Multi-Modal Intelligent Traffic Signal System

System Development, Deployment and Field Test Phase II Scope of Work

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RECORD OF CHANGES

A – Added, M- Modified, D - Deleted

Version Number	Date	Identification of Figure, Table, or Paragraph	Title or Brief Description	Change Request Number
1.0	4/3/2013	N/A	Initial Draft submitted for review and feedback.	
2.0	4/29/2013		Response to review comments and change in scope.	
3.0	5/15/2013		Response to review comments with final scope, schedule and budget.	
4.0	5/22/2013	Section 5	Added final budget information	
5.0	7/1/2013		Revised Start Date and Budget Numbers	
5.1	10/29/2013		Reviewed Scope of Work for Project Kick-Off	

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1 Scope of Project

The Multi-Modal Intelligent Traffic Signal System (MMITSS) project is part of the Cooperative Transportation Systems Pooled Fund Study (CTS PFS) entitled "Program to Support the Development and Deployment of Cooperative Transportation Systems Applications." The CTS PFS was developed by a group of state and local transportation agencies and the Federal Highway Administration (FHWA). The Virginia Department of Transportation (VDOT) serves as the lead agency and is assisted by the University of Virginia's Center for Transportation Studies, which serves as the technical and administrative lead for the PFS. More details of the CTS PFS can be found at http://cts.virginia.edu/CTSPFS_1.html.

The United States Department of Transportation (US DOT) has identified ten high-priority mobility applications under the Dynamic Mobility Applications (DMA) program for the connected vehicle environment where high-fidelity data from vehicles, infrastructure, pedestrians, etc. can be shared through wireless communications. Three of the applications (Intelligent Traffic Signal System, Transit Signal Priority, and Mobile Accessible Pedestrian Signal System) are related to transformative traffic signal operations. Since a major focus of the CTS PFS members – who are the actual owners and operators of transportation infrastructure – lies in traffic signal related applications, the CTS PFS team is leading the project entitled "Multi-Modal Intelligent Traffic Signal System" in cooperation with US DOT's Dynamic Mobility Applications Program.

Phase I of the MMITSS project was conducted by the University of Arizona in partnership with the University of California Berkeley – PATH, Savari, Econolite, and SCSC. Phase I consisted of four stages. The first stage included the development of the Concept of Operations (ConOps), including the solicitation of Stakeholder inputs and feedback. The reviewed Stakeholder inputs and ConOps were used to develop, define, and populate the MMITSS system requirements in the second stage. In the third stage, the system requirements and prior research were used to define the high level MMITSS system design. The design effort has been based on the California Test Bed and the Maricopa County Test Bed as the target implementation networks. Development, implementation, integration, deployment, and test plans based on this design have been defined in the final stage, and this stage constitutes the development of the scope, budget and schedule for the Phase II effort. Deliverables from the Phase I project can be obtained at http://cts.virginia.edu/CTSPFS_2.html.

The Phase II scope continues the MMITSS development into a system and software development effort that will result in an actual real-time field implementation for testing and verification of the requirements and estimation of the performance. The CTS PFS decided to task the University of Arizona team with the Phase II effort.

2 Purpose of Document

The purpose of the Multi Modal Intelligent Traffic Signal System (MMITSS) is to integrate information from connected vehicles, nomadic devices, and existing information from infrastructure based detection systems into more effective and safer traffic signal control system for multiple modes of travelers (e.g., non-commercial vehicles, pedestrians, transit, freight, and emergency vehicles). This integrated information can be used to make improvements in traffic control algorithms and logic resulting in better performing and safer operating systems. In addition to enhancing traffic control algorithms and logic, information from connected vehicles (CV) can be used to directly measure system performance and for the assessment of safety.

The purpose of this document is to establish a structured plan for development, deployment and field-testing of a select subset of MMITSS functionality. The plan is a continuation of the Phase I findings including the ConOps, Requirements, and Design.

3 Selected Use Cases for System Development

The Concept of Operations and Systems Requirements Documents, prepared in Phase I, developed and identified use cases, functional, and performance requirements that characterize the desired behaviors of MMITSS. Table 3-1 summarizes the use cases that were considered in the development of the Concept of Operations. These use cases have been reviewed to determine which should be included in the Phase II development and demonstration scope.

Table 3-1. Summary of Down Selected Use Cases for Implementation

	Operational Scenarios/Use Cases	**Include**	**Defer**	**AZ**	**CA**
11.0	MMITSS Operational Scenario				
11.0.1	Network Section 1	X		X	
11.0.2	Network Section 2	X			X
11.1	Intelligent Traffic Signal System Scenarios				
11.1.1	Basic Signal Actuation	X		X	X
11.1.2	Coordinated Section of Signals	X		X	X
11.1.3	Congestion Control		X		
11.1.4	Dilemma Zone Protection	X		X	X
11.2	Transit Signal Priority Operational Scenarios				
11.2.1	Basic TSP Scenario and Variations	X		X	X
	Nearside Bus Stop		X		
	Transit Signal Priority for Left Turn with Protected Signal		X		
11.2.2	Operational Scenarios for Rail Crossings in Urban Areas		X		
11.2.3	Extended TSP Scenario	X		X	X
11.3	Pedestrian Mobility Operational Scenarios				
11.3.1	Unequipped Non-Motorized Traveler	-			
11.3.2	Equipped Non-Motorized Traveler	X		X	X
11.3.3	Equipped Bicyclist		X		
11.3.4	Inclement Weather Accommodations for Non-Motorized		X		

	Travelers				
11.4	Freight Signal Priority Operational Scenarios				
11.4.1	Basic Freight Signal Priority	X		X	X
11.4.2	Coordinated Freight Signal Priority along a Truck Arterial	X		X	X
11.5	Emergency Vehicle Priority				
11.5.1	Single Intersection Priority/Preemptions	X		X	
11.5.2	Route Based Intersection Priority/Preemption		X		

The review of the use cases considered several factors in selecting a fundamental set for inclusion in the Phase II effort. The factors included: 1) importance to the demonstration of the MMITSS concept, 2) feasibility to validate the requirements associated with each use case, 3) technical feasibility to develop system components to achieve the desired behaviors given the resources available, and 4) the strengths of the Arizona and California Testbeds in terms of transit, pedestrians, freight, and emergency vehicles.

Use Cases 11.0.1 and 11.0.2 represent the highest-level goal of MMITSS. That is to establish a multi-modal operating policy that provides service to all modes of travel, but provides priority to one or more modes. For example, Use Case 11.0.1 represents a corridor where freight is favored over transit and pedestrians. Use Case 11.0.2 represents a corridor where transit and pedestrians are favored over freight. Emergency vehicles receive priority over all modes in both Use Cases. Arizona was selected for Use Case 11.0.1 since there is no transit service provided in the network (but transit service can be demonstrated using simulated buses). The California testbed was selected for Use Case 11.0.2 since there is transit service (but freight could be simulated if needed).

Use Cases 11.1.1 (Basic Signal Actuation), 11.1.2 (Coordination of Signals) and 11.1.4 (Dilemma Zone Protection) were selected since they represent the core traffic signal operation Use Cases. 11.1.2 (Coordination of Signals) represents the goal of having MMITSS provide some form of optimizing signal control. 11.1.1 and 11.1.4 represent the key benefit of being able to track the trajectory of equipped vehicles as they approach an intersection.

Note that the Congestion Control, Use Case (11.1.3) includes the use of queue length estimation to terminate a phase that is feeding an oversaturated movement. Other Congestion Control strategies include reverting to free operation at a congested intersection, and adjustment of the cycle length, splits and/or phase sequence to coordinate upstream signals to control flow into the congested intersection/movement. This Use Case was not selected based on the need for a sufficient network penetration rate of equipped vehicles (e.g. passenger vehicles) in the network to allow accurate traffic state estimation. This penetration rate is not feasible to achieve within the scope and budget available for Phase II of this project.

The Use Cases associated with priority control (11.2, 11.4, and 11.5), including transit, freight, and emergency vehicles, were selected since they represent core MMITSS functionality. All of these Use Cases utilize the same underlying behavior (e.g. a vehicle sends a request for priority and the infrastructure determines how priority can be accommodated). Only the basic Transit Priority (TSP) and extended TSP Use Cases (11.2.1 and 11.2.3) were included. Special behaviors for near side bus stops, protected left turn priority, and railroad crossings were excluded. Route based priority, or coordinated corridor priority, for each transit and freight was included despite some concerns about having route information available. It was assumed that the route information was available for transit routes and assumed known for freight corridor coordination, and not available for emergency vehicles.

Pedestrian Mobility (Use Case 11.3) was included due to the importance to MMITSS, the feasibility to validate the requirements, and the technical feasibility of implementation. Pedestrian Mobility is a significant opportunity for MMITSS to demonstrate the modal interactions. The underlying mechanism of Pedestrian Mobility is similar to Transit, Freight, and Emergency Vehicles priority, except it requires and utilizes non-DSRC nomadic devices. This is an important capability of MMITSS that may have wider implications for large scale deployment in the future.

4 Work Plan, Technical Approach, and Schedule

4.1 Task 1 - Project and Systems Engineering Management

The PFP/MMITSS Project Management Plan (PMP) defines how this project will be managed. The University of Arizona is responsible for contract management, monitoring, and control of the project. The project management team will include Principal Investigator Larry Head and co-Principal investigator Steven Shladover, assisted by Ann Wilkey (UA) and Kun Zhou (PATH Project Manager). The project management team will be responsible for progress monitoring and control of the project. The Project and Systems Engineering Management is comprised of the following subtasks:

- Conduct a project kick-off meeting within two weeks of the project start date, October 15, 2013. This meeting will be conducted as a webinar (using Webex). The purpose of the meeting will be to review the project plan including a draft PMP, a draft schedule, and the work plan and to identify any issues or concerns of the sponsor, panel, and project team.
- Prepare a Project Management Plan (PMP for guidance on Scope Management, Cost Management, Quality Management, Human Resources Management, Communications Management, and Risk Management.
- Submit a detailed project schedule that lists tasks, meetings, deliverables, and major milestones. The project schedule will be submitted electronically in Microsoft Project Plan (*.mpp) format.
- The MMITSS principal investigator (PI, Dr. Larry Head) and co-Principal Investigator Dr. Steven Shladover and the system engineer and PATH site project manager will participate in quarterly conference calls. During the quarterly conference calls, the PI and co-PI will provide a project summary including project progress, schedule, scope issues, budget, and CDRL status listing. Meeting minutes, including action items, will be submitted in PDF format within one week of the teleconference.
- Monthly progress conference calls will be held during the Field implementation and Testing (Tasks 6 and 7) and the System Test and Evaluation (Tasks 8 and 9). These

conference calls will focus on issues, challenges, and successes during the field efforts. Meeting minutes, including action items will be submitted in PDF format within one week of the teleconference.

- A monthly progress report will be compiled and submitted electronically to the Sponsors by the 15th of the month following the monthly reporting period. In cases where the 15th of the month falls on a weekend, the report will submitted the following Monday. The monthly progress report will consist of an executive summary, monthly budget information grouped by major task item, a current listing of scheduled milestones and deliverables, a listing of accomplishments for the current reporting period, and a listing of planned accomplishments for the next reporting period.
- Solicit state-level Stakeholder input (PFS members and associates) on standards and policies affecting future implementations and deployments of MMITSS. The USDOT representative suggested this subtask to extend, enhance, and share this common area among connected vehicle and DMA projects[1]. A representative from FHWA or AASHTO (e.g., Jim Wright) should be included in the subtask activities. The participation will consist of a webinar with electronic-based Stakeholder workbooks used for soliciting written feedback and comments from participants. In the event that a Stakeholder is unavailable to attend the webinar, the workbook can be reviewed, completed, and tallied in the feedback responses. This subtask will result in a comprehensive report including workbook, webinar meeting minutes, compilation of participant feedback, and a summary of recommendations, conclusions, and follow-on steps.
- Develop a plan, process, and overview documentation for sharing MMITSS-developed simulation files with the with the US DOT selected Impact Assessment (IA) contractor via an existing website developed by SAIC and managed by Noblis. This subtask will result in a written plan and process flow diagram for determining when and how MMITSS-developed simulation files will be uploaded to the existing website. In addition, each uploaded file will be accompanied by a brief description of the simulation file, intended use, expected outcomes, and HW/SW requirements for reusing the file.
- Coordinate a meeting with a Sponsor-defined third party to review and assess the benefits of MMITSS and ISIG-related activities and field-testing. As described by the USDOT representative on 2/27/13, this is not a third-party evaluation. In contrast, this is a scheduled interaction between a third-party representative of the Owners/Operators to review and pursue the findings of the testbed deployments, and field test results in a dynamic or interactive forum in contrast to the static activity of reading a final report. Meeting minutes will be compiled and submitted for this subtask.

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[1] Extension of material included in MMITSS System Requirements Document Sections 6.6.2 (Standards Compliance and Compatibility Requirements), 6.6.3 (Security Requirements), 6.6.4 (Privacy Requirements), 6.6.5 (Data Archiving Requirements), 6.6.6 (Priority Policy Requirements), and 6.7 (Deployment and Upgradeability Requirements).

- Develop and maintain a publication plan and associated informational releases. Transformative research efforts such as MMITSS can be expected to result in notable findings and outcomes. As such, a publication and informational release plan will be developed and maintained on a monthly basis for use by the sponsoring organization(s). The purpose of this subtask is to provide useful and timely media in the form of written scripts, photographs, and videos for use by the sponsoring organizations in developing their publications and press releases.
- Participate in National and International Standards processes to represent MMITSS and traffic control interests, Larry Head (PI) will participate in standards efforts as identified with US DOT. This effort may require travel (domestic and international). Steven Shladover is already participating in ISO standardization work in TC204 with DOT travel funding through separate channels for U.S. Experts.
- Larry Head (PI) and Steven Shladover (co-PI) will attend a project closeout meeting to be held during the last week of the project. During this meeting, they will present a summary of the work performed under each task, an overview and status of each deliverable, and overview of budgetary expenditures during the project.

- Task 1 Planned Deliverables (All deliverables based on a October 15, 2013 start date)

Task 1 Deliverable	Due Date
Prepare Briefing Materials	1 Week from Contract Start
Conduct Project Kick-Off Meeting	Within 2 weeks of Contract Start Date
Draft PMP	1 Week from Contract Start Date.
Final PMP	1 Week after Kick-Off Meeting
Draft Project Schedule	1 Weeks from Contract Award
Final Project Schedule	Within 1 week after Kick-Off Meeting
Quarterly Conference Calls and Meeting Minutes	January 13, 2014; April 1, 2014; July 1, 2014, October 1, 2014; January 5, 2015 Meeting minutes will be provided within one week of the conference call.
Monthly Conference Calls and Meeting Minutes during Tasks 6-9	April 1, 2014 – April 6, 2015 Monthly
Monthly Progress Report	Monthly by the 15^{th} of the following month
State-level Stakeholder Standards/Policy Webinar and Report	DATE TBD with Stakeholders.
Simulation Sharing Plan, Process, and Documentation	Simulation Sharing Plan and Process will be provided on February 10, 2014. Simulation files will be uploaded and updated as available on a quarterly basis: January 13, 2014; April 1, 2014; July 1, 2014, October 1, 2014; January 5, 2015, April 6, 2015

Third-party Owner/Operator Overview	DATE TBD Meeting minutes will be submitted within two weeks after the meeting
Develop a publication plan for internal/external informational releases	Provide a draft of the publication plan by Monday, February 10, 2014. Integrate Sponsor feedback and recommendations into final version by Monday, February 24, 2014. Provide monthly updates within the Monthly Progress Report.
Participate in National and International Standards	Schedule and Effort TBD 30 days of effort have been allocated to this effort (includes travel, meetings and document review)
Closeout Meeting	Wednesday, April 15, 2015

4.2 Task 2 – Conduct Detailed System and Software Design

The Phase I effort identified twenty eight (28) key system components (see Table 4-1 below) that are responsible for performing the functions required to realize the behavior captured in the concept of operations and systems requirements. Each of these system components was defined at a high, operational level such that individual developers can produce the functional software based on the defined set of responsibilities, provided/required interface definitions, and the hosting platform (node) specifications where the system component is to be deployed. Each software component is named with a prefix denoting the hardware nodes where it will be deployed, e.g. RSE_ – road side equipment, OBE_ – on-board equipment, Systems_- system level component, Nomadic_- nomadic device (e.g. smartphone), MRP_- MMITSS roadside processor, and Section_- section level component. Several of the components, six (6) RSE_ components and three (3) MRP_ components will require custom implementation based on the unique characteristics of the AZ and CA field test networks.

Table 4-1. Summary of System Components

System Component	Basic Responsibility
RSE_SecurityCertificateService[1]	Provide security certificates for vehicles
RSE_ServiceAdvertisementMgr[1]	Advertise available services, e.g. MMITSS
RSE_MessageTX[1]	Transmit WAVE messages from the roadside
RSE_MessageRX[1]	Receive WAVE messages at the roadside
OBE_BSMData_Transmitter	Send vehicle Basic Safety Messages

OBE_MAP_SPaT_Receiver	Receive MAP and SPaT data on a vehicle
RSE_MAP_SPaT_Broadcast[1]	Broadcast MAP and SPaT data from the intersection
MRP_EquippedVehicleTrajectoryAware	Be aware of the trajectories of equipped vehicles
System_ConfigurationManager	Set up sections (collections of traffic signals) and system level functions
MMITSSUserInterface	Display system information and status
System_N_LevelPriorityConfigurationManager	Configuration manager for N-Level priority policy
OBE_GUI	Tool for visualization of data available on a vehicle. The data includes priority related information – submitted requests, pending requests, active requests, and MAP and SPaT information.
Nomadic_SignalStatusReciever	Nomadic device application that receives traffic signal status data
MRP_NomadicDeviceTrajectorAware	Be aware of the trajectories of pedestrians equipped with nomadic devices
NomadicMMITSSApp	The application that provides MMITSS capabilities on the nomadic device. This application must be downloadable from the appropriate "store"
OBE_PriorityRequestGenerator	The vehicle based component that is responsible for sending a priority request
MRP_TrafficControllerInterface[2]	The component responsible for communications with the traffic signal controller (AZ – NTCIP, CA – AB3418)
MRP_TrafficControl[2]	The component responsible for traffic control logic – phase calls, phase extension, dilemma zone (AZ – NTCIP, CA – Caltrans software)
AuthorizedSpecialUserService	A service to support the authorization of nomadic devices and provide authorization for special (e.g. disabled) travelers
Nomadic_PriorityDataServer	A service (cloud based) component that relays data from the MMITSS to the nomadic device.
Nomadic_PriorityRequestGenerator	The nomadic device component responsible for
MRP_SignalStatus_Nomadic	An infrastructure based component responsible for sending signal status data to the Nomadic_PriorityDataServer for relay to the nomadic device.
MRP_PriorityRequestServer[2]	This component is responsible for managing all priority requests received at each intersection, including selection of the appropriate service strategy. The AZ and CA testbeds support different priority strategies so this component will be custom for each network.

MRP_PerformanceObserver	Acquires data and estimates intersection level performance measures
Section_Coordinator	Responsible for section level traffic control including coordination
Section_PerformanceObserver	Acquires intersection level data and estimates section level performance measures
Section_PriorityRequestServer	Responsible for section level priority control strategies
System_PerformanceObserver	Acquires section level data and estimates system level performance measures

[1]These components (6) require implementation on two RSE platforms (Savari and Arada).

[2]These components (3) will be based on different logic based on the Caltrans software (CA) and NTCIP based software (AZ)

The detailed system designs will be conducted at two fronts, including the design of core MMITSS functions and the design of the software architecture for MMITSS.

Task 2.1 – Develop Detailed Software Design

Detailed design includes the definition of the structure and logic of each software component. Structure can include classes, or data structures, that will be used to realize the software depending on the implementation language (e.g. C++ or C). The logic can be defined using pseudo code, UML activity and state diagrams, petri-nets, or simile logic flow charts. The detailed design for each software component will be developed in sufficient detail to ensure that the requirements will be satisfied and the components will meet the desired functional responsibilities. Each of the 28 software components, plus the 9 components that require custom features for the different test beds, will have a detailed software design plan including definition of how the component will be tested. The development team responsible for the software implementation will develop each component design.

The design of each component will include reviewing existing resources for potential re-use of existing software including:

- the Safety Pilot
- other US DOT/FHWA projects (e.g. Battelle SPaT/MAP)
- and SBIR projects (e.g. Savari InFusion and SmartCross projects)
- the Adaptive Transit Signal Priority (ATSP) system developed by PATH
- the Signal Priority system developed by University of Arizona

Where possible, open source software components will be adopted. When necessary, commercially available libraries and other developments may be adopted. If commercial components are adopted, the responsibility of the component will be clearly defined so that an open source version could be developed if desired. It is assumed that commercial components would be limited to communications packages that are hardware dependent – e.g. Savari or Arada.

All of the detailed designs will be compiled into a draft software design document that will be maintained throughout the design and development process.

Task 2.2 – Design Core System Functions

While there are more than two dozen system components that are essential to implement MMITSS, two system components are considered to be the core functions of MMITSS, namely MRP_TrafficControl (Task 2.2.1) and MRP_PriorityRequestServer (Task 2.2.2). These two functions represent the 'intelligence' that enables the future traffic control systems to consider and balance traffic demands from all vehicles as well as serving the priority requests for specified traveler groups at the intersection level, section level and network level. The traffic control function is essential to implement the Intelligent Traffic Signal System (ISIG).

As MMITSS will be able to acquire a richer set of data to represent the state of concerned intersections and surroundings, the ISIG control system will have greater ability to understand the needs of equipped vehicles in the context of the overall traffic conditions. To achieve this 'thorough understanding' capability, the algorithms for observing and predicting traffic flows will be developed based on both probe vehicles and infrastructure based detection. The new ISIG traffic control function will then be developed to make use of the 'thorough understanding' of the system condition to apply desirable control strategies --- optimum when possible and reasonably compromised when necessary according to a predetermined set of rules and a priority policy.

Built upon the ISIG control strategies, the priority servers will include algorithms that can accurately predict the time to arrival and departure from the intersection of requesting vehicles and need to deal with multiple signal priority requests and have greater ability to adjust signal timing for initiating and terminating priority treatments to provide maximized benefits to the needed vehicles or travelers and at the same time creating minimum impacts to the general traffic. Note that the priority request server (PRS) may need to be designed in conjunction with priority request generator functions. PATH and University of Arizona will apply their substantial prior experience on signal priority to the development of MMITSS priority strategies.

Task 2.3 – Conduct Critical Design Reviews

Two Critical Design Review (CDR) meetings will be conducted where the technical team (and panel as desired) will review each of the detailed software component designs. There will be two design reviews to facilitate the schedule constraints of the project. The first design review will focus on the basic MMITSS components to support vehicle-to-infrastructure and MMITSS-to-traffic signal controller communications. The second design review will focus on the MMITSS centric functionality of traffic control, priority signal control, and performance measurement.

Each software component will be presented to the CDR participants by the team responsible for the software implementation. Each CDR will be conducted over a two-day period at the University of Arizona. Any improvements, issues or deficiencies in the component design will be documented and the design revised before development of the software component will start.

Task 2.4 – Submit Final Detailed System Design

A final software design document including the improvements, issues, or deficiencies identified and resolved will be prepared. This document will be published as part of the open software documentation.

Task 2 Deliverable	Due Date
Task 2.1 – Detailed Component Design (28 components with 9 having customization for the different test beds)	All Designs completed by 3/4/2014
Task 2.2 – Design Core System Functions Report	Core System Function Report completed by 1/31/2014
Task 2.3 – Summary report from the Critical Design Review (CDR)	CDR #1 on 12/9-10/2013 CDR #2 on 2/3-4/2014
Task 2.4 – Final Software Design Documentation	Submit CDR #1 Report 12/20/2013 Submit CDR #2 Report on 2/14/2014

4.3 Task 3 – System and Software Development

An iterative and incremental approach will be used to the system development process. In this approach, called the Unified Process, groups of like system components will be developed together and tested in short development cycles. Each group of like system components is selected so that the entire system functionality will be built starting with the most basic required components then additional functionality added based on the initial components – in an iterative approach. Each set of like components is tested to ensure they provide the defined functionality as well as functioning when integrated with other components.

Table 4-2 summarizes the identified build cycles and associated components. The first cycle (1) consists of the basic WAVE messaging components required for security, service announcement, and communications between vehicles and the infrastructure. The second cycle (2) consists of the components that share basic vehicle data (BSM) and infrastructure MAP and SPaT data. The third cycle

(3) consists of the component to track active vehicles, initial nomadic device application, and the priority request generator and a display on the vehicle node. The fourth cycle (4) consists of the traffic control logic, interface to the traffic signal controller, and getting/sending status information to and from the nomadic device. The fifth cycle (5) consists of the N-level priority policy manager, tracking nomadic devices, nomadic device priority data server, and the main priority request server. The sixth cycle (6) consists of the special authorization service for nomadic devices and the nomadic device priority request server as well as the MMITSS main user interface and configuration manager. The seventh cycle (7) consists of the intersection level performance observer and the section level coordination manager. The eighth cycle (8) consists of the section level performance observer and the section level priority manager. The ninth cycle (9) consists of the system level performance observer. Because the testing that can be done in MMITSS Phase II will be constrained to include a limited number of equipped vehicles, the performance observer functions will be developed to the level needed for these experiments rather than to the level that will eventually be needed for high market penetration conditions.

Table 4-2. Target Build Cycle for each Software Component

Target Build Cycle	System Component
1	RSE_SecurityCertificateService
1	RSE_ServiceAdvertisementMgr
1	RSE_MessageTX
1	RSE_MessageRX
2	OBE_BSMData_Transmitter
2	OBE_MAP_SPaT_Receiver
2	RSE_MAP_SPaT_Broadcast
3	MRP_EquippedVehicleTracker
3	NomadicMMITSSApp
3	OBE_PriorityRequestGenerator
3	OBE_GUI
4	MRP_TrafficControllerInterface
4	MRP_TrafficControl
4	MRP_SignalStatus_Nomadic
4	Nomadic_SignalStatusReciever
5	System_N_LevelPriorityConfigurationManager
5	MRP_NomadicDeviceTracker
5	Nomadic_PriorityDataServer
5	MRP_PriorityRequestServer
6	AuthorizedSpecalUserService
6	Nomadic_PriorityRequestGenerator
6	System_ConfigurationManager
6	MMITSSUserInterface
7	MRP_PerformanceObserver
7	Section_Coordinator

8	Section_PerformanceObserver
8	Section_PriorityRequestServer
9	System_PerformanceObserver

Task 3 Deliverable	Due Date
Task 3.1 Execute Build – Test Cycle #1 Source Code and Build/Test Report	1/31/14
Task 3.2 Execute Build – Test Cycle #2 Source Code and Build/Test Report	2/21/14
Task 3.3 Execute Build – Test Cycle #3 Source Code and Build/Test Report	3/28/14
Task 3.4 Execute Build – Test Cycle #4 Source Code and Build/Test Report	5/2/14
Task 3.5 Execute Build – Test Cycle #5 Source Code and Build/Test Report	6/20/14
Task 3.6 Execute Build – Test Cycle #6 Source Code and Build/Test Report	7/25/14
Task 3.7 Execute Build – Test Cycle #7 Source Code and Build/Test Report	8/29/14
Task 3.8 Execute Build – Test Cycle #8 Source Code and Build/Test Report	9/26/14
Task 3.9 Execute Build – Test Cycle #9 Source Code and Build/Test Report	10/24/14

4.4 Task 4 – System Integration, Laboratory Testing and Simulation

System integration will be conducted to bring the MMITSS hardware and software components together into an integrated system. The integration work includes laboratory, hardware-in-the-loop, and intersection testing. The intersection testing will be accomplished using the PATH RFS intelligent intersection and University of Arizona test intersection (Speedway and Mountain). Limited simulations will be conducted to show expected performance of the MMITSS use cases to local authorities to convince them of the value of field testing these use cases and to assess some performance issues that cannot be tested directly in the field with very limited numbers of equipped vehicles.

It is assumed that each software component will be tested as part of the Task 3 Build – Test cycle. Once each component passes development test it will be integrated with the other components and tested in the systems integration and laboratory-testing task. Testing will include software, hardware in the loop, and full-scale testing on field (laboratory) sites (e.g. the PATH closed site).

An Integration and Laboratory Testing notebook will be developed that documents the integration process and testing outcomes. A wiki or other online tool may be used for the notebook.

The tests that will be conducted in Task 4 are identified as component or subsystem tests in the Appendix Test Plan, Section 7.2.

Task 4.1 Integration of System Components in Laboratory

The hardware and software components will be integrated into the MMITSS testing system in the laboratory. The integration will follow the build-test cycles. For example, Build cycle 2 and build cycle 3 components will be integrated to ensure that vehicles that are reporting their vehicle data (BSM) can be accurately tracked (e.g. position error within bounds). Since there will not be real-world inputs from either equipped or unequipped vehicles or travelers at this stage, emulated traffic and equipped vehicles/travelers will be used for the initial testing of the integrated system. During the course of the testing process, software and hardware will be modified when necessary to ensure correct functionality and to improve the performance of the components. A System Integration and Testing Notebook will be maintained that documents the integration and testing process.

Task 4.2 Conduct Testing using Hardware-in-the-Loop Simulation and Field Test Intersections

Additional integration testing will be conducted using Hardware-in-the-loop simulation and field test intersections. Hardware-in-the-loop simulation (HILS) testing will be conducted using the VISSIM simulation model, controller interface devices (CID), controllers (NTCIP and/or 2070 with Caltrans software), OBE and RSE devices. Figure 4-1 illustrates the HILS system. A System Integration and Testing Notebook will be maintained that documents the integration and testing process.

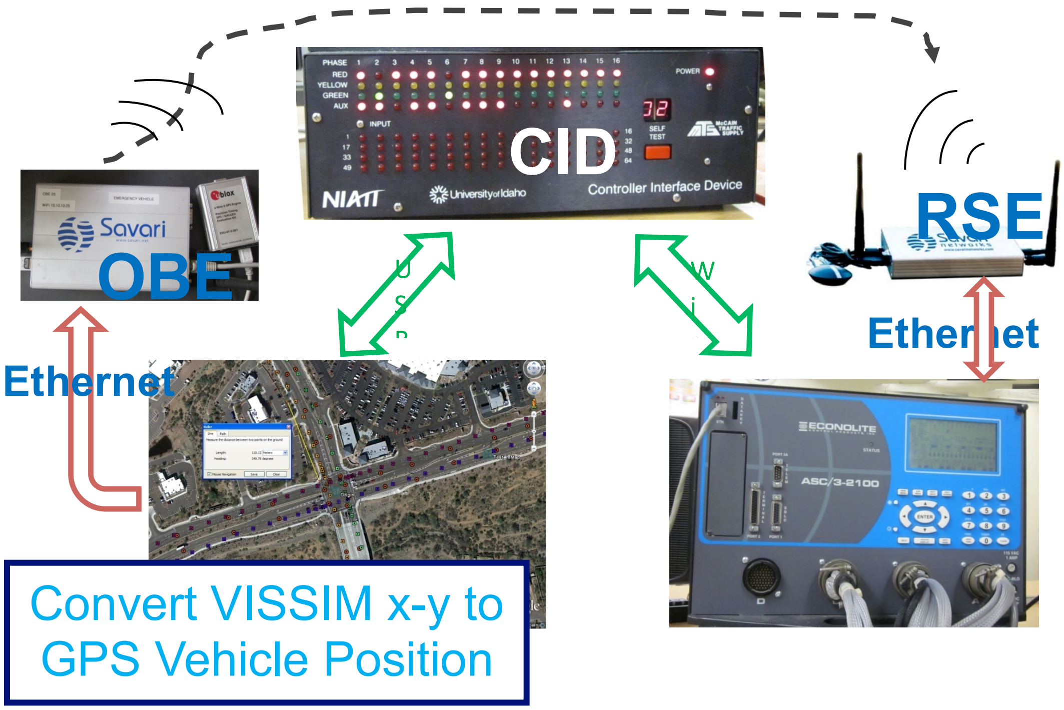


Figure 4-1. Hardware-in-the-Loop Simulation (HILS) system

The HILS system uses VISSIM as the microscopic simulation model. VISSIM allows different types of vehicles, including passenger cars, transit vehicles, trucks, etc., to be simulated. It also allows an external vehicle logic (drivermodel.dll) to override parts of the existing vehicle driver model. This external extension allows the vehicle position in VISSIM to be mapped to GPS coordinates so that a Basic Safety Message (BSM) can be passed from VISSIM to an OBE and communicated over the wireless DSRC channel to an RSE. The RSE, which will include the MMITSS Roadside Processor (MRP), communicates with the traffic signal controller using Ethernet/NTCIP (which will be modified to support the Caltrans AB3418 protocol over serial communications). The controller communicates the signal status through a special interface, called a Controller Interface Device – CID, that sets the simulated traffic signals in VISSIM to the same state as on the real traffic controller. This HILS system provides a closed loop environment for testing the integrated MMITSS components for an intersection. With additional CID devices, or using the NTCIP capable Software in the Loop (SIL) version of the Econolite ASC/3 controller, the HILS capability can be used to test a section of traffic signals.

The initial testing of MMITSS will be conducted at both California and Arizona sites, due to the differences of the in-place traffic controllers and the traffic demands at California and Arizona test sites. In addition to the HILS integration testing, both sites have intersections equipped with communications and control hardware that matches the actual test networks This capability will be used to field test the integrated components prior to deployment in the actual test network.

PATH will use its Intelligent Intersection for evaluating the integrated system. PATH's Intelligent Intersection at its Richmond Field State headquarter is designed for evaluating the implementation of Connected Vehicle technologies and alternative traffic signal control strategies. The intersection is on University property, in a lightly-traveled area, so experiments can be conducted without creating safety hazards or traffic disturbances. It is equipped with a wide variety of vehicle detection and traffic surveillance sensing system, DSRC communications and a D-GPS base station. The intelligent intersection allows communications-or sensor-based control and preemption. It is equipped with 170 and 2070 Traffic Controllers, housed in an ITS Cabinet. Both 802.11a and 802.11b wireless transceivers are located at the ITS Cabinet, connected with the controller through a PC-104 computer, also housed in the cabinet. The intersection is equipped with both Savari and Arada DSRC RSEs and other equipment identical to the field installations along El Camino Real since it has been used as the prototype installation to verify the testbed hardware and software prior to implementation along El Camino Real. Intersection level MMITSS processer will be instrumented to connect with the DSRC RSEs and the 2070 traffic controller. Necessary modifications to the 2070 controller will be made to be consistent with the controllers along the CA test site El Camino Real. Equipped vehicles will be used to verify basic MMITSS functions. Similarly, University of Arizona will conduct field tests using an equipped intersection near the University of Arizona campus. This intersection has DSRC communications. It is equipped with a shadow Econolite ASC/3 controller that provides SPaT data and allows priority controls/timing to be implemented without impacting traffic flow.

Task 4.3 Conduct Limited Simulation Experiments

Traffic microsimulations will be used for both the Anthem (AZ) and Palo Alto (CA) testbed sites, starting from detailed representations of the current traffic signal control strategies. The MMITSS application software (or an abstraction of its functionality) will be integrated with the traffic simulation models of the testbed sites using application programming interfaces (API) for the VISSIM simulation package. Simulation scenarios will be defined to represent the conditions and use cases that are planned for field testing. The simulations will be used to evaluate the performance of the MMITSS traffic control and priority strategies and to adjust their parameters to achieve the desired performance. The simulation results will be a valuable tool for communicating with the local agencies regarding the behavior that should be expected when the MMITSS field testing is executed. This knowledge will be needed to obtain local agency approval to conduct the field tests in live traffic and to provide some assurance that the testing will not produce adverse traffic impacts.

The effects of the MMITSS functions on the performance of the intersections and sections of intersections will be estimated using the simulations. A Limited Simulation Study report will document the simulation studies and findings.

Task 4 Deliverable	Due Date
System Integration and Laboratory Testing Notebook (Tasks 4.1 and 4.2)	Create version 1 on 2/14/14 and update with each Build-Test Integration (9) over 220 days (Final 12/5/2014)
Limited Simulation Experiment Report	Friday 1/30/15

4.5 Task 5 – Support Impact Assessment (IA) Contractor

The US DOT will select an independent Impact Assessment (IA) Contractor. The following language has been integrated into this scope of work. It was provided to the team by US DOT Support Contractor Noblis. It describes the effort required for the MMITSS team (called the Prototype Developer – PD) to support the IA contactor and evaluation of the MMITSS prototype.

> "The PD Contractor shall provide the IA Contractor with cleaned and documented "before" and "after" data. The IA Contractor is responsible for the collection of all performance and explanatory data not generated within the prototype system. The specific data that needs to be collected by the PD Contractor will be determined jointly by the PD Contractor and the IA Contractor in consultation with the USDOT. Note that the activities to be conducted by the PD and IA Contractors will help USDOT understand the technical issues, refine the concept (as needed), and assess the benefits of deploying MMITSS more widely. [Task 5.1]
>
> *National Level DMA Program Evaluation*: The PD Contractor shall coordinate with the DMA Program Evaluation Contractor throughout the prototype development as well as small-scale demonstration activities. The PD Contractor shall also provide the DMA Program Evaluation Contractor with cleaned and documented "before" and "after" data.
>
> The MMITSS Team will provide the input files required, as well as the specific VISSIM configuration, for each simulated test site. The IA Contractor will be required to acquire suitable VISSIM capability to precisely match the required configuration documented by the MMITSS Team. The MMTISS Team will assist the IA Contractor in the development of a testing and verification plan that demonstrates consistency between both groups generating analytical results obtained using identical inputs. The MMITSS Team will alert the IA Contractor to any adaptations to the VISSIM configuration during the period of performance of this effort.
>
> *Open Source Applications Development Portal (OSADP)*[2]: The PD Contractor shall make all methods, algorithms, and source code, developed under this task order available on

[2] Open Source Applications Development Portal (OSADP), http://itsforge.net/joomla/, accessed February 8, 2013.

the OSADP under the Apache 2.0 license[3] for further collaboration with and possible commercialization by, the academia or the industry. Only those algorithms and code developed under this task order need be made available using this license; existing software or Commercial Off-The-Shelf (COTS) products integrated into the prototype need not be made available using the Apache 2.0 license. [Task 5.2]

Research Data Exchange (RDE)[4]: The DMA and DCM Programs expect data collected under the sponsorship of the two programs to be made freely available to the public on the RDE. Hence, the PD Contractor shall transfer all data collected under this task order to the RDE, and shall abide by the terms of use, available on the RDE web site." This includes documenting the approval to disseminate data collected during the MMITSS field test from primary sources. [Task 5.3]

It is assumed that this effort will occur during the integration and laboratory testing effort as well as during field testing and demonstration.

Task 5 Deliverable	Due Date
Participate in Coordination Meetings (3)	TBD (1st Meeting - 10/31/13)
Deliver Before and After Data	2/6/15
Deliver All Methods, Algorithms, and Source Code to OSADP	1/2/15
Transfer Data to Research Data Exchange	3/27/15

The dates when these activities will occur depend on the US DOT selection of a Impact Assessment contractor.

4.6 Task 6 – Field Integration and Testing (AZ)

The proof-of-concept field operational tests of MMITSS will utilize the California Connected Vehicle (CV) testbed and the Maricopa County Department of Transportation (MCDOT) SMARTDrive Field Test Network. This task defines the key activities to be performed in the MCDOT SMARTDrive Field Test Network include installing MMITSS hardware and software components (including RSE upgrades, MMITSS Roadside Processors (MRP), networking devices, and central server hardware), and the development of detailed testing procedures to be conducted in Task 8.

[3] The Apache Software Foundation Licenses, http://www.apache.org/licenses/ , accessed January 31, 2013.

[4] Research Data Exchange (RDE), http://www.its-rde.net, accessed January 31, 2013.

It is assumed that both networks have RSE installed and integrated (power, communications to the controller, and antenna) in the field. The RSEs in the Maricopa County Department of Transportation (MCDOT) SMARTDrive Field Test Network are from an older generation and need to be upgraded to the version 3.1 specification to provide two DSRC channels and onboard GPS capabilities.

Task 6.1 Installation of MMITSS in the MCDOT SMARTDrive Testbed

RSE upgrades and MMITSS software developed under Tasks 3 and 4 will be installed in MCDOT SMARTDrive testbed. OBEs will be installed in instrumented test vehicles as well as selected emergency services (Daisy Mountain Fire Department) fleet vehicles; MMITSS mobile applications will be installed on selected nomadic devices; and a central server will be installed at the MCDOT Traffic Operations Center to host the MMITSS System and Section level components. OBE installation will be performed at the earliest possible stage of the testbed implementation to support field testing the components developed under Task 3 and 4. MAP data will be generated for each intersection in the testbed using high accuracy RTK-GPS survey equipment.

Task 6.2 Field Integration and Operational Testing in MCDOT SMARTDrive Testbed

MMITSS components, including hardware, software and communications, will be integrated under this Task. Operational tests will be conducted incrementally as the software components are developed, laboratory tested, and determined to be field ready. Field testing will be used to ensure the communications among OBEs, mobile applications, RSEs, traffic controllers and the MMITSS central server. The operational tests under this task are different from the system test defined in Task 9. The focus of this Task is incrementally bring the MMITSS capabilities to an operational state in the testbed.

Validation testing of traffic signal timings and operation will be conducted during off-peak periods to avoid impacting the normal traffic control operations

Task 6.3 Development of Test Procedure for System Test in MCDOT SMARTDrive Testbed

A detailed test procedure will be developed for the full-scale system test defined in Task 8. The detailed test procedures will define the sequence of events required for testing each of the MMITSS functions, including where to stage priority eligible vehicles (transit, emergency, and freight); how equipped pedestrians will interact with the vehicles; how equipped passenger vehicles will be used in the testing.

Task 6.4 Collecting of the Baseline ("Before") Data

To evaluate the performance of MMITSS, baseline data ('with MMITSS functions turned off') will be needed and will be collected under this task. We understand that the objective of this project is not only for validating MMITSS functional requirements but is also to assess the potential performance improvements possible using CV technologies through MMITSS.

Task 6 Deliverable	Due Date
Task 6.1 - Installation of MMITSS in the MCDOT SMARTDrive Testbed Notebook	12/12/14
Task 6.2 Field Integration and Operational Testing Notebook	12/19/14
Task 6.3 Development of Test Procedures Document	1/130/15
Task 6.4 Baseline ("Before") Data	1/15/15

The resource estimate for Task 6 is based on deploying a six-person team plus MCDOT personnel (Traffic Engineer, Traffic Technician, Communications Engineer, and REACT Vehicle Personnel) at the test site (to allow for driving multiple test vehicles to represent the various use case scenarios), with daily 300-mile round trips to and from the University of Arizona in Tucson. The installation and testing is grouped into 6 logic tasks (installation of RSEs, basic connected vehicle operations, basic traffic control, priority control, section coordinated priority, pedestrians, and the integrated corridor case), with testing at one intersection first, then extending to the entire corridor (6 intersection). Total time testing is expected to be 15 days in the field. This represents a total of 90 person-days of field work, plus the travel costs associated with the testing and traveling to and from the test site.

4.7 Task 7 – Field Integration and Testing (CA)

The proof-of-concept field operational tests of MMITSS will utilize the California Connected Vehicle (CV) Testbed. The envisioned research to be performed under this task includes installing MMITSS software and hardware (particularly the OBE units on test vehicles), necessary modifications to the Testbed that support specific tests to be performed, and the development of testing procedure plan for MMITSS system tests to be conducted under Task 9. The modifications will enhance the Testbed itself, improving its usefulness for other future CV research and testing in general.

It is assumed that the RSEs and roadside processors will already be installed and integrated (power, communications to the controller, and antenna) in the field when this task is begun.

Task 7.1 Installation of MMITSS in California Testbed

MMITSS software developed under Tasks 3 and 4 will be installed in the California Testbed. Newer and compatible version of firmware for road-side equipment (RSE) units, if available, will be updated. OBEs will be installed on PATH instrumented test vehicles as well as selected transit fleet vehicles, and MMITSS mobile applications will be installed on selected nomadic devices. OBE installation will be performed at the earliest possible stage upon the completion of California Testbed implementation to allow collecting real-world data to be used for development under Task 3 and 4. In addition, MAP data will be generated for the California Testbed. The generation of MAP data is planned to be based on a combination of using Caltrans existing intersection diagrams, Google Maps and trajectory data collected by GPS-instrumented PATH test vehicles. Validation of MAP data will also be conducted to ensure that its quality meets the application needs of MMITSS.

Task 7.2 Field Integration and Operational Testing in California Testbed

MMITSS-specificcomponents will be integrated under this subtask. Operational tests will be conducted to ensure the communications among OBEs, mobile applications, RSEs, traffic controllers and the MMITSS central server. The operational tests under this subtask are different from the system test that is going to be conducted under Task 9. The focus of this subtask is to prepare the testbed to be ready for the system test. Testing of changing signal timings will likely be conducted during off-peak periods such that more intensive testing can be performed without impacting the normal traffic control operations. Furthermore, the software modules developed under Task 3 and 4 that process CV data, such as OBE and nomadic device tracking and arrival time prediction, and data fusion of infrastructure-based traffic detection with CV data for performance measures, will also be tested and validated using real-world data. In the event that software changes are needed to support the MMITSS applications, there will likely be a need for corresponding software changes in the RSEs, OBEs and the nomadic devices that link with the traffic controllers and the MMITSS central server so that there is seamless information flow among them.

Task 7.3 Development of Test Procedure for System Test in California Testbed

A test procedure will be developed for the Task 9 system test in the California Testbed. Some of the MMITSS functional requirements should have been verified under Task 3 and 4, while others will need to be verified under Task 9 – in the field environment. The plan will include identifying the type of data that will be stored and how in order to verify the MMITSS functional requirements, and to evaluate of the performance of MMITSS, within the constraints imposed by the limited number of equipped vehicles available for testing.

Task 7.4 Collecting of the Baseline ("Before") Data

To evaluate the performance of MMITSS, baseline data ('with MMITSS functions turned off') will be needed and will be collected under this subtask. We understood that the objective of this project is not only validating MMITSS functional requirements but, more importantly, also assessing the improvements enabled by CV technologies through MMITSS. The baseline data will be collected shortly before the experiments with the MMITSS functions activated in order to minimize the differences in other conditions (weather, seasonal traffic patterns) that could otherwise distort the comparison.

The resource estimate for Task 7 is based on assuming that the field implementation requires a team of three people on the site, spending an average of two days per intersection for implementation, debuggging and acceptance testing of the basic functionality. For the eleven intersections in California, this amounts to 66 person days. Then, implementing each of the nine use cases to be tested in California is expected to require three people for five days, representing an additional 135 person days. The resource needs also have to allow for test vehicle use expenses including fuel expenses and the monthly insurance on the vehicles.

Task 7 Deliverable	Due Date
Task 7.1 - Installation of MMITSS in the CA Testbed Documented	8/1/14
Task 7.2 Field Integration and Operational Testing Documentation	9/12/14
Task 7.3 Test Procedure Document	1/30/15
Task 7.4 Baseline ("Before") Data	1/30/15

The team has proposed an optional effort that could be a Phase III or separate effort to use a comprehensive video detection system installed at the California Testbed to detect traffic conditions and to emulate equipped vehicles and travelers as well as probe vehicles with various penetration levels. This approach will enable the project team to evaluate all aspects of MMITSS functions in a real-world condition, for a wide range of penetrations (from 0% to 100%). This detection system will enable the team to test a majority of the MMITSS functions in real-world conditions and with much higher market penetration conditions than it will be possible to do using actual equipped vehicles. If this system can be implemented in time to support the MMITSS Phase II testing, the team will propose modifications to the testing plan to take advantage of the additional data collection opportunities that it provides.

4.8 Task 8– System Test and Evaluation (AZ)

A formal system test will be conducted using the MCDOT SMARTDrive testbed to 1) validate MMITSS functional requirements, 2) assess the system performance, and 3) investigate the impacts of the CV penetration rate (optional depending on the ability to equip passenger vehicles). The tests to be conducted are identified in the Appendix, Section 7.2. The detailed testing procedures are developed in Task 6.3.

Task 8.1 Execute MCDOT SMARTDrive Test Plan

The focus of this Task is to verify MMITSS functional requirements that have been developed in the MMITSS system. The project team will coordinate with volunteer drivers (e.g. MCDOT REACT vehicles, Daisy Mountain Fire Department, Valley Metro Transit, and team member vehicles) to operate test vehicles and team members as users of nomadic devices in the execution of the detailed test procedures. Each of the detailed test procedures will be executed. Key data will be collected and test logs will be kept that will detail and issues or deviations in the test plan.

Task 8.2 Development of MCDOT SMARTDrive Test Plan Documentation

This Task will develop documentation of the results of the tests done to validate the MMITSS functional requirements based on the identified verification methods for each of the tested functional requirements (see Section 7.2).

Task 8.3 Evaluation of MMITSS System Performance

Extensive “after” (with MMITSS functions turned on) data will be collected under this subtask. A “before” and “after” evaluation study will be conducted to assess the performance of MMITSS. Evaluation will consist of special test procedures to estimate the performance of priority for fleet vehicles (emergency, transit, and freight) as well as equipped passenger vehicles and equipped pedestrians. It is difficult to collect sufficient field data in such a complex environment to ensure statistical significance, so the focus will be on collecting sufficient data to support the Task 5 – Simulation Experiments findings.

Similar to the optional effort identified in Task 7 that could be a Phase III or separate effort to use a comprehensive video detection system installed at the California El Camino Real test site the team has proposed an effort to equip a large number of vehicles in the Arizona test site to achieve a reasonable market penetration. The approach will be to either utilize VAD devices that broadcast vehicle data on 100 or more volunteer’s vehicles.

Task 8.4 Transition or Decommission System

When the field testing and demonstration is complete, the MMITSS system will either be transitioned to MCDOT for support and maintenance or decommissioned. It is understood that MCDOT intends to continue to utilize the SMARTDrive network for deployment and research activities. Funding for the continued operation of the MMITSS system will be sought from a variety of sources in partnership with MCDOT and UA.

Task 8 Deliverable	Due Date
Task 8.2 MCDOT SMARTDrive Test Plan Document	3/27/15
Task 8.3 MMITSS System Performance Document	3/27/15
Task 8.4 Transition or Decommission System Plan	4/10/115

The resource estimate for Task 8 is based on deploying a six-person team plus MCDOT personnel (Traffic Engineer, Traffic Technician, Communications Engineer, and REACT Vehicle Personnel) at the test site (to allow for driving multiple test vehicles to represent the various use case scenarios), with daily 300-mile round trips to and from the University of Arizona in Tucson. The field testing and evaluation is structured around the use cases in Table 3-1 (Integrated Operation, ISIG, Transit, Pedestrians, Trucks, and Emergency Vehicles). It is assume that a minimum of three days of field testing and evaluation will be needed for each use case category for a total of 15 days in the field. This represents a total of 90 person-days of field work, plus the travel costs associated with the testing and traveling to and from the test site.

4.9 Task 9 – System Test and Evaluation (CA)

A proof-of-concept system test will be conducted using the California CV Testbed to 1) validate MMITSS functional requirements, and 2) assess the system performance within the constraints imposed by the limited number of available equipped vehicles. , The tests to be conducted are identified in the Appendix, Section 7.2.

Task 9.1 Executing California Test Plan

The focus of this subtask is to verify MMITSS functional requirements that have been identified to be conducted in the field environment. The already developed California test plan and procedure will be executed under this subtask. The project team will coordinate with volunteer drivers for PATH test vehicles, volunteer users of nomadic devices, and involved transit agency and Caltrans traffic operators for productive test plan execution.

Task 9.2 Development of California Test Plan Documentation

This subtask will develop documentation of the results of the tests done to validate the MMITSS functional requirements, based on the identified verification methods for each of the tested functional requirements. The reporting methods included in the final report will adopt the documentation approaches developed under this subtask.

Task 9.3 Evaluation of MMITSS System Performance

"After" (with MMITSS functions turned on) data will be collected under this subtask. A "before" and "after" evaluation study will be conducted to assess the performance of MMITSS.

Task 9 Deliverable	Due Date
Task 9.2 California Test Results Document	4/8/15
Task 9.3 MMITSS System Performance Evaluation Document	3/20/15

Caltrans has decided that the California Testbed implementation should not be decommissioned at the end of this project, but should remain available for use in future projects.

The resource estimate for Task 9 is based on stationing a four-person team at the test site (to allow for driving multiple test vehicles to represent the various use case scenarios), with daily 100-mile round trips to and from their normal work place. The use cases are estimated to be clustered in five groups for testing (basic ISIG, dilemma zone, priority, pedestrians, and the integrated corridor case), and each use case cluster is expected to occupy four days of on-site testing. This represents a total of 80 person-days of work, plus the vehicle insurance and fueling costs associated with the testing and traveling to and from the test site.

4.10 Task 10 – System Demonstration and Final Documentation

Task 10.1 – System Demonstration (AZ)

A formal system demonstration will be conducted in the MCDOT SMARTDrive Testbed. This demonstration will be aimed at highlighting the functionality and capability of MMITSS.

Task 10.2 – System Demonstration (CA)

A formal system demonstration will be conducted in the California Testbed. This demonstration will be aimed at highlighting the functionality and capability of MMITSS.

Task 10.3 Final Documentation

A project summary report will be developed that details the overall project experience and findings. It will provide a summary and reference to the detailed technical documentation including the detailed software design documents, simulation modeling developments (tools) and simulation experimentation results, laboratory and field test procedures, general impressions and findings, as well as recommendations for future MMITSS development and deployment.

Task 10 Deliverable	Due Date
Task 10.1 – System Demonstration (AZ)	3/30/15
Task 10.2 – System Demonstration (CA)	4/3/15
Task 10.3 Final Documentation	4/15/15

5 Proposed Technical Team

The University of Arizona

The University of Arizona has been active in transportation research for over 40 years. In 1991 The Systems and Industrial Engineering Department began conducting research in adaptive signal control (RHODES) and since that time has developed a strong research program in traffic signal systems (emergency vehicle priority, transit priority, adaptive control), network modeling (dynamic traffic assignment (DynusT), evacuation, and transit planning).

The University of Arizona has been instrumental in the development of two (2) field test laboratories. Recently, in partnership with Maricopa County Department of Transportation, they have developed the Maricopa County Connected Vehicle Test Bed as part of the SMARTDrive Program. This network consists of six intersection each equipped with Savari Network DSRC radios (RSE) that are connected to Econolite ASC/3 controllers. The network has been used to test and demonstrate priority control for emergency vehicles, transit priority, and for the two Savari Network SBIR projects (11.1-FH1 Smartphone Signal Alert Status and 11.1-FH2 Augmenting Inductive Loop Vehicle Sensor Data with SPAT and GrID (MAP) via Data Fusion). The network is planned to be expanded to include a total of nine (9) intersections that will form a loop so that equipped test vehicles can circulate more easily around the network. All of the intersections are connected to the MCDOT traffic management center where they can be accessed remotely. In 1994, the City of Tucson established the Tucson Living Transportation Laboratory where the University of Arizona deployed the RHODES traffic adaptive signal control system. The Living Lab has two DSRC equipped intersections where the University of Arizona tests Connected Vehicle applications.

Key University of Arizona personnel include:

- Dr. Larry Head, PI, Department Head and Associate Professor.
- Graduate Research Assistants: Yiheng Feng, Mehdi Zamanapour, Shayan Khoshmagham

PATH Program/University of California, Berkeley

The University of California PATH Program was the first ITS research program in the U.S., with 25 years of leadership in the field of ITS. The program was initiated as a partnership between the Institute of Transportation Studies of the University of California, Berkeley and the California Department of Transportation (Caltrans), and that partnership has continued for 25 years, with the addition of funding from the U.S. DOT and private industry partners. PATH's research has emphasized cooperative systems since the beginning, long before it was fashionable, so its research staff has in-depth knowledge of both the in-vehicle and infrastructure aspects of ITS. Under sponsorship of Caltrans and the Metropolitan Transportation Commission's VII California program, PATH implemented the first DSRC testbed environment in the U.S. That testbed is currently being modernized under the sponsorship of the ITS JPO of the U.S. DOT, bringing it up to full compatibility with the other national DSRC test beds, based on the latest national standards.

PATH has developed and field tested adaptive transit signal priority systems in several California corridors, including the corridor that will be used for testing in the proposed project. Under the sponsorship of the FHWA Exploratory Advanced Research Program, PATH is also developing enhanced traffic signal control strategies based on the assumed availability of large quantities of probe vehicle data, providing a very good starting point for consideration for the ISIG and the FSP applications.

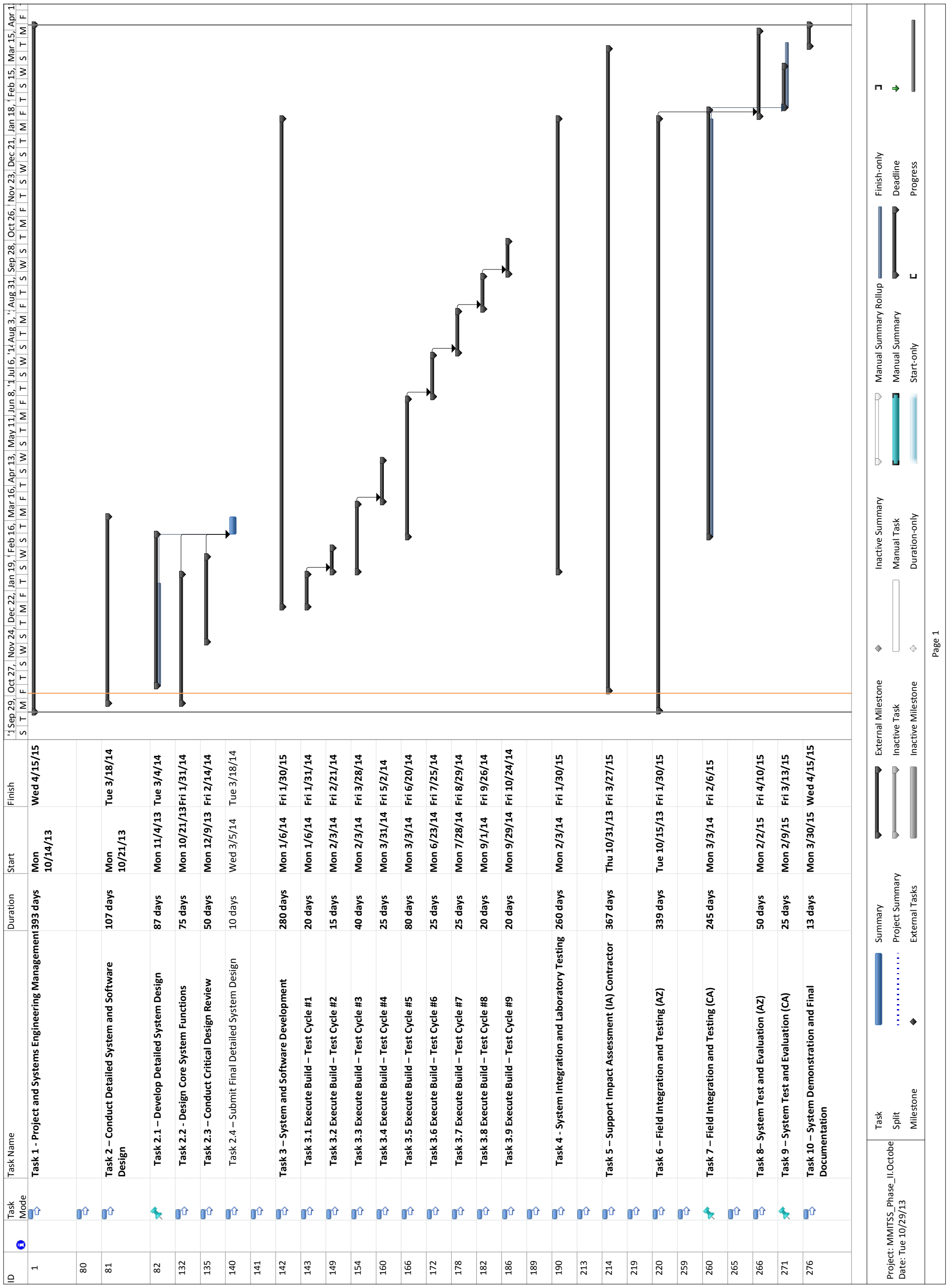
Key PATH/University of California Berkeley personnel include:

- Dr, Steven Shladover, P.I., Research Engineer
- Wei-Bin Zhang, Research Engineer
- Dr. Kun Zhou, Research Engineer
- Somak Datta Gupta, Research and Development Engineer
- John Spring, Research and Development Engineer

Key Technology Partners include:

- Econolite - Gary Duncan and Eric Raamot
- Savari Networks – Ravi Puvvala

6 Proposed Schedule



ID	Task Name	Duration	Start	Finish
1	Task 1 - Project and Systems Engineering Managemen	393 days	Mon 10/14/13	Wed 4/15/15
80				
81	Task 2 – Conduct Detailed System and Software Design	107 days	Mon 10/21/13	Tue 3/18/14
82	Task 2.1 – Develop Detailed System Design	87 days	Mon 11/4/13	Tue 3/4/14
132	Task 2.2 - Design Core System Functions	75 days	Mon 10/21/13	Fri 1/31/14
135	Task 2.3 – Conduct Critical Design Review	50 days	Mon 12/9/13	Fri 2/14/14
140	Task 2.4 – Submit Final Detailed System Design	10 days	Wed 3/5/14	Tue 3/18/14
141				
142	Task 3 – System and Software Development	280 days	Mon 1/6/14	Fri 1/30/15
143	Task 3.1 Execute Build – Test Cycle #1	20 days	Mon 1/6/14	Fri 1/31/14
149	Task 3.2 Execute Build – Test Cycle #2	15 days	Mon 2/3/14	Fri 2/21/14
154	Task 3.3 Execute Build – Test Cycle #3	40 days	Mon 2/3/14	Fri 3/28/14
160	Task 3.4 Execute Build – Test Cycle #4	25 days	Mon 3/31/14	Fri 5/2/14
166	Task 3.5 Execute Build – Test Cycle #5	80 days	Mon 3/3/14	Fri 6/20/14
172	Task 3.6 Execute Build – Test Cycle #6	25 days	Mon 6/23/14	Fri 7/25/14
178	Task 3.7 Execute Build – Test Cycle #7	25 days	Mon 7/28/14	Fri 8/29/14
182	Task 3.8 Execute Build – Test Cycle #8	20 days	Mon 9/1/14	Fri 9/26/14
186	Task 3.9 Execute Build – Test Cycle #9	20 days	Mon 9/29/14	Fri 10/24/14
189				
190	Task 4 - System Integration and Laboratory Testing	260 days	Mon 2/3/14	Fri 1/30/15
213				
214	Task 5 – Support Impact Assessment (IA) Contractor	367 days	Thu 10/31/13	Fri 3/27/15
219				
220	Task 6 – Field Integration and Testing (AZ)	339 days	Tue 10/15/13	Fri 1/30/15
259				
260	Task 7 – Field Integration and Testing (CA)	245 days	Mon 3/3/14	Fri 2/6/15
265				
266	Task 8– System Test and Evaluation (AZ)	50 days	Mon 2/2/15	Fri 4/10/15
271	Task 9 – System Test and Evaluation (CA)	25 days	Mon 2/9/15	Fri 3/13/15
276	Task 10 – System Demonstration and Final Documentation	13 days	Mon 3/30/15	Wed 4/15/15

7 Appendices

7.1 Acronyms

ABSM	Alternate Basic Safety Message
AC	Alternating Current
ADA	Americans with Disabilities Act (1990)
AQ	Air Quality
APS	Accessible Pedestrian Signals
ASC	Actuated Signal Controller
ATIS	Advanced Traveler Information Systems
ATDM	Active Traffic and Demand Management
ATV	All-Terrain Vehicle
BRT	Bus Rapid Transit
BSM	Basic Safety Messages
CA	California
CDRL	Contract Deliverables Requirements List
CMMI	Capability Maturity Model Integration
CONOPS	Concept of Operations
CTS	Cooperative Transportation System
CV	Connected Vehicle
DC	Direct Current
DMA	Dynamic Mobility Applications
DOORS	Dynamic Object Oriented Requirement System
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
EMS	Emergency Medical/Management Services
ESD	Electro-static Discharge
ETA	Estimated Time of Arrival
EV	Emergency Vehicle
EVM	Earned Value Method
EVP	Emergency Vehicle Preemption
FHWA	Federal Highway Administration
FOM	Figure of Merit
FPS	Feet Per Second
FTA	Federal Transit Administration
FYA	Flashing Yellow Arrow
GID	Geometric Intersection Description
GPS	Global Positioning Systems
IC	Information Center
ID	Identification
IM	Incident Management
INCOSE	International Council on Systems Engineering
ISIG	Intelligent Traffic Signal System
ITS	Intelligent Transportation System

LOS	Level of Service
MD	Maryland
MHz	Megahertz (10^6 Hertz)
MMITSS	Multi-Modal Intelligent Traffic Signal System
MOE	Measures of Effectiveness
MPH	Miles Per Hour
MTBF	Mean Time Between Failure
MTTF	Mean Time to Failure
NHTSA	National Highway Traffic Safety Administration
NTCIP	National Transportation Communications for ITS Protocol
OBE	On-Board Equipment
OD	Origin-Destination
OEM	Original Equipment Manufacturer
PATH	Partners for Advanced Transportation Technology
PFP	Pooled Fund Project
PFS	Pooled Fund Study
PI	Principal Investigator
PII	Personally Identifiable Information
PMPP	Point to Multi-Point Protocol
POV	Privately Owned Vehicle
R&D	Research and Development
RSE	Roadside Equipment
RV	Recreational Vehicle
SE	Systems Engineering
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSM	Signal Status Message
STMP	Simple Transportation Management Protocol
SVN	Subversion (PFP Repository with Version Control)
SyRS	System Requirements
TMDD	Traffic Management Data Dictionary
TSC	Traffic Signal Controller
TSP	Transit Signal Priority
UA	University of Arizona
UC	University of California
UML	Unified Modeling Language
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VDOT	Virginia Department of Transportation
VMT	Vehicle Miles Traveled

7.2 Appendix: Verification Test Plan - Overview

7.2.1 Summary of Requirements Used in Phase II

The MMITSS Concept of Operations Document identified 19 operational scenarios or use cases, and the System Requirements Document listed 552 parent and children requirements (resulting in 467 unique requirements after removing the parent requirements that were redundant with subsequent children requirements). The MMITSS Phase II project proposes to prototype 9 of the 19 operational scenarios or use cases as shown in Table A1. In order to establish a requirement verification test plan for the Phase II project, the list of MMITSS requirements was first scanned to determine which requirements were related to each operational scenario.

Table A1. MMITSS Phase II Requirements to be Verified in Phase II by Operational Scenario.

MMITSS Phase II Operational Scenarios / Use Cases	Related Requirements	Can Be Addressed in Phase II	Phase II Percentage
Basic Signal Actuation	93	35	38%
Coordinated Signal Actuation	78	45	58%
Dilemma Zone Protection	33	23	70%
Transit Signal Priority	76	38	50%
Unequipped Non-Motorized Traveler	4	4	100%
Equipped Non-Motorized Traveler	40	31	78%
Freight Vehicle Signal Priority	64	30	47%
Coordinated Freight Signal Priority	54	34	63%
Emergency Vehicle Signal Priority	83	38	46%
Total (Unique Requirements)	339	123	36%

The operational scenarios proposed in Phase II mostly related to intersection and section level use cases, so one of the guiding assumptions in the verification test plan was that only requirements related to the intersection or section level would be addressed in the proposed project. System level requirements were thus not included as part of the verification test plan. Looking at unique requirements (and excluding parent requirements that have children), 339 of the 467 total requirements were related to the Phase II operational scenarios.

However, for each scenario, there were a number of requirements that were determined to be unverifiable in the scope of the Phase II project. Typically, the requirements that were determined to be unverifiable in the Phase II project were related to estimating intersection and section performance metrics from equipped vehicles. Although algorithms for calculating performance metrics from equipped vehicles can be developed, they cannot be verified since the Phase II project testing will only include a limited number of equipped test vehicles. Similarly, performance metrics requiring long-term observations such as intersection crash statistics could not be verified in the Phase II project. As shown in Table A1, generally, between 37 and 75 percent of the requirements for each operational scenario can be verified within the scope of the Phase II project, and overall, 36 percent or 123 of 339 requirements related to the 9 operational scenarios addressed in the Phase II project can be verified.

(Note: some requirements apply to multiple operational scenarios.) Looking at the total number of unique requirements, 26 percent or 123 of the 467 total MMITSS requirements can be addressed within the scope of the Phase II project.

7.2.2 Summary of Verification Methods

The verification of each of the Multi-Modal Intelligent Traffic Signal System (MMITSS) requirements will be accomplished in Phase II of the project using one of two general test plan methods:

1. Component or Sub-System Testing in either a Laboratory or Field Setting
2. Field Testing

Of the 123 unique requirements which could be addressed and verified within the Phase II scope, 56 percent were listed as being verifiable through demonstration, 41 percent testing, and the rest through similitude. In creating the MMITSS requirements and verification methods, requirements that were listed as verification by the analysis method were conceived to be verified using traffic simulation, largely based on recognizing that the field implementations of MMITSS in Phase II of the project would not yield a high penetration of connected vehicles. Since the MMITSS Phase II project will not include a large simulation component, many of the performance metric calculation requirements cannot be verified. However, if any of the field implementations can achieve a high market penetration of equipped vehicles or if any of the field implementations can include enhanced monitoring of real-time traffic and emulation of equipped vehicles by identification of their full trajectories, then many of these requirements could eventually be verified in the field testing.

7.2.2.1 Component or Sub-System Testing

In the MMITSS Phase II project, some of the requirements can be verified through component or sub-system integration testing, meaning that the verification of the requirement does not require the entire system to be functional to test whether or not the MMITSS requirement has been satisfied. The requirements to be verified using this testing method were generally conceived with the notion that verification would be through either the demonstration or testing method, and in general, the requirements that will be verified using this test plan method deal with acquiring or transmitting data. As an example, a requirement stating that the MMITSS system will acquire information from a traffic signal controller would only need to be verified using the MMITSS processor and a traffic signal controller in a laboratory setting.

Title: MMITSS Nomadic Device Install & Configure Test	
Method: D	**RQIDs:** A1303, A8301
Verification Test Plan: The nomadic device application must be able to be downloaded, installed, configured, and upgraded on a supported smartphone. Verification of this requirement is a visual demonstration of those processes.	
Test Plan Details: 1. The verification demonstration for the initial install and configure will need to be done twice, first to download and install the general NMT application, and the second to download, install, or configure the NMT application version that is authorized to provide additional crossing time for elderly or disabled NMTs. The installed application on the nomadic device can then be shown to work with a bench test setup or at a field or test track intersection to place a call to actuate the signal. 2. The nomadic device upgradability requirements can be demonstrated visually by downloading and installing an upgraded version of the software.	

Title: MMITSS Vehicle OBE Component Communications Test	
Method: T	**RQIDs:** A1001, A1002
Verification Test Plan: The vehicle OBE is required to acquire SSM, SPaT, and MAP messages broadcast from the intersection. The vehicle OBE hardware/software to receive these messages can be tested in either a laboratory or field setting. For each message type, the OBE should be placed into a testing mode which saves the raw messages and logs the arrival of each message. The received messages can then be compared to the transmitted messages, demonstrating the OBE is capable of acquiring each message type while in communications range of a simulated RSE.	
Test Plan Details: The test plan should be run for each unique message type: SSM, SPaT, and MAP.	

Title: MMITSS Nomadic Device Component Communications Test	
Method: T	**RQIDs:** A1301, A1302
Verification Test Plan: The nomadic devices are required to acquire SSM, SPaT, and MAP messages broadcast from the intersection. The nomadic device hardware/software to receive these messages can be tested in either a laboratory or field setting. For each message type, the nomadic device should be placed into a testing mode which saves the raw messages and logs the arrival of each message. The received messages can then be compared to the transmitted messages, demonstrating the nomadic device is capable of acquiring each message type while in communications range of a simulated RSE.	
Test Plan Details: The test plan should be run for each unique message type: SSM, SPaT, and MAP.	

Title: MMITSS RSE Component Communications Test	
Method: T	**RQIDs:** A2002, F2003, A2016
Verification Test Plan: The MMITSS Intersection RSEs are required to acquire various messages broadcast from equipped vehicles and nomadic devices. The RSE hardware/software to receive these messages can be tested in either a laboratory or field setting. For each message type, the RSE should be placed into a testing mode which saves the raw messages and logs the arrival of each message. The received messages can then be compared to the transmitted messages, demonstrating the RSE is capable of acquiring each message type while in communications range of a simulated equipped vehicle or nomadic device.	
Test Plan Details: 1. The test plan should be run for SRMs from equipped passenger vehicles, transit vehicle, freight vehicles, emergency vehicles, and nomadic devices. 2. The test plan should be run for BSM Part II messages.	

Title: MMITSS Traffic Signal Controller Communications Test	
Method: T	**RQIDs:** A2012, A2101
Verification Test Plan: The MMITSS intersection RSEs are required to communicate with the TSCs (traffic signal controllers) to both get current information and settings and change those settings based on current priority requests. The verification of these requirements can take place in a laboratory or field setting since the method only requires a MMITSS RSE and a traffic signal controller. The RSE will either poll the current information from the TSC and save it to file (or display it on a screen in real-time) or try to set an updated program to the TSC, depending on the specific requirement to be verified. Visual inspection by the tester can then be used to verify that the MMITSS intersection or TSC acquired the correct information.	
Test Plan Details: 1. The MMITSS RSE will acquire the current signal timing parameters including signal intervals and active interval information from the TSC. 2. The MMITSS RSE will acquire field sensor detection data from the TSC.	

7.2.2.2 Field Testing

In the MMITSS Phase II project, some of the requirements may only be verified through field testing once most of the system components are in place. As an example, although simply transmitting and receiving messages by the RSEs or OBEs could be tested in a bench or laboratory setting, higher level requirements such as verifying whether a particular vehicle class can determine whether or not it can request priority at a particular intersection needs the majority of the MMITSS to be implemented before testing. Some of the field testing could occur at the testbed intersections being instrumented and built as part of the MMITSS Phase II project, but others may only require a prototype test track intersection, such as the one located at California PATH's Richmond Field Station.

Title: MMITSS Intersection Equipment Installation & Configuration Test	
Method: I, D	**RQIDs:** B0101, B0102, B0103, A2501, A4101, A4102, A7001, A7002, A7003
Verification Test Plan: The MMITSS RSEs and OBEs must be designed to be able to be installed at the MMITSS Phase II testbed intersections, and the equipment at each intersection must be configurable to provide the services to be offered at that intersection. Likewise, the OBEs must be configurable to support each type of equipped vehicle. The requirements related to the equipment installation and configuration tests will typically be verified by inspection or demonstration.	
Test Plan Details: 1. Verify by visual inspection that the MMITSS RSE fits in standard equipment cabinets or is mounted securely in the designated locations in the intersection. 2. Demonstrate that the MMITSS RSE equipment is adequately powered, and demonstrate the RSE software can handle, log, and recover from power losses and communication failures. 3. Demonstrate that the MMITSS software functions with the RSEs, OBEs, and the TSC at the test intersection. 4. Demonstrate that emergency vehicle OBEs can be configured to only request priority when in active response mode. The MMITSS RSE can log OBE SRM messages, and an emergency vehicle equipped with an OBE can approach the intersection both normally and in active response mode. The RSE logs can verify whether or not a SRM message requesting priority was received in each case. 5. Demonstrate that the MMITSS RSE can be assigned an intersection ID and a section ID. For the MMITSS Phase II project, there may not be an implementation of system level functionality, but intersection and section IDs will be will need to be set and verified on at least the section and intersection levels.	

Title: MMITSS Intersection Communications Field Test	
Method: T	**RQIDs:** A2004, A2005, A2009
Verification Test Plan: The MMITSS Intersection RSEs are required to provide various elements of data, through a number of different messages, to equipped vehicles and nomadic devices. Some of the messages include SPaT, MAP, and SSM messages. These requirements should be verified as part of the field testing of the prototyped MMITSS intersection. The verification of the software and hardware to satisfy these requirements need only be performed at a single intersection with an equipped vehicle OBE and/or nomadic device. For each message type, the vehicle OBE or nomadic device, depending on the requirement, will need to save, log, and/or display the messages or data elements sent by the MMITSS RSE.	
Test Plan Details: 1. The test plan should be run for each of the following unique messages using an equipped vehicle OBE to receive the messages: SSM, SPaT, and MAP/GID. 2. The test plan should be run for each of the following unique messages using an equipped nomadic device to receive the messages: SSM, SPaT, and MAP/GID.	

Title: MMITSS Intersection Vehicle and NMT Tracking Test	
Method: T	**RQIDs:** A2006, A2007, A2008, A2014, A2102
Verification Test Plan: The MMITSS intersections are required to track equipped vehicles and pedestrians through their broadcast messages, as well as to estimate or predict certain metrics such as time to reach or depart the intersection. The testing to verify these requirements involves a single MMITSS intersection, an OBE equipped vehicle, and an equipped nomadic device, depending on the specific requirement. Both the RSE and the OBE/nomadic device should be capable of saving an output file. The RSE should save the tracked vehicle or NMT position and associated predictions of the time to reach or depart the intersection, and the OBE/nomadic device should save the device's actual position to be used as a ground truth measure. A comparative analysis of the saved RSE and OBE/nomadic device log files can then be used to verify that the MMITSS system hardware and software fulfill the required tracking and prediction requirements.	
Test Plan Details: 1. The test plan should be run with the MMITSS intersection tracking an OBE equipped vehicle to verify that the system is capable of tracking the equipped vehicle and predicting its arrival and departure times. 2. Some of the test runs with the MMITSS intersection tracking an OBE equipped vehicle should include the condition where the vehicle passes over an intersection loop detector to verify whether or not the MMITSS intersection correctly associates the loop detector with the correct TSC channel and correctly detects when the OBE vehicle activates the loop detector. 3. The test plan should be run with the MMITSS intersection tracking an equipped nomadic device to verify that the system is capable of tracking and predicting arrival and departure times of the NMT through the crosswalk.	

Title: MMITSS Intersection Basic Signal Actuation Test	
Method: D or T	**RQIDs:** A2010, A2011, A2021, A2103, A8101, A9058, A9101
Verification Test Plan: One of the MMITSS scenarios proposed is BSA (Basic Signal Actuation). In this scenario, vehicles and NMT nomadic devices will broadcast their BSMs and SRMs to request a signal change with a specified N-Level of priority, and the MMITSS system will process those messages and command the TSC to respond when appropriate. The verification of the requirements related to the BSA scenario can be accomplished at a single MMITSS intersection, either in the field or on a test track, with one or more OBE equipped vehicles or nomadic devices to provide the requests for signal actuation.	
Test Plan Details: 1. The MMITSS RSE will need to process both the broadcast BSMs and SRMs to match the phase on which to place a call for the equipped vehicle. In the first set of tests to verify that the MMITSS can process these messages, equipped vehicles emulating various classes of vehicles (passenger cars, transit buses, freight, or emergency vehicles) should approach the intersection from each direction. The MMITSS RSE should calculate and either log or display the correct phase to call for each SRM received, and then place that call to the TSC. 2. The MMITSS RSE will also need to process the messages broadcast by equipped NMT nomadic devices. To verify the requirements related to BSA through a nomadic device, an equipped NMT should approach the intersection from each direction, and active a signal change request from the nomadic device. The MMITSS RSE should log or display the correct phase to call for each request, and then place that call to the TSC. 3. The MMITSS RSE will demonstration that it can log intersection level performance measures, although, given the low penetration of equipped vehicles along the test section, the performance metrics logged may not qualify as statistically significant.	

Title: MMITSS Intersection Dilemma Zone Application Test	
Method: D	**RQIDs:** A2019
Verification Test Plan: One of the MMITSS scenarios proposed is the dilemma zone application. In this scenario, an OBE equipped vehicle will approach the intersection at the tail end of the signal cycle. Using the BSM messages broadcast by the vehicle, the MMITSS intersection will track the vehicle, predict the stopping time, and extend the green so that the green signal does not change to amber while the driver is in the dilemma zone. To verify these requirements, the MMITSS RSE at a test intersection either in the field or at a test track will save a log or display changes to the single timing in response to the equipped vehicle driving through the intersection trying to get captured in the dilemma zone.	
Test Plan Details: The test may need to be repeated for OBE equipped vehicles emulating passenger vehicles, transit vehicles, and freight vehicles.	

Title: MMITSS Section Communication Test	
Method: D	**RQIDs:** A3001, A3002, A3103
Verification Test Plan: The MMITSS section level controller could reside at an intersection or even at a traffic control center, depending on the individual design; however, some MMITSS applications requires that information from the intersection level be transmitted to the section level. To verify that the section level controller can acquire information from each intersection in the section, both the intersection and section level controllers should be capable of logging the intersection information that it is required to be communicated. A demonstration of a section level communications test should consist of setting up a section controller with several intersections, logging the data at the section controller, and then verifying the section controller's receive logs with each intersection's transmit log, and vice versa.	
Test Plan Details: 1. The MMITSS section communication test should include verification of whether or not active priority requests from the various vehicle types are being transmitted from the intersection level to the section level. 2. The MMITSS section communication test include verification of whether or not intersection performance metrics such as queue length, delay, throughput, traffic counts, and their associated variability are being transmitted from the intersection level to the section level. 3. The MMITSS section communication test should include verification that the section level controller can set the intersection offsets for each intersection in a section. This test will need to be run from the section level controller through to the TSC, with manual verification on the TSC that the correct settings were transmitted.	

Title: MMITSS Section Basic Signal Actuation Test	
Method: T	**RQIDs:** A1003, A1004, A3102, A8001, A8002, A8101, A9059
Verification Test Plan: One of the MMITSS scenarios is coordinated signal actuation along a section supporting configurable N-Level priority policies. In this scenario, vehicles will broadcast their BSMs and SRMs to request a signal change with a specified N-Level of priority, and the MMITSS system will process those messages and command the TSC to respond when appropriate. Some of the requirements related to the coordinated signal actuation scenario will require demonstrating various classes of vehicles traversing a section or multiple sections of intersections to verify.	
Test Plan Details: 1. The test implementation should demonstrate that sections of intersections can be configured to support either a transit-centric or freight-centric priority policy. 2. One of the components of both the basic and coordinated signal activation scenarios is that the vehicle OBEs be capable of determining whether or not the vehicles is eligible to request priority and what level or priority to request. As part of the verification testing, several intersections should be configured to allow priority requests at various levels or priority for the test vehicle type, and several should be configured as part of a different section which do not allow priority requests for the test vehicle type. As the vehicle travels through the test intersections, the RSE should log the SRMs to determine whether or not the vehicle was correctly requesting priority based on the test conditions. 3. The MMITSS section controller should demonstrate its capability of logging section performance metrics, although, given the low penetration of equipped vehicles along the test section, the performance metrics logged may not qualify as statistically significant.	

Title: MMITSS Section Platoon Identification Test	
Method: T	**RQIDs:** A3003, A3004
Verification Test Plan: One of the advanced MMITSS applications that can only be realized with a high market penetration of equipped vehicles is the ability to detect and track platoons of vehicles travelling along a section and to adjust the intersection offsets along a section to accommodate the vehicle platoons. The MMITSS Phase II project will likely not result in the ability to fully test a field implementation with a high market penetration of equipped vehicles, but the requirements for platoon identification and tracking should be able to be verified using a platoon of the Phase II available equipped vehicles (nominally 6 in each testbed location). Alternatively, if the MMITSS Phase II project includes several field testable intersections with the ability to track most non-equipped vehicles and emulate their movements as equipped vehicles, the verification of the algorithms to detect, identify, and track platoons could be done more extensively using real traffic patterns.	
Test Plan Details: At this stage in the MMITSS development, the verification of the platoon tracking requirements is primarily a verification of the algorithms that will be used to identify and track the platoons and the algorithms used to adjust intersection offsets to accommodate the platoon.	