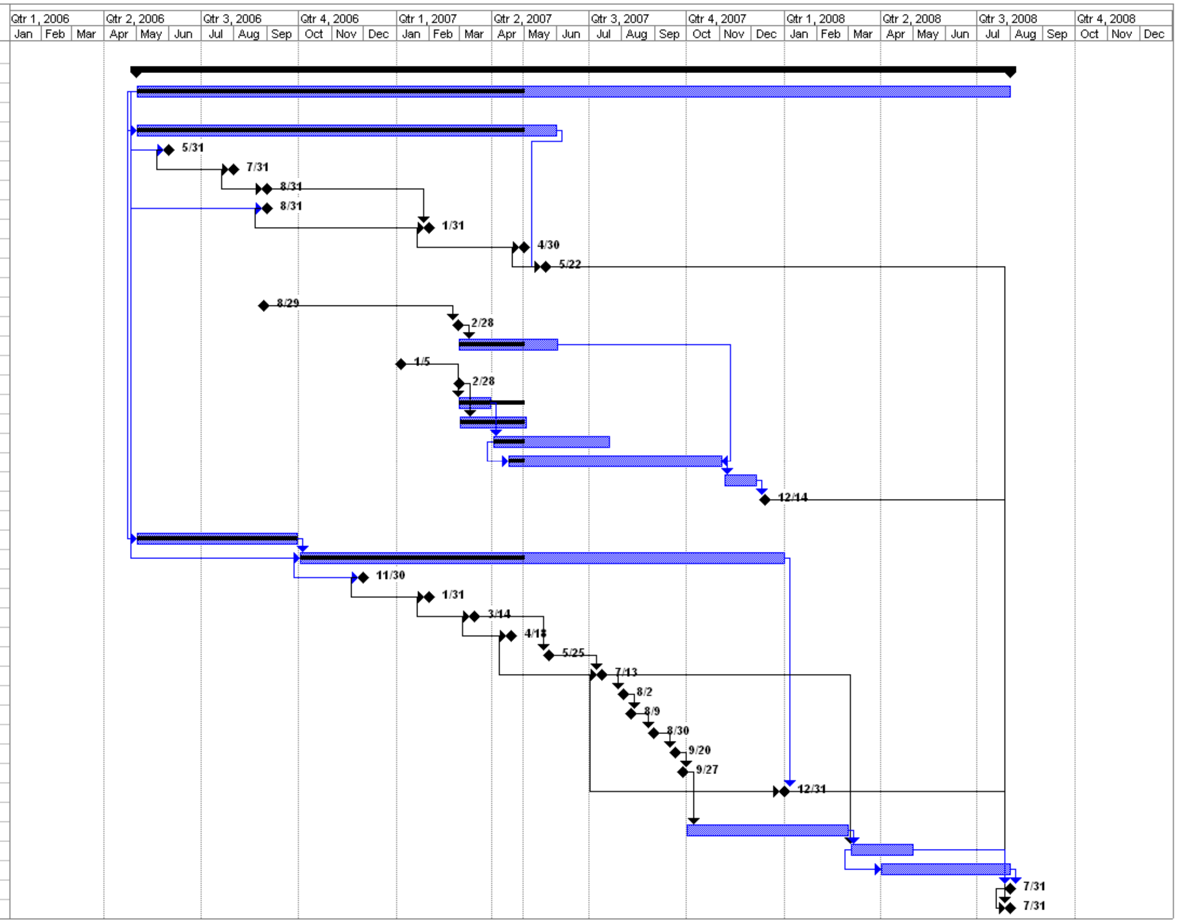
Yang, C. Y. D., & Najm, W. G. (2006). *Analysis of Red Light Violation Data Collected from Intersections Equipped with Red Light Photo Enforcement Cameras*. DOT HS 810 580. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www-nrd.nhtsa.dot.gov/departments/nrd-12/810580/2937RedLight Violations/images/810580.pdf

4 Project Schedule

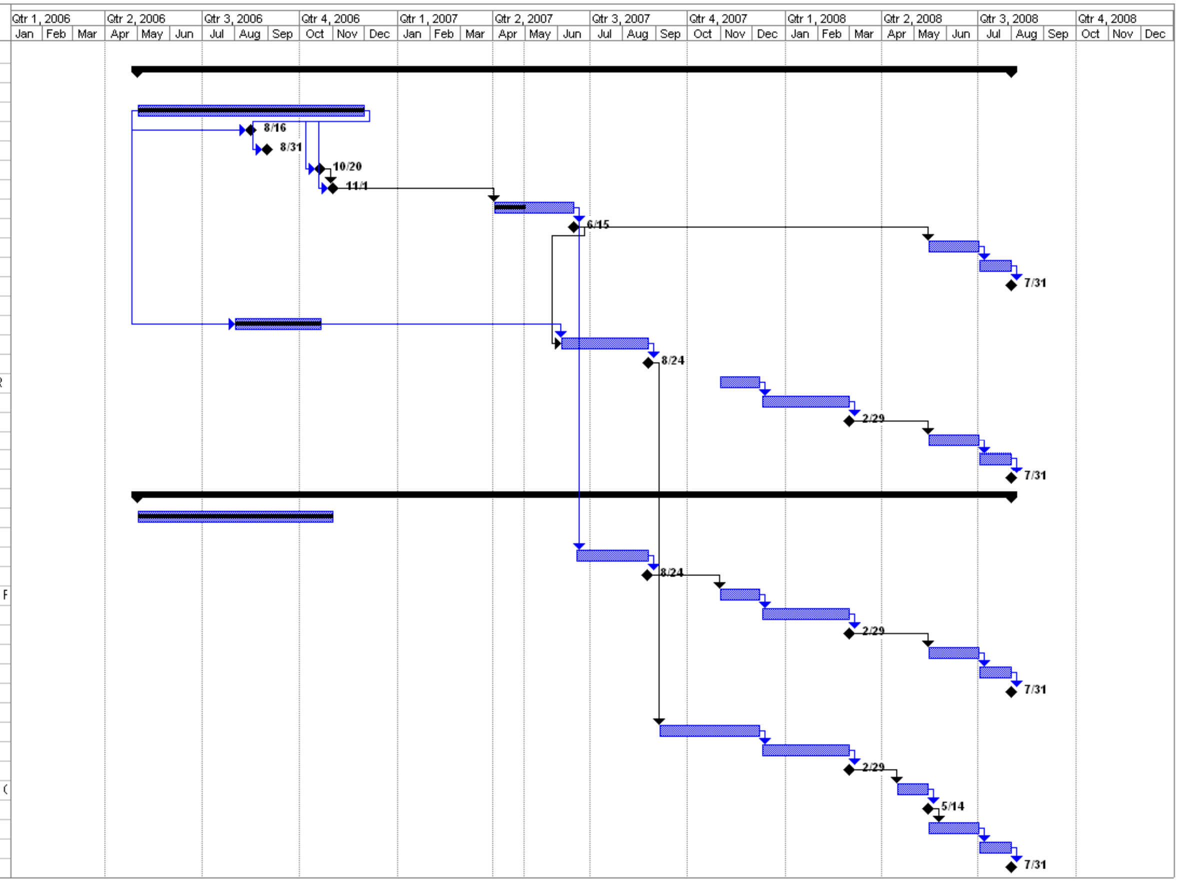
ID	Task Name
1	**Phase I**
2	**Base Tasks**
3	**Task 1 - Project Management & Risk Management**
4	Project Starts
5	Program Oversight
6	Prepare Program Management Plan
7	Draft Program Management Plan
8	Develop Revised Program Plan
9	Revised Project Plan Deliverable
10	Prepare Risk Management Plan
11	Risk Management Plan Deliverable
12	Quarterly Progress Briefings
13	Quarterly Progress Briefing 1
14	Quarterly Progress Briefing 2
15	Quarterly Progress Briefing 3
16	Quarterly Progress Briefing 4
17	Quarterly Progress Briefing 5
18	Quarterly Progress Briefing 6
19	Quarterly Progress Briefing 7
20	Quarterly Progress Briefing 8
21	Final Briefing
22	Quarterly Status & Financial Reports
23	Quarterly Status & Financial Report 1
24	Quarterly Status & Financial Report 2
25	Quarterly Status & Financial Report 3
26	Quarterly Status & Financial Report 4
27	Quarterly Status & Financial Report 5
28	Quarterly Status & Financial Report 6
29	Quarterly Status & Financial Report 7
30	Quarterly Status & Financial Report 8
31	Quarterly Status & Financial Report 9
32	Annual Reports
33	1st Annual Report
34	2nd Annual Report
35	**Task 2 - Coordinate w/ Standards Development**
36	Standards Coordination
37	Prepare Standards Support Plan
38	Standards Support Plan Deliverable
39	Report on the State of the DSRC Standards
40	**Human Factors Research**
41	**Task 3 - Human Factors Research**
42	Human Factors Oversight
43	**Subtask 3.1 - Mine 100-Car Database**
44	Mine 100-Car Database
45	Taxonomy of Driver Behaviors Completed
46	Data Filtering Software Completed
47	Filtered Sample of Intersections Ready
48	Data Reduction Software Completed
49	Data Reduction Completed



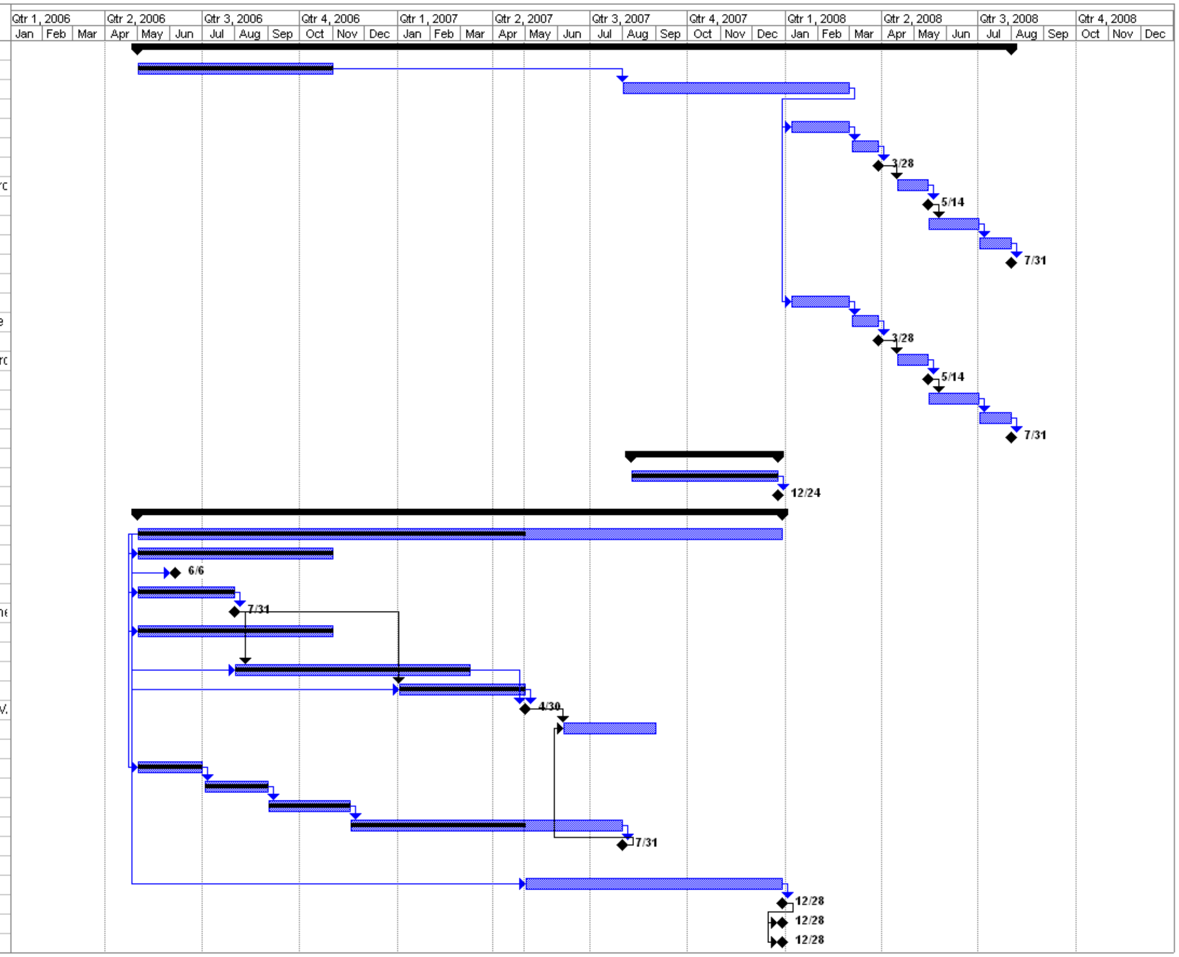
ID	Task Name
40	**Human Factors Research**
41	**Task 3 - Human Factors Research**
42	Human Factors Oversight
43	**Subtask 3.1 - Mine 100-Car Database**
44	Mine 100-Car Database
45	Taxonomy of Driver Behaviors Completed
46	Data Filtering Software Completed
47	Filtered Sample of Intersections Ready
48	Data Reduction Software Completed
49	Data Reduction Completed
50	Data Analysis Completed
51	Subtask 3.1 Report Deliverable
52	**Subtask 3.2 - Collect Naturalistic Driving Data**
53	Stop sign intersections selected
54	Finished data collection at stop sign intersection
55	Analysis of stop controlled data
56	Signalized intersections selected
57	Acquire Radar for First Signallized Intersection
58	First signallized intersection radar installation
59	second and third signallized intersection radar installation
60	signalized intersection data collection
61	Intersection data analysis and report writing
62	TMT & CMC Report Review
63	Subtask 3.2 Report Deliverable
64	**Subtask 3.3 - Evaluate DVIs on Test Track**
65	Symbol Comprehension Testing
66	Conduct Test Track Studies
67	Data Collected and Analyzed for Study 1
68	Data Collected and Analyzed for Study 2
69	Data Collected and Analyzed for Study 3
70	Data Collected and Analyzed for Baseline
71	Decision DVI together with Brake Pulse
72	Data Collected and Analyzed for DVI 1 with Brake Pulse
73	Data Collected and Analyzed for DVI 2 with Brake Pulse
74	Decision DVI for Panic brake assist
75	Data collected and analyzed for DVI1 with PBA w/ shorter timing
76	Data collected and analyzed for DVI2 with PBA w/ shorter timing
77	Decide preferred DVI for Pilot FOT
78	Subtask 3.3 Report Deliverable
79	**Subtask 3.4 - Pilot FOT**
80	Planning and Logistics
81	Pilot FOT Data Collection
82	Data Analysis and Report Writing
83	Task 3 Final Report Deliverable
84	Reduced Experimental Data Deliverable



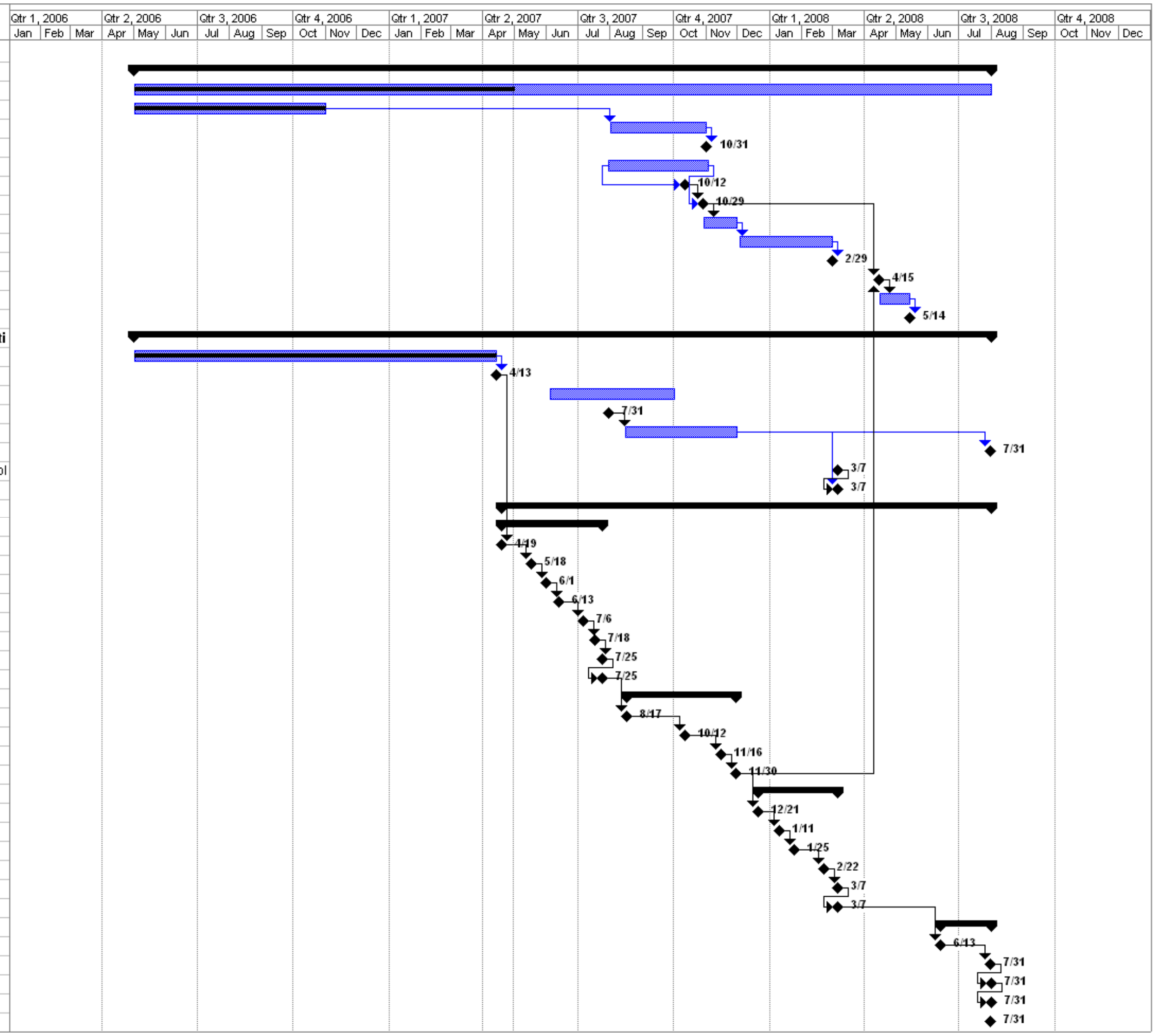
ID	Task Name
85	**System Design**
86	**Task 4 - Concept of Operations & Systems Requirements**
87	**Concept of Operations**
88	Develop Initial ConOps & System Reqmts
89	USDOT/VSC2 Consensus on Prelim. ConOps Milestone
90	Proposed Approach for Refining ConOps Document Deliverable
91	Preliminary Concept of Operations Document Deliverable
92	Concept of Operations Technical Workshop Deliverable
93	Prepare Interim ConOps Document
94	Submit Interim ConOps Deliverable
95	Prepare Final Phase I ConOps Document
96	TMT & CMC Review Final Phase I ConOps Document
97	Submit Final Phase I ConOps Deliverable
98	**High-Level Requirements**
99	Prepare initial System Requirements Document
100	Prepare Preliminary High-Level Requirements Specification
101	Preliminary High-Level Requirements Specification Deliverable
102	Revised High-Level Requirements to Incorporate Comments from PDR
103	TMT & CMC Review Interim High-Level Requirements Document
104	Interim High-Level Requirements Document Deliverable
105	Prepare Final Phase I High-Level Requirements Document
106	TMT & CMC Review Final Phase I High-Level Requirements Document
107	Submit Final Phase I High-Level Requirements Deliverable
108	**Task 5 - System Architecture & System Design**
109	Develop the System Architecture and Design
110	**System Architecture Description**
111	Prepare Preliminary System Architecture Description
112	Preliminary System Architecture Description Deliverable
113	Revise System Architecture Description to Incorporate Comments from F
114	TMT & CMC Review Interim System Architecture Description
115	Interim System Architecture Description Deliverable
116	Prepare Final Phase I System Architecture Description
117	TMT & CMC Review of Final System Architecture Descrition
118	Final Phase I System Architecture Description Deliverable
119	**System Requirements Specification**
120	Prepare Preliminary Systems Requirements Specification
121	TMT & CMC Review Preliminary System Requirements Specification
122	Preliminary Systems Requirements Specification Deliverable
123	Revise System Requirements Specification to Include Comments from (
124	Interim System Requirements Specification Deliverable
125	Prepare Final Phase I System Requirements Specification
126	TMT & CMC Review Final System Requirements Specification
127	Final Phase I System Requimrents Specification Deliverable



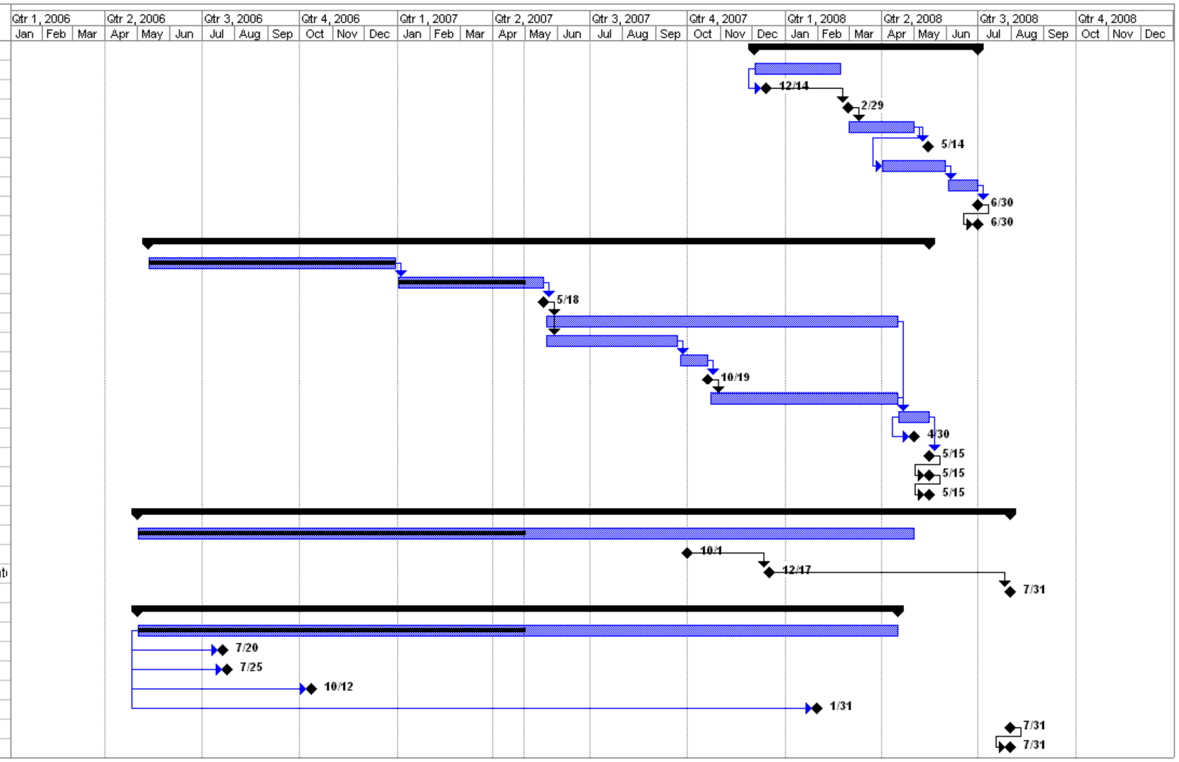
ID	Task Name
128	**Task 6 - Development of Performance Specifications**
129	Develop Preliminary Performance Specifications
130	TMT Develops System Peformance Requirements
131	**System Performance Specification - Vehicle**
132	Prepare Preliminary System Performance Specifications - Vehicle
133	TMT & CMC Review of Preliminary Peformance Specifications - Vehicle
134	Preliminary Performance Specifications - Vehicle Deliverable
135	Revise Performance Specifications - Vehicle to Incorporate Comment frc
136	Interim Performance Specifications - Vehicle Deliverable
137	Prepare Final Phase I Performance Specifications - Vehicle
138	TMT & CMC Reviews Final Performance Specifications - Vehicle
139	Final Phase I Performance Specifications - Vehicle Deliverable
140	**System Design Specification - Infrastructure**
141	Prepare Preliminary System Design Specifications - Infrastructure
142	TMT & CMC Review of Preliminary Design Specifications - Infrastructure
143	Preliminary System Design Specifications - Infrastructure Deliverable
144	Revise Design Specifications - Infrastructure to Incorporate Comment frc
145	Interim Design Specifications - Infrastructure Deliverable
146	Prepare Final Phase I Design Specifications - Infrastructure
147	TMT & CMC Review Final Design Specifications - Infrastructure
148	Final Phase I Design Specifications - Infrastructure Deliverable
149	**Task 7 - Development of Test Plans & Objective Test Procedures**
150	Develop Test Plans & Test Procedures
151	Task 7 Report: System Test Plan
152	**Task 8 - Prototype Build & Testing**
153	Prototype Build and Testing Oversight
154	Subtask 8.1 - Select Vehicles & Procure
155	Joint USDOT/VSC2 Decision on Criteria for Vehicle Selection
156	Subtask 8.2 - Select Intersections
157	Joint USDOT/VSC2 Decision on Intersections Used in Functional Developme
158	Subtask 8.3 - Develop Signal Sniffer Load Switch
159	Subtask 8.4 - Install RSE and Antenna at Intersections
160	Wave Radio Based RSU Development and Installation
161	VII Developed RSU System and Antenna Installation
162	Intersections Ready for Engineering Tests (N=10; 3 in MI, 3 in CA, 4 in V.
163	Subtask 8.5 - Intersection Infrastructure Functional Test
164	Subtask 8.6 - Intersection Map Development and Verification
165	Develop Map Specifications
166	Develop Message Format for Map Broadcast
167	Test and Verify Map Format
168	Conduct Phase I Intersection Mapping & Verification
169	Intersections for Engineering Tests Mapped
170	Subtask 8.7 - Application Development
171	Subtask 8.8 - System Refinement
172	Task 8 Report: Prototype Build & Testing Deliverable
173	One Engineering Prototype Vehicle per OEM & 10 Intersections Developed
174	USDOT Reviews Task 8 Report



ID	Task Name
175	**Build & Validate Prototype FOT System**
176	**Task 9 - Systems Development Plan**
177	Conduct Systems Engineering Oversight
178	Prepare System Development Plan
179	Complete system development plan
180	System Development Plan Document Deliverable
181	Prepare for Stakeholder PDR
182	Send PDR Materials to Stakeholders
183	Conduct Stakeholder PDR
184	Prepare Stakeholder PDR Report
185	TMT & CMC Review of PDR Report
186	Submit Stakeholder PDR Report Deliverable
187	Stakeholder CDR
188	Prepare Stakeholder CDR Report
189	Stakeholder CDR Report Deliverable
190	**Task 10 - Integration of Subsystems, Prototype Vehicle Build & Outfitti**
191	OBE selection and development
192	Selection of Denso as OBE and FOT software supplier
193	Actual Vehicle build
194	VII RSEs available
195	Intersection HW upgrade and DAS integration
196	Task 10 Subsystem Integration Report Deliverable
197	One Vehicle per OEM w/ Prototype CICAS-V Pilot FOT Systems & DAS Compl
198	Ten CICAS-V FOT Prototype Intersections (4 in VA w/ DAS) Completed
199	**Denso Development Schedule**
200	**WP1: Software Specification and Design**
201	Kickoff meeting
202	Camp provides inputs to Denso
203	Software specification draft
204	Specification review meeting
205	Software design document draft
206	Software design review
207	Software specification (final)
208	Software design document (final)
209	**WP2: Baseline Implementation and release**
210	Alpha executable (as is)
211	Alpha executable
212	Baseline executable
213	Baseline source code
214	**WP3: Pilot FOT implementation and Release**
215	CAMP provides refined specification
216	Acceptance Test Plan (draft)
217	Updated software specification and design document
218	Pilot FOT executable
219	Pilot FOT source code
220	Acceptance Test Plan and test results documentation
221	**WP4: Phase I implementation and Release**
222	CAMP provides feedback on software revision
223	Phase I executable
224	Phase I source code
225	Updated software specification and design document
226	**WP5: Integration of CICAS-V on VII OBE**



ID	Task Name
227	**Task 11 - Vehicle & Intersection Objective Testing**
228	Objective Test Preparation
229	Preliminary System Test Procedures
230	Final Phase I System Test Procedures
231	Conduct Objective Tests - Intersection and Vehicle
232	Send Data Det to Volpe
233	Objective Test Data Analysis & System Test Report Preparation
234	TMT & CMC Review System Test Report (Task 11 Final Report)
235	System Test Report Deliverable (Task 11 Final Report)
236	Copies of Test Data Deliverable
237	**Task 12 - FOT Data Acquisition System**
238	Coordinate DAS Requirements with VTTI
239	Develop Prototype Vehicle DAS
240	Vehicle DAS Available
241	Test & Evaluate Vehicle DAS
242	Develop Prototype Intersection DAS
243	Refine Intersection DAS
244	Intersection DAS Available
245	Test & Evaluate Intersection DAS
246	Final Refinements for Vehicle and Intersection DAS
247	Task 12 Report Deliverable
248	DAS Design Documentation Milestone
249	Software for All DASs Milestone
250	Vehicle & Infrastructure DAS Hardware Milestone
251	**Task 13 - Prepare for Field Operational Test**
252	Develop Plans for the Field Operational Test
253	Alternatives for "recrafted" FOT
254	Evaluation of alternatives with coparative ranking and refined budget estimat
255	Report on selected test strategy and preliminary test plan
256	**Task 14 - Human Use Approval**
257	Conduct IRB Reviews and Obtain Approvals
258	IRB Approval for Subtask 3.1 Received
259	IRB Approval for Subtask 3.2 Received
260	IRB Approval for Subtask 3.3 Received
261	IRB Approval for Subtask 3.4 Received
262	Phase I Ends
263	Joint USDOT/VSC2 Decision to Proceed w/ Phase II



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