

STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION  
**TECHNICAL REPORT DOCUMENTATION PAGE**  
 TR0003 (REV. 10/98)

|  |  |                                  |   |   |  |
|--|--|----------------------------------|---|---|--|
| 1. REPORT NUMBER<br>CA12-1935  |  | 2. GOVERNMENT ASSOCIATION NUMBER |   | 3. RECIPIENT'S CATALOG NUMBER   |  |
| 4. TITLE AND SUBTITLE<br>The Connected Traveler Project: a Component of the SafeTrip-21 Initiative   |  |                                  |   | 5. REPORT DATE<br>May, 2012   |  |
|  |  |                                  |   | 6. PERFORMING ORGANIZATION CODE   |  |
| 7. AUTHOR(S)<br>Larson, Greg   |  |                                  |   | 8. PERFORMING ORGANIZATION REPORT NO.   |  |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>California Department of Transportation (Caltrans)<br>Division of Research and Innovation, MS-83<br>1227 O Street<br>Sacramento, CA 95814   |  |                                  |   | 10. WORK UNIT NUMBER  |  |
|  |  |                                  |   | 11. CONTRACT OR GRANT NUMBER<br>Task Order 6615, and<br>Contracts 65A0301; 65A0343;<br>65A0346; and 65A0348 |  |
| 12. SPONSORING AGENCY AND ADDRESS<br>Research and Innovative Technology Administration (RITA)<br>Volpe National Transportation Systems Center<br>55 Broadway, Kendall Square<br>Cambridge, MA 02142-1093   |  |                                  |   | 13. TYPE OF REPORT AND PERIOD COVERED<br>Final Report   |  |
|  |  |                                  |   | 14. SPONSORING AGENCY CODE<br>913   |  |
| 15. SUPPLEMENTAL NOTES   |  |                                  |   |   |  |
| 16. ABSTRACT<br><p>This report describes the Connected Traveler Project, research performed under the SafeTrip-21 Initiative, which was part of the Vehicle-Infrastructure Integration Program administered by the US Department of Transportation's Research and Innovative Technology Administration. The purpose of the SafeTrip-21 Initiative was to build upon current and prior research into the use of sophisticated information, navigation, and communications technologies to further national transportation goals in safety and mobility. The Connected Traveler Project provided a Field Test Site with Intelligent Transportation Systems (ITS) applications, and was comprised of the Connected Traveler Test Bed, with the appropriate hardware, software, and architecture to field test a broad range of ITS applications, together with intermodal ITS applications covering the mobility, safety, and e-payment areas. This project integrated the Field Test and ITS applications into a product that was:</p> <ul style="list-style-type: none"> <li>showcased at the 2008 ITS World Congress in New York City;</li> <li>field-tested and evaluated on real roads to address mobility and safety needs in the greater San Francisco Bay Area; and</li> <li>demonstrated to prospective users and applications developers in order to stimulate deployment of SafeTrip-21 technologies.</li> </ul> <p>This report is a high level summary of the individual components of the Connected Traveler Project, with the details of each of these components being described in greater detail in the separate deliverables that are referenced in it. These deliverables are contained on the Compact Disks that accompany the report, and are also available on the Caltrans research web site at: <a href="http://www.dot.ca.gov/newtech">http://www.dot.ca.gov/newtech</a></p> |  |                                  |   |   |  |
| 17. KEY WORDS<br>SafeTrip-21; IntelliDrive; Vehicle-Infrastructure Integration (VII); Connected Vehicle; Connected Traveler; Mobile Century; Mobile Millennium; Networked Traveler   |  |                                  | 18. DISTRIBUTION STATEMENT<br>No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161 |   |  |
| 19. SECURITY CLASSIFICATION (of this report)<br>Unclassified   |  | 20. NUMBER OF PAGES<br>24 Pages  |   | 21. PRICE   |  |

Reproduction of completed page authorized

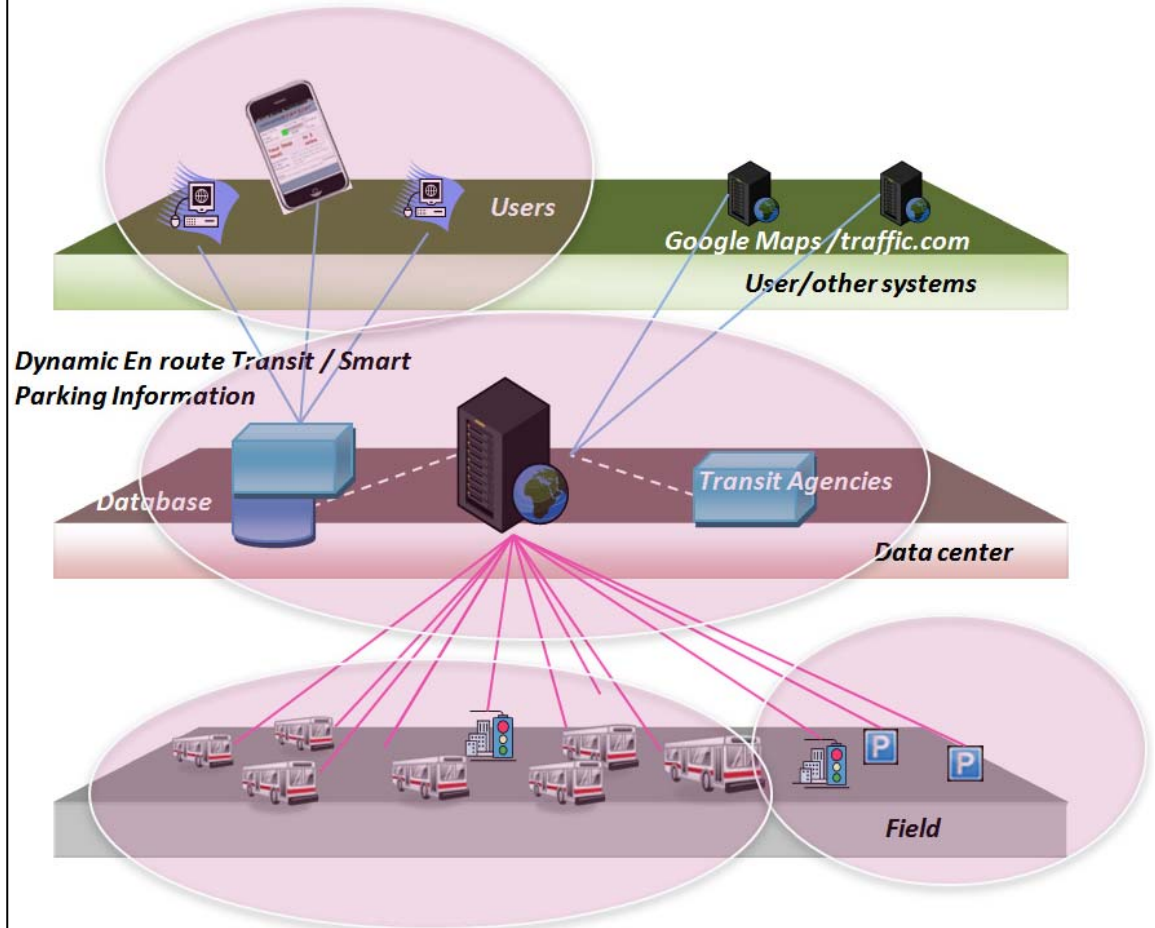


Division of Research  
and Innovation

# The Connected Traveler Project

A Component of the SafeTrip-21 Initiative

Final Report



# **The Connected Traveler Project**

**A Component of the SafeTrip-21 Initiative**

**Final Report**

**Report No. CA12-1935**

**May 2012**

*Prepared By:*

The California Department of Transportation (Caltrans)  
Division of Research and Innovation  
1227 O Street  
Sacramento, CA 95814

*Prepared For:*

The Research and Innovative Technology Administration (RITA)  
Volpe National Transportation Systems Center  
55 Broadway, Kendall Square  
Cambridge, MA 02142-1093

## **DISCLAIMER STATEMENT**

**This document is disseminated in the interest of information exchange. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This publication does not constitute a standard, specification, or regulation. This report does not constitute an endorsement by Caltrans of any product described herein.**

## Table of Contents

|   |           |
|---|-----------|
| <b>Overview</b> .....   | <b>2</b>  |
| <b>Track 0 – Caltrans Project Management</b> .....              | <b>4</b>  |
| Milestones.....   | 4         |
| Deliverables (on Disk 1) .....                                  | 5         |
| <b>Track 1 – The Connected Traveler Test Bed</b> .....          | <b>6</b>  |
| Milestones.....   | 6         |
| Deliverables (on Disk 1) .....                                  | 6         |
| <b>Track 2 – Mobile Millennium</b> .....                        | <b>7</b>  |
| Mobile Century .....  | 7         |
| Development of the Mobile Millennium Test.....                  | 7         |
| Mobile Millennium Launch.....                                   | 8         |
| Milestones.....   | 9         |
| Deliverables (on Disk 2) .....                                  | 9         |
| <b>Track 3 – Group Enabled Mobility and Safety (GEMS)</b> ..... | <b>10</b> |
| DSRC Fading Test.....   | 10        |
| VII Tolling Test .....  | 10        |
| ITS World Congress Demonstrations.....                          | 10        |
| Focus after the ITS World Congress.....                         | 11        |
| Networked Traveler – Foresighted Driving.....                   | 12        |
| Development of Networked Traveler – Foresighted Driving.....    | 13        |
| Public Launch.....  | 14        |
| Networked Traveler – Foresighted Driving Experiment .....       | 14        |
| Milestones.....   | 15        |
| Deliverables (on Disk 3) .....                                  | 15        |
| <b>Track 4 – Smart Parking</b> .....                            | <b>16</b> |
| NetworkedTraveler.org .....                                     | 16        |
| PATH2Go Smart Phone Application.....                            | 18        |
| Travel Times on Changeable Message Signs .....                  | 18        |
| Geo-fencing .....   | 18        |
| Field Testing .....   | 19        |
| Milestones.....   | 19        |
| Deliverables (on Disk 4) .....                                  | 19        |

## Overview

In March of 2008, the California Department of Transportation (Caltrans) and its partners submitted a research proposal in response to the solicitation from the Volpe National Transportation Systems Center (Volpe Center) regarding the SafeTrip-21 Initiative (*Safe and Efficient Travel through Innovation and Partnerships for the 21<sup>st</sup> Century*). The objective of the SafeTrip-21 Initiative was to expand and accelerate the USDOT's Vehicle-Infrastructure Integration (VII) Program (now called the Connected Vehicle Program), building upon current and prior research into the use of sophisticated information, navigation, and communications technologies to further national transportation goals in safety and mobility.

The submitted proposal was entitled, "The Connected Traveler Project". In accordance with the requirements of the solicitation, it provided for a Field Test Site with ITS Applications, and was comprised of the Connected Traveler Test Bed (built upon the existing VII California Test Bed), with the appropriate hardware, software, and architecture to field test a broad range of ITS applications, together with intermodal ITS applications covering the mobility, safety, and electronic-payment areas. The proposal described how the project would integrate the Field Test and ITS Applications into a product that could be:

- showcased at the 2008 ITS World Congress in New York City
- field-tested and evaluated on real roads to address mobility and safety needs in the greater San Francisco Bay Area, and
- demonstrated to prospective users and applications developers in order to stimulate deployment of SafeTrip-21 technologies.

The Connected Traveler Project proposal, led by Caltrans, was submitted as a public-private-academic partnership. It included the following private sector partners: Nokia, the largest cell phone handset manufacturer in the world; NAVTEQ, the largest digital map-maker in the world; and Nissan, a prominent auto maker. Public sector partners included the Metropolitan Transportation Commission (MTC), the metropolitan planning organization for the San Francisco Bay Area; SamTrans, the public transportation owner/operator for San Mateo County; and Santa Clara Valley Transportation Authority, the public transportation owner/operator for Santa Clara County. The academic partners were the California Partners for Advanced Transit and Highways (PATH), and the California Center for Innovative Transportation (CCIT), both of which are located at the University of California, Berkeley (UC Berkeley).

The Connected Traveler Project proposal was selected by the Volpe Center for the initial round of SafeTrip-21 funding (with subsequent funding later provided to other proposers, as well as to add Smart Parking scope to this Connected Traveler Project), and a Cooperative Agreement (DTRT57-08-H-00001) describing the work was signed by both Caltrans and the Volpe Center on April 30, 2008. The work of the Connected Traveler Project was broken up into the following four "Tracks", which were identified in the proposal:

- Track 0 – Caltrans Project Management
- Track 1 – The Connected Traveler Test Bed
- Track 2 – Mobile Millennium
- Track 3 – Group Enabled Mobility and Safety (GEMS)

On October 20, 2008, the Cooperative Agreement was amended to add scope to the initial Connected Traveler Project; this modification added Track 4 (Smart Parking), which incorporated a real-time smart parking element into the existing work plan, and added Parking Carma, a supplier of smart parking systems, as a private sector partner to the project.

Work on the first four tracks (0-3) began almost immediately after the signing of the Cooperative Agreement, taking advantage of existing contracts in place between Caltrans and its academic partners, PATH and CCIT. Since the first major milestone was to showcase the capabilities of this technology development at the 2008 ITS World Congress, there was much work to complete in limited time. It was an ambitious schedule, as the ITS World Congress was set to start on November 17, 2008, giving less than six months to prepare for it.

While the project was originally planned to be completed by January 31, 2010, for a variety of reasons, it was extended three times, finally ending on April 30, 2011. The reasons for these extensions will be presented in the body of this report.

The subsequent sections of this report provide details on each of the five tracks in the project, including the milestones and the deliverables. It is important to note that Tracks 2, 3, and 4 also have comprehensive final reports that describe their results in a greater level of detail, which are contained in the four Compact Disks that accompany this report. In a sense, these three tracks are more like individual projects of their own that have been bound together to create the Connected Traveler Project. The work in Tracks 2, 3, and 4 constitutes the bulk of the research findings from the project.



## Track 0 – Caltrans Project Management

The primary tool that was used for project management was a biweekly telephone conference call, called the “SafeTrip-21 Management Teleconference”, which took place every two weeks, and was led by the Agreement Officer’s Technical Representative, Gary Ritter of the Volpe Center, and the Caltrans Project Manager, Greg Larson. Representatives from the partners on the project team also participated, including those from PATH, CCIT, Nokia, NAVTEQ, and Parking Carma. The purpose of these calls was to report progress, chronicle any decisions made and the rationale for making the decision, and identify any pending action items and their due dates. The first conference call took place on Friday, May 16, 2008, and the last was on Monday, November 15, 2010. In all, 60 calls were held, and the minutes from 58 of these are included in the deliverables on [Disk 1](#). Minutes from the other two calls have been lost.

A secondary tool used for project management was the Quarterly Report, which described the progress made during the quarter and the plans for the next quarter. In all, 13 Quarterly Reports were submitted by Caltrans, beginning with the fourth quarter of state fiscal year 2007/2008 (April 1, 2008 to June 30, 2008), and ending in the fourth quarter of state fiscal year 2010/2011 (April 1, 2011 to June 30, 2011). Copies of the Quarterly Reports, along with the financial summaries that went with them, are included in the deliverables on [Disk 1](#). In addition, a Test Site Management Plan was developed jointly with the Volpe Center, and was updated as necessary to ensure that all partners were aware of the test objectives, methods, roles and responsibilities, and milestones.

During the course of the project, seven amendments were made to the Cooperative Agreement between Caltrans and the Volpe Center, ranging from advancing additional federal funds and/or extending the period of performance to adding scope, such as the Smart Parking amendment.

This list summarizes the amendments:

- Amendment 1 – added the scope and funding for the Smart Parking work (Track 4)
- Amendment 2 – advanced additional federal funding to cover progress to date
- Amendment 3 – no-cost time extension to 4/30/2010
- Amendment 4 – increased the federal obligation to accommodate changes in scope
- Amendment 5 – advanced additional federal funding to cover progress to date
- Amendment 6 – no-cost time extension to 11/30/2010
- Amendment 7 – increased the federal obligation, and time extension to 4/30/2011

### Milestones

- Project Kick-off Meeting, held in Sacramento, CA on Monday, June 16, 2008
- Media Event announcing the start of the SafeTrip-21 Initiative, held at the San Francisco-Oakland Bay Bridge Toll Plaza on Wednesday, June 25, 2008
- SafeTrip-21 Evaluation Kickoff Meeting, held at PATH on Tuesday, April 28, 2009
- SafeTrip-21 Presentation at the ITS America Annual Meeting, held in Union Harbor, Maryland, on Wednesday, June 3, 2009
- “Stop Work” notice, received from Volpe on October 28, 2009
- SafeTrip-21 Presentation at the TRB Annual Meeting, held in Washington, DC, on Monday, January 11, 2010



- Research and Innovative Technology Administration (RITA) Administrator visit to PATH, February 2, 2010
- Formal end of the Connected Traveler Project, Friday, April 30, 2011

**Deliverables (on Disk 1)**

1. [Cooperative Agreement, DTRT57-08-H-00001](#)
2. [Minutes from 58 SafeTrip-21 Management Teleconferences](#)
3. [Quarterly Reports for 13 quarters](#)
4. [Test Site Management Plan](#)
5. [Table of Deliverables \(Appendix A to Amendment 7\)](#)

## Track 1 – The Connected Traveler Test Bed

The original intent of the Connected Traveler Project proposal was to build upon the existing “VII California Test Bed”, which was created by Caltrans and MTC through an investment of \$1.5 million each in 2005/2006. As described in the proposal, this track had three tiers:

- Tier 1 – build upon the existing VII California Test Bed investment
- Tier 2 – purchase the parts needed to expand this test bed to a total of 40 sites
- Tier 3 – leverage the recently completed I-880 Integrated Corridor Management study to identify opportunities for safety improvements

Tier 1 was already complete at the start of the project, with 10 Dedicated Short Range Communications (DSRC)-based Roadside Equipment (RSE) locations already installed and operating. Under Tier 2, PATH purchased 30 additional RSE devices from TechnoComm (now Kapsch), and prepared them to be installed at signalized intersections along State Route 82 (also known as El Camino Real), in close proximity to the existing ones. For reasons explained in more detail in the write-up on Track 3, these RSE devices were never installed as planned. At a high-level, the main reason was that the direction of the research steered away from the concept of installing additional fixed infrastructure, and instead investigated the growing potential of using smart phones for both collecting traffic data and disseminating traveler information. Smart phones had the benefit of being supported by existing infrastructure, in the form of the cell phone network, and were becoming increasingly capable and sophisticated at the time such that they could perform many of the functions originally envisioned in the Connected Traveler Project.

Tier 3 involved building upon the foundation that was created by the corridor study of I-880 that was completed in 2007. This study identified safety challenges along the corridor, primarily due to having insufficient capacity to meet the growing demand for travel. Tier 3 had a strong connection to Track 3, the Group Enabled Mobility and Safety, in the sense that the original plan was to tie together the VII California Test Bed with the I-880 corridor in ways that would improve safety and mobility there. In the end, however, the biggest connection between Tier 3 and Track 3 was due to the inclusion of I-880 as one of the corridors to be used for the Networked Traveler – Foresighted Driving research.

### Milestones

None

### Deliverables (on [Disk 1](#))

1. [Report on the analysis of the I-880 corridor to determine opportunities for safety improvements](#)

## **Track 2 – Mobile Millennium**

The concept behind the Mobile Millennium track was quite simple: to derive real-time traffic conditions by collecting probe vehicle data from GPS-equipped cell phones as they travel through the roadway network. It took advantage of advances in cell phone technology, particularly the trend of including GPS chips in the phones that enable precise speed and location determination. In addition, when this track began in 2008, many cell phone manufacturers were beginning to increase the amount of intelligence contained in the hardware of their phones, making them into “smart” phones, as they are commonly known today. Finally, the cell phone network service providers were increasing the emphasis on transmitting data through their networks, in addition to the voice component that was the original impetus for cell phone development, enabling this GPS data in the phone to be sent back to a central location. It was the convergence of these three trends that made the Mobile Millennium research possible.

The transportation community had already considered the potential for cell phones to operate as traffic data collection devices for several years. Historically, in order to obtain traffic data, transportation agencies deploy networks of infrastructure-based traffic sensors that are expensive to install and maintain. Leveraging the existing infrastructure of commercial cell phone networks could drastically cut the ongoing costs of traffic monitoring and expand coverage to thousands of miles of highways and urban arterials, for which sensors are not currently a viable option. However, further testing was needed in order to confirm whether or not this innovative approach would work.

### **Mobile Century**

On February 8, 2008, Nokia and CCIT demonstrated the ability to reconstruct traffic conditions on roadways using cell phones by running an experiment, called “Mobile Century”, which included 100 cars traveling in 10-mile loops on I-880 for eight hours, which amounted to 2-5% of the total traffic volume during that period. Using an application running on GPS-equipped Nokia N95 smart phones in the cars, speed and location data were continuously sent in a privacy-protecting manner through the cell phone network back to data servers at Nokia and CCIT. At the servers, the data from each of the cars was processed and aggregated with data from other cars in the experiment into traffic speed-map information that was displayed in real-time on video monitors at the event sites. This speed-map information was compared side-by-side with information obtained from loop detector sensors, showing a strong correlation between the two. Subsequent analysis of the raw data showed clearly that, even with only a small fraction of the cars on the roadway equipped (again, 2-5%), the traffic information derived from the vehicle probes was as good, if not better, than that coming from the infrastructure-based sensors. Funded by Caltrans, this successful experiment was the precursor to Mobile Millennium, which was then crafted to take the concept and experience gained from Mobile Century and test it further by giving access to the smart phone application to the general public.

### **Development of the Mobile Millennium Test**

There were two primary technology components to the Mobile Millennium test: the Traffic Pilot application; and the back office computer servers and algorithms that processed the incoming probe data and provided the speed-map information back to the users. The researchers at Nokia had sole responsibility for the development and ongoing maintenance of the Traffic Pilot application. Nokia developed versions of the Traffic Pilot for two operating system platforms:

Symbian (for Nokia phones), and Blackberry (for Research In Motion phones). The application gathers speed and location data in a privacy-preserving environment, relying on a technology called “Virtual Trip Lines”, which is a data sampling paradigm that anonymizes the GPS-based data and aggregates it into a single data stream. The aggregated data is then encrypted and sent through the cell phone network to servers at Nokia and CCIT. In addition to the initial version available at the Mobile Millennium launch, Nokia prepared several updates to the Traffic Pilot application along the way to add features and fix bugs.

Researchers at CCIT, in conjunction with NAVTEQ, were responsible for developing the back office systems for Mobile Millennium, particularly the traffic model algorithms used to create the speed-maps for freeways and arterials. They constructed an unprecedented traffic monitoring system capable of fusing GPS data from smart phones with data from existing traffic sensors to create accurate and reliable real-time traffic information. This information was then sent back to the user’s smart phone through the cell phone network, where it was displayed on the screen.

### **Mobile Millennium Launch**

Before Mobile Millennium could be pilot-tested, there needed to be a way to compel members of the general public to install the application on their smart phones; there had to be something in it for them so that they would agree to share their traffic data during the test. This payback was given in the form of a speed-map that would show their map location on the smart phone display, along with green-yellow-red indications of the relative speed of traffic driving their route. After launching the application, drivers could tap the phone to display the speed map on the screen, and it moved along with them, keeping their location centered to continuously show the traffic conditions around them. After a brief time, the screen would darken in order to reduce the battery drain, while the application continued to run and send the traffic probe data in the background. The user interface for the application conformed to California laws governing the use of cell phones while driving, enabling it to operate “hands free”.

The launch of Mobile Millennium to the general public, including the release of the free smart phone application called the “Traffic Pilot”, was announced at a special preview event at UC Berkeley on November 10, 2008. Leaders from transportation, government, and academia assembled there to see presentations about the technology and how it worked. An audience of invited early adopters, the media, and live webcast viewers took part in this event. Following a brief presentation, guests were invited to download the application and drive off as the first mobile probes in the Mobile Millennium system. The Traffic Pilot application was made available to San Francisco Bay Area and Sacramento area residents with compatible smart phones. The first phase of the launch included traffic information for freeways, while information on arterial routes was introduced later as more and more users came online and sufficient probe data became available.

During the one-year period of the Mobile Millennium test, from November 10, 2008 to November 10, 2009, more than 4,000 users downloaded the Traffic Pilot application into their smart phones. Due to the privacy protection techniques employed, there was really no way to determine whether an individual was using it at any given time, or whether the people that downloaded it were even using it. Due to the size of the test region, and the most likely distribution of these users in both time and space, it is reasonable to assume that most of the

traffic information content on the speed-maps came from sources other than the smart phone probes.

### **Milestones**

- Kickoff Event, November 10, 2008 in Berkeley, CA
- Arterial testing and demonstrations in Manhattan, during the ITS World Congress, November 17-20, 2008
- Demonstration for attendees of the AASHTO Annual Meeting, held in Palm Desert, California, on Friday, October 23, 2009
- Public links to the Mobile Millennium Application shut down, November 10, 2009
- Arterial testing conducted in the San Francisco Bay Area, May 2010
- Briefing for Jeff Lindley and staff from the FHWA Office of Operations, held on Tuesday, August 17, 2010

### **Deliverables (on [Disk 2](#))**

1. [Mobile Century Data](#)
2. [Arterial Data from New York City Testing](#)
3. [Arterial Data from San Francisco Testing](#)
4. [Freeway Traffic Model](#)
5. [Arterial Traffic Model](#)
6. [Mobile Millennium Test Plan](#)
7. [Visualization Tool](#)
8. [Final Report for Mobile Millennium](#)

## Track 3 – Group Enabled Mobility and Safety (GEMS)

The proposed GEMS work intended to create a host of multi-modal applications related to safety, mobility, and electronic payment, hinged around the use of consumer devices that travelers already carry with them. One portion of GEMS would develop and showcase applications based on existing consumer devices as a mean of generating and providing traffic and safety data, while another would develop transit-related applications. All these applications were aimed at creating a *Connected Traveler* for the benefit of new developers, existing institutional users, and the traveling public. The concept of the GEMS and Transit applications was to stimulate developers and implementers of services stemming from these applications to bring their integrated development to the California field test site for test and evaluation.

### DSRC Fading Test

Since the field test site, as well as the 2008 ITS World Congress demonstration site in New York City, used DSRC-based Roadside Equipment as one means of communication, it was critical to determine the capabilities and limitations of DSRC in real world situations, such as in “urban canyons” and in various types of geographic terrain. To gain insight into the performance of DSRC under these conditions, PATH researchers collaborated with the VII Consortium (a partnership of auto makers performing pre-competitive research) in conducting signal strength tests. Specifically, PATH provided the Roadside Equipment and engineers needed for performing the test, while the VII Consortium provided the vehicles and drivers used in the testing. The tests took place at several locations in downtown San Francisco, as well as on State Route 1 just south of San Francisco. The results of this testing helped guide the VIIC in designing the DSRC infrastructure configuration for their demonstrations at the ITS World Congress in New York City, which had an urban setting that was very similar to downtown San Francisco. For the Connected Traveler Project, the GEMS demonstrations conducted at the ITS World Congress used the same DSRC infrastructure, so it also benefited from this real world test experience. The test results are included on [Disk 3](#) as the “DSRC Fading Test Final Report”.

### VII Tolling Test

In addition to this signal strength testing, the research team performed another field test related to Electronic Toll Collection. In support of the electronic payment application mentioned in the Overview section, this task evaluated the performance of using DSRC to record a toll transaction, including not just the roadside-to-vehicle communications, but also the back office processing necessary to confirm that the transaction successfully occurred. With assistance from PATH for the Roadside Equipment portion, MTC led the testing, which took place at the Dumbarton Bridge Toll Plaza on State Route 92. [Disk 3](#) contains the results of this testing as the “VII Tolling Test Final Report”.

### ITS World Congress Demonstrations

The proposed plan was to showcase the GEMS work at the ITS World Congress in New York City in November of 2008. With only about six months to prepare, it was urgent to plan and execute a demonstration that would adequately both announce and promote the existence of the SafeTrip-21 Initiative. In order to maximize the number of participants, the project team decided to use a transit bus as the vehicle of choice for the demonstrations, making arrangements with New York City Metro to borrow and equip one of their buses. The demonstrations took place as a 30-minute ride along the streets of Manhattan near the site of the ITS World Congress, with the

first half of the trip representing the “driving” experience (where participants were asked to pretend that they were driving) and the second half representing the “riding” experience, as if participants were riding on public transportation, as they were.

The demonstrations were composed of the following three parts:

1. **Tell me about my trip:** pre-trip planning for drivers and transit riders, including route comparisons and travel times, as well as transit connection and transfer information
2. **Tell me about the road:** while en route, receiving real-time road conditions, estimated time of arrival, school and work zone alerts, and parking availability
3. **Watch out for me:** alerting drivers to the presence of nearby pedestrians, roadway workers, or disabled vehicles

As the demonstration participants entered the bus, they were handed a Wi-Fi enabled smart phone on which to witness the different capabilities. There were also large displays mounted inside the bus to show the same information as on the phones. Participants were first asked to “plan” both the “driving” and “riding” parts of their trip using the browser on the smart phone, with researchers nearby to help with any problems. This was the “tell me about my trip” part of the demonstration. The bus then travelled the planned route, with real-time information about posted speed limits and simulated construction events related to their trip being delivered to the smart phone at the appropriate places in order to make the trip safer and more efficient. This was the “tell me about the road” part of the demonstration. The “watch out for me” part was demonstrated using a volunteer pedestrian whose smart phone generated an alert to the bus driver that he was nearby. Moreover, at the end of the trip, the full circle was made to the “tell me about the trip”, and the green house gas emission savings of the transit trip taken versus a nominal individual trip taken with a private automobile was posed.

The technology used to enable these capabilities was based on DSRC for the infrastructure-to-bus-portion of the information transfer. DSRC-based roadside equipment had been installed at various locations along the route to support the demonstrations, and they transmitted information from the roadside to corresponding DSRC-based on-board equipment on the bus. This information was received in the bus and then re-transmitted to the smart phones of the participants using the on-board Wi-Fi network.

### **Focus after the ITS World Congress**

After the ITS World Congress, the project team reassessed the objectives of the research, and determined that the original vision of GEMS was not the best way to continue forward. While the demonstrations in New York were a success, they depended heavily on specialized infrastructure installed specifically for this event, with a great deal of time and effort invested. Duplicating that same capability at the test bed site in the San Francisco Bay Area would result in, at best, a geographically small test area, and a small number of potential users for testing the concepts. The project team wanted to cover a larger area, and access a greater number of potential users than would have been accommodated with the original plan. One lesson that had been learned from the ITS World Congress experience was the potential for smart phones to become a ubiquitous tool for both collecting data and sharing information on a personal level. Recognizing this potential, the project team decided to move away from the use of DSRC and focus instead on smart phones as the mechanism for achieving the desired objectives of SafeTrip-21: to expand and accelerate the at the time IntelliDrive Program using existing and



emerging technologies. Using the existing cell phone network and the emerging trend of smart phone availability was chosen by the project team as the best way to achieve these objectives.

The GEMS demonstrations at the ITS World Congress used smart phones running a web browser under the Windows Mobile operating system as the means for showing the demo results, and it became clear to the PATH developers that this web browser approach was not suitable for continued development due to the poor quality of user experience. At the time (mid-2008), only a small number of cell phones were technically capable of even running a web browser, and doing so was often a slow and frustrating user experience. Coupled with that problem, the cell phone network itself was just becoming capable of transmitting the data at speeds necessary to truly support web user sessions, and even so often with significant reliability issues. The original Apple iPhone had been released only a year earlier (June 2007), and depended on AT&T's EDGE network (only with "2G" data rates) to make it work; "3G" network coverage from AT&T and Verizon was just starting to become commonly available and reliable in major urban areas.

At around the same time, the iPhone's popularity made the concept of smart phone applications ("apps") widely acceptable. With web-based applications, the user experience was dependent on the speed of the servers in the back office, the ability of the cell phone network to reliably deliver information from the servers to the smart phone, and the speed of the phone's mobile web browser to display the information. In contrast, smart phone apps combined the use of a webserver and on-board processing, leveraging the ever-increasing performance of the phone hardware to make the user experience more acceptable. This approach buffered and mitigated the relatively slow speed of the cell phone network and the back office data servers. The result was a reasonable user experience that was far superior to the browser-based one. Therefore, the project team chose to use smart phone applications for the user interface instead of mobile web browsers.

While examining the objectives of the project after the ITS World Congress, the project team made another decision worth noting. In October of 2008, incorporation of the smart parking track into the existing work gave an opportunity to reconsider the division of work between the GEMS track and the Smart Parking track. Based on these considerations, the decision was made to split the GEMS track into two pieces, one with an emphasis on providing "soft safety" for drivers, and the other with an emphasis on delivering the necessary real-time information to travelers while en-route that would enable them to make better decisions on mode, route, and time of travel. The "soft safety" work was kept in Track 3, and renamed "Networked Traveler – Foresighted Driving", while the GEMS transit mobility work was moved into Track 4, and renamed "Networked Traveler – Transit and Smart Parking". The remainder of the discussion in this track will focus on describing Networked Traveler – Foresighted Driving, and Track 4 will summarize the work on Networked Traveler – Transit and Smart Parking.

### **Networked Traveler – Foresighted Driving**

The hypothesis that was tested under the Networked Traveler – Foresighted Driving research was whether or not an "alert" delivered to drivers regarding slow or stopped traffic ahead would change their behavior with respect to avoiding end-of-queue type crashes on freeways. It was called "soft safety" in the sense that it did not require the driver to take immediate action to avoid a crash, a case which would have been more appropriately in the realm of a "hard safety"

warning. The timeline for the test was to deliver this alert about one minute (roughly one mile upstream at free-flow freeway speeds) before the end of the queue of the slow or stopped traffic ahead was encountered. It was intended to capture the attention of inattentive drivers so that they could begin to slow down in a controlled manner, prior to reaching the end-of-queue. This approach was aimed at increasing the “situational awareness” of the driver in a way that could reduce the number and severity of freeway end-of-queue crashes.

The rationale for choosing to address this safety problem came out of prior research performed for the I-880 Integrated Corridor Management Project, as well as analysis completed by PATH safety researchers for the larger San Francisco Bay Area freeway network. This analysis showed that 40-50% of the crashes that occur on freeways in the Bay Area, and from a sample received from Florida DOT, can be classified as “end-of-queue” type crashes. A primary causal factor was distracted or inattentive drivers travelling at free-flow speeds suddenly encountering significantly slower or stopped traffic ahead, and not having enough time to brake safely before crashing into the vehicle in front of them. Based on this analysis, the research team decided to pursue the concept of providing an alert to drivers that would help ensure their concentration on the driving task so that they could avoid these types of crashes.

### **Development of Networked Traveler – Foresighted Driving**

There were three main components of Networked Traveler – Foresighted Driving that were needed in order for the test to be successful. The first was the mechanism for delivering the alert to drivers. The research team decided to use smart phones to achieve this objective, creating an application that generated an audio alert (intended to reduce driver distraction), as well as displaying a symbol on the phone display to indicate at a glance that an alert had been issued. The original design also had the option for drivers to touch the phone screen if they considered the alert to not be justified, so that the system could learn the driver’s preferences and eventually minimize the number of nuisance alerts issued.

The second major component was the ability to detect slow or stopped traffic on freeways so as to determine when an alert should be delivered to the driver. Since traffic queues do not always form in predictable manner, developing this capability was quite a challenge. The research team decided that the use of infrastructure-based sensors was the only realistic way to detect the presence of traffic queues, with the understanding that many sensors would be needed to get the best coverage, but also that not all locations would be covered due to the large geographic size of the region. Two partners on the team gave access to the traffic data from their own sensors: MTC provided data from 520 SpeedInfo side-fire radar sensors, and NAVTEQ Traffic provided data acquired from 1,650 of their sensors of multiple types. While not continuous and with some lag, the data from these 2,170 point sensors gave fairly comprehensive coverage of the major urban freeways in the Bay Area, enabling traffic queues to be detected in almost all the locations where concentrations of end-of-queue crashes occur.

The final component was the back office processing of the traffic data from the sensors to determine the location of queues, as well as an algorithm for determining if an alert was warranted. Computer servers in the back office used GPS data from the smart phone to track vehicles as they moved through the freeway network, and compared the vehicle location with the location of known traffic queues. If the criteria under the alert algorithm – a speed differential

of 15 mph and a heading toward the end of queue – were met, an alert condition would be identified and sent to the smart phone in the vehicle through the cell phone network.

### **Public Launch**

As with the Mobile Millennium track, the intent of Networked Traveler- Foresighted Driving was to have a public launch of the smart phone application, so that anyone with a compatible smart phone in the Bay Area could download the application into their phone from a web site and use it to increase their safety while travelling on freeways. The initial application was only compatible with Windows Mobile smart phones, with the plan was to migrate it to other smart phone types as time went on, and it was made ready for a public launch to take place on Thursday, November 5, 2009. PATH researchers had already made arrangements with several organizations, including MTC, AAA, and Transportation Management Association (TMA) SF, to endorse and promote the application to the public.

The week before the public launch was to occur, Caltrans received notice from Volpe that it should stop work and make arrangements to wrap up the project prematurely. This notification came out of growing concerns by the USDOT of the potential for distraction caused by the use of cell phones by drivers while driving. The notification also gave Caltrans and Volpe the option to negotiate a change to the scope of the project that would allow it to move forward if the concerns over driver distraction could be addressed. Both sides considered suitable options for modifying the project in a way to would be acceptable to all concerned.

### **Networked Traveler – Foresighted Driving Experiment**

After careful consideration, an agreement was reached that mitigated the driver distraction concerns. Instead of a public launch, the project team would perform a controlled experiment on real freeways using a suitable number of naïve drivers to test the effectiveness of the concept in improving freeway safety. In addition, the alert was to be given in audio form only, through the existing stereo system in the car, so as to minimize the potential for distraction.

This experiment involved 24 drivers and four cars that were equipped to capture key aspects of driver behavior, including speed, acceleration, and braking, amongst others. The four cars were loaned to the individual test drivers for a two-week period; during the first week, no alerts were issued, so the drivers exhibited their naturalistic driver behavior, which was captured via the on-board sensors in the car. During the second week, the end-of-queue alerts were turned on, and again the driver's behavior was recorded. Based on the changes to driver behavior from the first week to the second, the hypothesis was tested to see if it was valid.

The data collection began in July of 2010, and continued until November of 2010. There were some technical issues with the instrumented cars, so the data collection actually took longer than what was planned. After the data was reduced and analyzed, it did show a change in driver behavior from the first week of driving to the second. In general, the drivers tended to “coast” more after receiving the end-of-queue approaching alert, taking their foot off the accelerator as they moved closer to the slow or stopped traffic ahead. Based on this behavior change, it is expected that such an alert would have a positive impact on freeway safety if it was widely deployed. The detailed results of the experiment are available on [Disk 3](#).

## Milestones

- DSRC Fading Test, conducted in downtown San Francisco on April 14-15, 2008
- Demonstration for the ITS America Board of Directors, held at PATH on Wednesday, August 6, 2008
- Demonstration for the AASHTO Subcommittee on System Operations and Management, held at PATH on Wednesday, August 13, 2008
- VII Tolling Test, conducted at the Dumbarton Bridge Toll Plaza on Tuesday, September 30, 2008
- ITS World Congress demonstrations, held in New York City from Monday, November 17 to Thursday, November 20, 2008
- Experimental testing began, Saturday, July 17, 2010
- Experimental testing ended, Monday, November 15, 2010

## Deliverables (on [Disk 3](#))

1. [DSRC Fading Test Final Report](#)
2. [VII Tolling Test Final Report](#)
3. [Task Order 6615 Final Report, entitled “SafeTrip-21 in California: Enabling the Connected Traveler”](#)
4. [Networked Traveler – Foresighted Driving Experimental Design](#)
5. [Networked Traveler – Foresighted Driving Preliminary Report](#)
6. [Networked Traveler – Foresighted Driving Final Report](#)

## Track 4 – Smart Parking

This track was added by an amendment to the initial Cooperative Agreement between Caltrans and the Volpe Center on October 20, 2008. It was based on a separate proposal that was submitted during the initial SafeTrip-21 solicitation. Since Caltrans was also the lead partner for this effort, the Smart Parking work was simply incorporated under the existing Cooperative Agreement rather than being accomplished through a separate agreement.

The original proposal for Smart Parking was to provide information related to transit travel time and parking availability to freeway drivers to entice them to switch modes from driving to riding public transportation. The hypothesis was that, if enough drivers did switch modes, congestion on the freeway would be reduced, benefiting all drivers while taking advantage of under-utilized capacity on existing public transportation. If the hypothesis was valid, then it would result in a better balancing of transportation demand across different modes and the existing supply.

The location chosen to test the hypothesis was the US-101 corridor between Santa Clara in the South and San Francisco in the North (the original proposal had an option to perform additional testing in the San Diego region, but this option was never exercised). The rationale for this selection was the availability of high-quality public transportation adjacent to and running parallel with US-101: the SamTrans-operated Caltrain heavy commuter rail travelling between San Jose and San Francisco; the BART high-speed subway train connecting to the Caltrain in Millbrae and covering much of the Bay Area; and the VTA-operated Bus Rapid Transit (BRT) line travelling along El Camino Real (State Route 82), a signalized arterial running the entire length of this corridor. For much of the US-101 corridor, each of these modes of public transportation had available capacity to accommodate additional passengers, as well as excess parking to provide drivers with easy access to their services. The main ingredient still missing was availability of timely, accurate, and reliable multi-modal traveler information that would give drivers confidence in choosing to switch modes of travel. To investigate traveler behavior if such information was given was the purpose for the test.

As described briefly in the discussion of Track 3, the original intent of the Smart Parking proposal was modified slightly to accommodate the transit mobility aspects of the original GEMS work. In this respect, the objectives of the test were broadened to entice mode switching by providing time savings benefits for choice travelers, but also to enhance the provision of traveler information to those travelers already planning to ride transit. The new approach was called “Networked Traveler – Transit and Smart Parking”, and it focused on three major components:

1. A web-based, integrated, multi-modal, pre-trip planning tool
2. A smart phone application that delivered real-time, multi-modal traveler information to both drivers and transit riders while they were en route
3. Real-time, multi-modal information displayed on roadside Changeable Message Signs, comparing driving time versus train travel time, also with parking availability

### [NetworkedTraveler.org](http://NetworkedTraveler.org)

To support the first two components, PATH developers created a publicly accessible web site, called NetworkedTraveler.org. From this web site, users could perform three main functions:

1. Plan a trip

2. Download the mobile application into a compatible smart phone
3. View the real-time location of trains and buses, as well as parking availability, at a glance

These functions were heavily dependent on access to information regarding both the real-time and the scheduled location of the public transportation vehicles (trains and buses). This information was already available directly from BART, but PATH also negotiated with SamTrans to obtain permission to instrument all 29 Caltrain locomotives with Automated Vehicle Location (AVL) devices, and with VTA to similarly equip the BRT buses. Driving times on US-101 were also needed, and MTC provided them through its existing 511 system. In addition, parking space availability at selected lots was obtained using sensors that PATH installed at the exits and entrances, with the data being transmitted through ParkingCarma's real-time parking information system and then accessed by the NetworkedTraveler.org web site.

Using all this rich information as the foundation, the web-based integrated multi-modal, pre-trip planning tool was capable of providing comparisons of different modes based on travel times, cost of transportation, and carbon footprint. It also made note of the fact that time spent riding on transit could be considered "productive time", in the sense that the rider could work, sleep, or read during this time instead of having to drive.

The method used for planning a Networked Traveler trip is quite simple: after selecting the trip planning tool from the opening web page, a map of the San Francisco Bay Area is shown on the screen, along with different ways for selecting the origin and destination for the trip. Once this step is completed, the tool displays one or more transportation options for the trip, at least one of which is driving. These trips options are displayed for side-by-side comparison, showing individual travel times, estimated trip costs, and estimated impact on the environment (driving alone has the biggest impact; at the other end of the scale, biking and/or walking has the least; everything else is somewhere in between). By clicking on a specific trip option, users can examine the details of the itinerary, including route, transit stations, and connections/transfers. This information is primarily real-time, and assumes that the traveler is leaving immediately, with an option to plan a trip for later also available. The value of this tool is that in one integrated web site, the traveler can access and compare the information for multiple modes and operators, instead of having to jump from site to site based on the jurisdiction involved. Even more value is added in the sense that the information displayed is primarily real-time in nature, rather than scheduled, so it reflects travel options based on current conditions.

The second function, downloading the smart phone application, was fairly straightforward: registered users of the service could follow the instructions contained in this link to install the associated mobile application into their compatible smart phone. More details on the smart phone application are provided later in this report.

The third function, viewing of real-time traveler information on the web site, was suggested by staff at MTC, and is based on their own past experience. Access to the first two functions required that users have an account on the system, and they had to be logged in to their account to use them. MTC's experience with similar systems was that this approach is sometimes a deterrent from getting users to participate at all. They suggested that PATH create a way for casual users to view the real-time traveler information without having to establish an account, as

a way to show them the value of the tool. This experience could convince these users to take the next step of actually creating an account. Since the only way to collect data on user behavior (needed in order to determine the success of the test) was through accounting for trips planned and taken by logged-in users, this function was added with that objective in mind.

### **PATH2Go Smart Phone Application**

The smart phone application for Networked Traveler – Transit and Smart Parking was called “PATH2Go”. It was the main focus of this test. The project team believed that, while having the ability to plan a trip based on then current travel conditions was certainly useful, the real value of this research was in its ability to deliver key pieces of trip-related information to travelers while they are en route, enabling them to make good decisions based on real-time conditions, which can change rapidly after a trip is planned. Having the PATH2Go application installed and running on their smart phones gave travelers this capability.

PATH initially developed versions of PATH2Go for the iPhone and Windows Mobile smart phones, and later added a version for Android smart phones. The NetworkedTraveler.org web site gave users instructions on how to download and install the application on their phone. Once installed, users could upload trips into their phone that had been planned using the web site tool, then PATH2Go would guide them throughout the duration of the trip. For drivers, this guidance came in the form of travel time and estimated time of arrival at their destination, as well as alerts for traffic conditions ahead (such as crashes, major slowdowns, or lane closures). Park-and-ride transit riders received information on parking availability, station arrival times for trains and buses, estimated time of arrival at their destinations, connection and transfer information, and “your stop next” alerts. Having access to this real-time information enabled travelers to make better decisions that improved both their safety and mobility.

### **Travel Times on Changeable Message Signs**

The third component of the research in this track was the real-time information posted on existing Caltrans Changeable Message Signs along the US-101 corridor. Prior research had already pioneered the means for posting driving times versus scheduled Caltrain travel times along the corridor, and train travel times are often competitive with driving times during peak travel hours, or when any type of incident occurs on US-101. The work under this component replaced the scheduled Caltrain travel time with real-time information coming from the AVL devices in the locomotives, and added information about parking space availability generated from the instrumented Caltrain parking lots. The value of this component is that even drivers that are not using the PATH2Go application can still get the benefits of access to real-time traveler information related to their trip by viewing the signs as they pass.

### **Geo-fencing**

As with the Networked Traveler – Foresighted Driving research, the Networked Traveler – Transit and Smart Parking test created concerns about the potential for distracted driving, so it too was affected by the stop work notice discussed in Track 3. The test was slated for a public launch, but that plan was delayed while Caltrans and Volpe negotiated ways to address the distracted driver concerns. One approach that was considered and eventually adopted was called “geo-fencing”.



In this context, the term “geo-fencing” was used to describe the code added to the PATH2Go application that enabled it to determine whether or not the user might be driving a car while accessing the application. If it was determined that the user might be driving, then the application was disabled from use. The objective was to enable the application for transit users, where driver distraction is not an issue, and to disable it for those that are likely to be driving, so as to not be a distraction.

Functionally, the geo-fencing code checked the speed information from the GPS receiver in the smart phone, and if it was above a threshold, it would be assumed that the user was travelling in a moving vehicle. If the vehicle position, also obtained from the GPS receiver in the smart phone, could not be associated with the known location of one of the instrumented transit vehicles (Caltrain, BART, or a BRT bus) taking part in the test, it was assumed that the user was driving. In this case, the application would display a warning on the smart phone, informing the user that it could not be used while driving, and preventing its use. Note that the PATH2Go application would also be disabled even if the user was just a passenger in a car, since developing the capability to differentiate between driving or just riding in a car was beyond the technical scope of this research. To be clear, geo-fencing was implemented in a manner to favor disabling the application if there was any indication that the user might be driving.

In addition to the geo-fencing code development, PATH researchers performed a literature search for commercially available smart phone applications that performed functionally the same purpose as the PATH2Go geo-fencing. They also analyzed and compared the features and performance of these products, and the results of that work are one of the deliverables on [Disk 4](#).

### **Field Testing**

Due to the driver distraction concerns, the Networked Traveler – Transit and Smart Parking test could not be conducted as it was initially planned. In the original proposal, the emphasis of the test was to explore whether access to real-time traveler information delivered to freeway drivers while they are en route would entice them to switch modes from driving to riding transit. Due to the concerns regarding the potential for driver distraction, however, it became a considerably different test, instead emphasizing the pre-trip planning portions, and only delivering en route real-time information to transit riders that were not subject to these concerns. The main results from the test were qualitative in nature, being the survey inputs from registered users. These survey results are contained in the Final Report on [Disk 4](#).

### **Milestones**

- Amendment 1 to the Cooperative Agreement, adding the Smart Parking work, was signed on Monday, October 20, 2008
- Demonstrations for the APTA General Managers during their Annual Meeting, held in Santa Monica on Saturday, January 24, 2009
- Geo-fencing field tests, Monday, March 29 – Friday, April 2, 2010
- Field testing began, Thursday, July 29, 2010
- Field testing ended, Monday, November 15, 2010

### **Deliverables (on [Disk 4](#))**

1. [Feasibility Report for Smart Parking](#)
2. [Networked Traveler – Transit and Smart Parking Experimental Design](#)

3. [Commercial Products for Geo-fencing Final Report](#)
4. [Geo-fencing Test Results](#)
5. [Networked Traveler – Transit and Smart Parking Final Report](#)