Responder Phase 2

Final Report

by

Daniell Richter
Research Associate

Kelvin Bateman
Research Associate

Douglas Galarus
Program Manager
Systems Engineering and Development Integration

of the

Western Transportation Institute
College of Engineering
Montana State University

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EXECUTIVE SUMMARY

The California Department of Transportation (Caltrans) has contracted with the Western Transportation Institute (WTI) at Montana State University (MSU) to develop the "Redding Responder System." The system integrates hardware and software to form an incident reporting platform that is usable in both rural and urban areas. Responders use the included digital camera to photograph incidents. Photos are uploaded to a Tablet PC, and can be annotated using a pen-like stylus and combined with other relevant incident information including location that is automatically recorded with GPS software. Incident information is sent to the Transportation Management Center (TMC) via cellular or satellite modem. The information is used for incident response.

The purpose of this document is to present a summary of Phase 2 of this project.

At the conclusion of Phase 2, all project deliverables will have been delivered, and the project will have achieved its goals. A third phase is anticipated to start in early 2010, to carry forward with the work conducted in Phase 2, and prepare the system for corporate deployment.

In Phase 2, the project team further developed and hardened the system for pilot evaluation throughout Caltrans. Two units were deployed that included a communication briefcase, providing both cellular and satellite service. Two more units were deployed with cellular service and GPS both integrated into standalone ToughBooks. These units were tested in nearly all Caltrans districts, including rural and urban areas. The system in general was well-received and there was great interest in proceeding with prospective deployment throughout Caltrans.

While the system performed well and was generally well-received, a number of technical and institutional issues were encountered that require further attention in an anticipated third phase. These include problems with satellite data service providers, as well as procurement and general support challenges within Caltrans. And, other technology – specifically smartphones – has progressed to a point where alternate platforms for the system should be given more serious consideration.

The system functionality and overall concept has generally remained the same throughout this phase. The emphasis on ease of use and general rather than agency-specific implementation for documentation of incidents has proven to be key in the success of this phase.

1. INTRODUCTION

The purpose of this document is to summarize the work completed as part of Phase 2 of the Responder project.

1.1. Phase 2 Goals

The goal of Phase 2 was to evaluate and prepare for full corporate deployment of the Responder system. The objectives, as stated in the original scope of work, were:

1. Develop a business case to help Caltrans to determine whether and how to proceed with full deployment.

   The WTI project team, in cooperation with Caltrans, will conduct a business case analysis and produce documentation for use in a Feasibility Study Report (FSR). WTI will develop plans for long-term maintenance of the system.

2. Conduct further system development to "harden" the system, making it ready for field use.

   The project team will evaluate hardware to reduce the size of equipment and to harden the system for use in extreme heat and cold. Software will be finalized to accommodate hardware updates and to increase usability and robustness of the system.

3. Test the system in multiple locations and with multiple crews in real use situations.

   The system will be installed in vehicles for use by several crews over a one- to two-month period during which incidents and usage are most likely to occur (Winter/Spring). Training materials will be prepared and onsite training will be conducted to prepare crews for system use, and support will be provided to assist them during the trial.

4. Evaluate the system under real use situations.

   The WTI project team will evaluate system use during the testing period. Criteria will include ease of use, usefulness and reliability.

1.2. Project Tasks

The work plan for Responder Phase 2 consisted of the following five tasks:

- Task 1: Project Management
- Task 2: Business Case Development
- Task 3: On-Going Development and Documentation
- Task 4: Pilot Testing – Unsupervised
- Task 5: Evaluation

1.3. Report Organization

This report presents a summary of activities that were and were not completed during Phase 2 of the Responder effort. As project management activities encompassed work related to budget maintenance, communications with the project sponsor, scheduling and the like, a discussion of the work completed for that specific task has been excluded. Remaining chapters of this report will summarize each of the remaining tasks listed above.

2. BUSINESS CASE DEVELOPMENT

At a high level, the Responder system is consistent with the Caltrans mission and goals of safety, reliability, performance, flexibility, stewardship and delivery. At a lower level, Responder benefits users in terms of situation awareness. For instance, Responder can be used by responders to quickly and accurately collect and communicate information about an incident with their TMC and other interested parties.

The Responder system is also consistent with stated goals in the Federal Transportation Reauthorization Bill. In particular, Section 1702, "Real-Time System Management Information Program," calls for nationwide ability to "… provide the capability and means to share (management) data with state and local governments," as well as statewide incident reporting systems that facilitate the "real-time electronic reporting of incidents to a central location for use in monitoring the event, providing accurate traveler information, and responding to the incident as appropriate." In remote rural areas, such electronic reporting of incidents has generally been impractical.

In a separate document, the project team presented a preliminary business case and other information gathered in preparation for an FSR, as is required by Caltrans for the mainstream implementation of new technology. Since the FSR is an internal Caltrans document, it was not the intent of the authors to present a complete FSR within that document. Rather, the intention was to provide supporting information that Caltrans can use in preparation of a final FSR for the Responder system. There is certain information required in the final FSR that only Caltrans can supply. The referenced document does follow the general outline of an FSR and includes placeholders for information that will subsequently be supplied by Caltrans, as well as several inline comments.

3. ON-GOING DEVELOPMENT AND DOCUMENTATION

Phase 1 of Responder presented a proof of concept for an application to assist responders in documenting incident information and communicating that information to the TMC and cooperating responders. The initial Responder unit created for field testing consisted of a Panasonic Toughbook with a Verizon Wireless cellular modem card and a custom incident organizer application. WTI then built a communications case that added a Globalstar satellite modem in addition to the Verizon cellular modem, and additional equipment to communicate with the Toughbook. This was followed by another Panasonic Toughbook with fully integrated GPS and Verizon cellular modem, and another communication case version for a total of four pilot units. All four units were sent to Caltrans to be distributed to field locations for testing. Field testers were asked to fill out a survey to rate the features, usability, and reliability of the Responder hardware and software. The results of this initial survey were analyzed, which led to another round of development with changes made to the application to reflect user comments and bugs found in the initial testing. All four pilot units were brought back to WTI, retrofitted with the changes, and delivered back to Caltrans for distribution to field personnel for additional testing. An additional Repsonder Toughbook and communications case was set up for use by WTI for support, testing and further development. The sections that follow summarize some of the steps and actions taken during this on-going development.

Review Phase 1 and Early Phase 2 Feedback

As part of the Responder Phase 1 pilot test, a number of evaluation survey responses were received. The following is a list of issues requested changes that were extracted from these responses:

- Have the software automatically select postmile based on location.
- Add ability to send emails to multiple recipients.
- Remove initial email and extra whitespace in email document. (The initial email included minimal, text-only information about the incident.)
- Users suggested having checkboxes to describe the incident (lane, side of road, direction, etc.).
- Add timestamp as part of incident name.
- Incident naming wasn't descriptive enough and sorting was troublesome.
- Add option to close incident so it doesn't show up on incident selection list.
- Add chain control map.*
- Attach downloaded weather data to email.*
- Add ability for software to generate standard Caltrans forms based on incident.*
- Make maps more up-to-date.
- Make Responder work with any camera without changing .ini configuration file.
- Mobile desktop or PC mounting system.*

- Add ability to resize or minimize the Responder application.
- Add ability to save the incident under any name and at any location on the hard drive.

The items designated with an asterisk were not addressed within this phase.

Software Development and Testing

The suggestions for improvement from the initial testing were evaluated and, where necessary, discussed with Caltrans project manager and project champion and improvements were agreed upon. Development of the software continued, fixing bugs and making usability improvements. These software changes were then thoroughly tested in-house at WTI prior to deployment. All four of the pilot units (two with a communication box, two standalone) were returned to WTI for examination and refitting in June 2008. All four units received a new version of the Responder application incorporating changes suggested during the previous round of testing.

A few bugs were discovered during pilot testing, all of which were fixed in the latest version installed on the four pilot units in June 2008. A few examples include:

- Clicking the “Remove Photo,” “Copy to Sketches,” and “Remove Sketch” buttons when there was no photo or sketch to act on would cause the application to crash.
- Missing data in the downloaded weather files would cause the application to crash.
- There were unnecessary blank pages in the Microsoft Word document that is sent as part of the incident email. These were removed.
- On display of “Nearby Conditions” in the weather tab all text would be selected. The application was modified to not select any text on the tab.
- Migrated the application to Microsoft .Net 2.0 and eliminated the need for Franson GPSgate software. This had been causing some intermittent problems on the fully integrated (standalone) Responder Toughbooks.
- An issue arose with the LandCellular modem used in the Responder communications case to supply Verizon cellular coverage, when unable to connect to the Verizon network. This was determined to be the modem not having the most recent preferred roaming list.

This list is not complete, but provides a few examples of bugs that were discovered and fixed with the help of pilot testers.

In addition to discovering bugs in the software, the pilot testers also made suggestions to improve the usability and effectiveness of the Responder software. The following is a broad, though still not comprehensive, list of improvements made as a result of user feedback:

- Added ability to resize or minimize the Responder window.
- Moved county and state FIPS codes to an external file to make changes or additions easier. These are used primarily when accessing weather information.
- Changed the naming convention for incidents to be more useful for identification. Included in the name are postmile, observer, and date and time of incident.
- Added options to sort the list of incidents when opening a previous incident. Incident names can be sorted by date and time or alphabetically by incident name.

- Added the option to mark an incident as “closed,” meaning it won’t appear among the list of incidents when opening a previous incident unless the “Include closed incidents” box is checked. This was done to shorten the list of saved incidents in the “Open New or Select Saved Incident” dialog box.
- Created a single “Open New or Select Saved Incident” dialog box to replace a string of successive dialog boxes that were previously used.
- Added a postmile database to the application with ability to automatically select nearest postmile based on location.
- Added a button to the summary tab that automatically inserts the current date and time to the next blank line in the description box. This was requested as a way to simplify creation of a timeline as events pertaining to the incident are added to the description.
- Added dropdown boxes “Facility” and “Incident type” to summary page to help better identify the incident.
- Added the ability to choose a specific location on the MapPoint street map as the location of the incident. Latitude and longitude are automatically copied to the summary page. The systems had to be upgraded to MapPoint 2006 to support this feature. This upgrade also brought in the latest maps available from Microsoft.
- Added “Change Photo Source” to add photos dialog box to allow photos to be imported from alternate sources. This was added so that the Responder software would work with cameras other than the Olympus provided with the Responder systems.
- Added an option to turn off initial text email through the Responder.ini because some testers thought it was unnecessary.
- Added a display to the messaging tab that will show which photos and sketches will be sent with the incident.
- Added the ability to send incident email to more than one email address. Previously used addresses are saved so they don’t need to be added on subsequent incidents. The list is displayed in the messaging tab and recipients of the current incident can be selected from the list with checkboxes.
- Added ability to send incident emails as “chunks,”—i.e., multiple emails with one photo or sketch per email. This feature was added for remote areas where satellite service is intermittent and is the only form of communication available. Small chunks can be sent while the satellite is available, while the complete incident email may take longer to send. This option can be turned on and off with a setting in the Responder .ini file.
- Added an option to keep trying to send email until successful or canceled by user. The option is available in the “Confirm Send” dialog box.
- Added a more informative email confirmation box to the “send email” functionality. New box adds information about satellite and cell availability and estimated transmission times.
- Added a more robust progress display to the email send functionality.

- Added a maintenance application to the two responder units equipped with communications boxes that updates the cellular modem preferred roaming list.
- Added support of integrated AT&T cellular modems to support Lenovo tablets for Caltrans District 4.

There were a few suggestions from pilot testing that were not acted upon in the on-going development but deserve to be noted.

- Suggestion to add Caltrans chain control maps: Since weather information for Responder is primarily served by the WeatherShare system and WeatherShare doesn't include these maps, there was no easy way to implement this feature within the scope of this Phase.
- Suggestion to add Caltrans DHIPP aerial images to the Responder application: This was investigated but copyright issues were complicated, and it was determined that this could be deferred indefinitely.
- Attach downloaded weather details to the incident email: This was not implemented for fear it could cause the incident email to grow excessively large. Each time the weather information is downloaded from within the Responder software it is saved with the incident on the Toughbook. This means that if needed for documentation purposes all the weather downloads are archived.
- Ability to generate Caltrans forms: While this potential feature continues to generate interest, there are a number of technical and other issues with its prospective implementation. First of all, there would need to be an agreed-upon format for these forms that would readily work with the system's tablet implementation. While both Microsoft Word and Adobe Acrobat formats are logical candidates, neither of these are guaranteed to be sufficient. Perhaps most practical is the observation that nothing precludes users from using either Microsoft Word or Adobe Acrobat on Responder systems, but separate from the Responder application
- Mobile desktop or PC mounting system or having communications box permanently mounted in a vehicle: These were deemed to be issues to be addressed in the final deployment stage as the current systems needed to be mobile to facilitate pilot testing by as many testers as possible.

Evaluation and Testing of Hardware and Software Alternatives

Requirements for the hardware associated with the Responder specified that the components should be field-ready, hardened components with shock and water resistance and the capability to operate in extreme heat and cold.

Final Hardware

- Panasonic Toughbook CF-19 or CF-18
    - A tablet PC was chosen as the platform of choice for its ability to support the sketching feature of Responder as well as having a keyboard for entering incident descriptions.
    - The Panasonic CF-18 (and later CF-19) was chosen for rugged/hardened build.

  - NOTE: Other tablets are possible for system use, although they may not offer the hardened capability of the Toughbooks. See below for a description of use of a Lenovo tablet that is not hardened.
- Olympus Stylus 410 Digital or Olympus Stylus 770 SW for one system (WTIRESP04)
  - The requirements were for a compact, weatherproof camera with optical viewfinder;the Olympus was one of the few that meet the requirement.
  - Lack of an optical viewfinder was seen as undesirable as the LCD viewfinders can be hard to view in bright sunlight.
  - The ability to use additional digital cameras was facilitated in this Phase.
- Lantronix EDS4100 ethernet terminal server
- GlobalStar GSP-1600 satellite phone and car kit
- GlobalSat BR-355 GPS with 12-volt power supply
- Land-Cellular CDM-819s cell modem and antenna
- Netgear FWG114P WiFi router and antenna

Test Deployment in District 4 with Lenovo X200 Tablet

District 4 of Caltrans wanted to deploy the Responder software on non-hardened hardware with a lower price point. The anticipated locations for use in District 4 were urban areas where cellular service is available, so a communications box would not be needed. The hardware that was selected by Caltrans for this purpose was a Lenovo X200 tablet computer with an integrated AT&T cellular modem and GPS. This was seen as a good opportunity to test the Responder system on another hardware platform.

The initial development hardware sent to WTI was a Lenovo X200 with an integrated Verizon cellular modem. With some initial setup for the computer, the Responder application was functional on this hardware, but the integrated Verizon cellular modem was not activated, so cellular communications could not be tested. For the purpose of testing with an AT&T modem, WTI was sent a Cardbus modem with an activated SIM card. The Lenovo X200 only has an ExpressCard slot, so the Cardbus modem was traded for an ExpressCard modem, which worked fine as a connection to the Internet, but had issues integrating with the Responder software.

Responder integrates with Windows Dialup Networking to connect to the Internet and automatically close the connection when it’s finished. The AT&T modem card didn’t work with Windows Dialup Networking; it required its own proprietary software to connect. Also, the GPS functionality of the AT&T card interfered with the GPS in the integrated Verizon hardware, and neither would work.

As a resolution, WTI was sent an X200 with an integrated AT&T cellular modem, specifically an Ericsson F3507g, which was found to work with Windows Dialup Networking. To accommodate the different modem, the Responder software had to be changed to use different commands to measure the signal strength and to initialize the GPS. The necessary commands were added as options in the Responder.ini file.

After development and successful testing of the modified Responder application, the Lenovo tablet was sent to Larry Hammond of Caltrans for additional testing in the field. His testing was mostly successful. There was one unexplained problem that resulted in a loss of data; this issue has not been replicated by him or by WTI since it occurred. While this issue has been noted and recorded, the inability to replicate the problem precluded finding the cause and fixing it.

As a way of distributing the software for District 4, an external hard drive was purchased and loaded with software and map tiles needed for Responder, and shipped to California. Licensed software was excluded from the install —Microsoft MapPoint and Microsoft Office— District 4 needed to purchase on its own licenses in order to distribute Responder.

Even though the Responder software tested well on the Lenovo tablet at WTI, District 4 encountered several problems. The command the Responder software uses to check signal strength prior to dialing reported an invalid RSSI of 99 in a 3G area. This error was not encountered at WTI because WTI is in a 2G area, in which the system functions properly. A minor modification to the Responder software allowed it to be configured to ignore a signal strength value of 99 and assume it’s valid.

There were also several issues with email. The Responder software depends on an external SMTP provider to send an email. Caltrans IT policy doesn’t support opening SMTP to its email servers, so an external server is needed. The service used in testing was a paid subscription service called Runbox, but Caltrans policy presented problems with funding a paid subscription service for the project. District 4 attempted using Google’s Gmail for testing, which only supports encrypted SMTP. Responder was modified to support encrypted SMTP and the use of GMail was tested successfully at WTI; however, the standard image that Caltrans loads on all its computers, including the Lenovo tablets, includes antivirus software that blocks encrypted SMTP communication. The issue has yet to be resolved.

While this deployment on alternate hardware proved the viability of implementing the Responder application on platforms other than the Panasonic Toughbook it left a few questions and unresolved issues that would need to be handled in a full deployment phase of this project.

- Email—the current Responder system uses email to send incident information to the desired recipients using a paid subscription to a commercial SMTP provider. As outlined above, this was not seen as desirable in the District 4 implementation. The various alternatives will need to be evaluated for practicality and fit within the Caltrans infrastructure.
- Long-term testing of the non-hardened platform—the Panasonic Toughbooks have been tested by a number of users from various Caltrans districts over multiple seasons and have held up well. The Lenovo, or any alternate platform, should be subjected to a more comprehensive field test.
- AT&T cell coverage—again the coverage and reliability of the AT&T cellular service has not been subjected to a comprehensive field test. This should be done to come up with recommendations for future deployments, although we do not anticipate any serious problems.

Communication

Communication is one of the most important aspects of the Responder system, and one of the most challenging. In remote areas, sometimes the only choice for communication is through satellite. The currently deployed Responder systems have been tested with GlobalStar as the satellite provider. While initially the GlobalStar service was satisfactory, it has since suffered from degraded performance due to issues with the amplifiers for its S-band antennas. This has rendered the service spotty at best from a temporal perspective. WTI purchased and ran some tests on systems from two alternate satellite providers: Iridium and Inmarsat. Below is a summary of the results from testing the three satellite providers.

GlobalStar

GlobalStar has an initial hardware cost of around $700, although the hardware costs have been decreasing with the reliability of service. (Because of hardware failures in their satellite constellation, Globalstar service has declined significantly over the past seveeral year.) The recurring costs are relatively cheap. With a loyalty plan, unlimited usage is about $24.95/month (the regular price is $34.95/month). GlobalStar uses a constellation of Low Earth Orbit (LEO) satellites that are continuously in motion relative to the Earth's surface. This means that much of the world is covered by a signal at one time or another, but it also means that where there is a signal, it may be intermittent. Since its introduction, GlobalStar service has degraded as issues with satellite hardware have occurred. GlobalStar has been promising a constellation upgrade for several years, and the current timeline puts it in summer of 2010.

GlobalStar provides an availability tool that tracks signal availability over a specific time period at a certain location. Tests performed in Bozeman, MT, have shown that the availability tool tracks closely with actual availability.

Table 1 and

Table 2 show these results.

Table 1: GlobalStar Test in Bozeman on April 6–7, 2009

Monitored Duration	12:50:55
Total Uptime	06:29:34
GlobalStar Availability Tool Estimated Total Uptime	06:31:20
GlobalStar Availability Tool Estimated Average Uptime	00:19:52

Table 2: GlobalStar Test in Bozeman on April 7, 2009

Monitored Duration	07:31:53
Total Uptime	03:44:57
GlobalStar Availability Tool Estimated Total Uptime	03:13:20
GlobalStar Availability Tool Estimated Average Uptime	00:17:34

Iridium

Iridium has much higher entry and service prices than GlobalStar at present; the hardware cost is around $1700, and service is allotted in prepaid minutes with an expiration date: 200 minutes in 6 months for $399, 500 minutes in a year for $695, or 3000 minutes in 2 years for $2969.

Like GlobalStar, Iridium uses a constellation of LEO satellites, although Iridium has a denser constellation. However, Iridium seems a lot less tolerant of a loss in signal. Whereas GlobalStar will tolerate a loss of signal for about 3–5 seconds without dropping the connection, Iridium drops the connection as soon as a signal is lost. (The project team has tried to overcome this issue with numerous attempts and techniques and has been unsuccessful.) The following description is from a section of the Iridium web site on troubleshooting:

> ***While connected, the handset seems to stop transferring data***
>
> *This problem tends to manifest itself when signal quality is an issue. Users who are attempting data calls from inside of a building also tend to have this difficulty. When your call drops, look at the signal strength indicator in the upper left corner of the LCD on the phone and verify that your signal is in the range of 4 to 5 bars. If you are not getting 4 to 5 bars of signal, you may want to adjust your antenna to get a better view of the sky.*

Tests of the Iridium system at WTI were unsuccessful at sending anything more than a minimal text incident. As the following summary of tests in Bozeman show, the total uptime over the monitored period is high, but the average period between signal losses is very short: See Table 3 and

Table 4.

Table 3: Iridium Test in Bozeman on April 6–7, 2009

Monitored Duration	12:45:32
Total Uptime	11:16:16
Average Uptime	00:01:35

Table 4: Iridium Test in Bozeman on April 7, 2009

Monitored Duration	07:34:26
Total Uptime	07:12:15
Average Uptime	00:03:16

An incident from District 4 (SOL 80 14.74) on 22 July 2009 provides an example of the issues with signal loss on the Iridium system. The low resolution Word document was 196KB, and to send this document using the Iridium at 2400 bits/sec would take an estimated 13 minutes of continuous service. With an average uptime of just over three minutes, the difficulty posed by sending a file of this size is apparent. A minimum incident with just text, no pictures or sketches, would be about 20KB and would require about 85 seconds to send plus about 25 seconds to establish the connection. These small incident emails can usually be sent between service interruptions.

Subsequent but brief testing revealed weakness that were attributable either to the external antenna or the antenna cable; signal reliability fared significantly better with the built-in phone antenna. Over the course of two or three test periods of approximately two to three hours each, the phone did not drop below four bars of signal strength and maintained a steady data connection. This setup is not feasible for field use, as it involves a long data cable attached directly to the phone, which in turn was attached to a tripod to hold it in the air and upright. Despite the attached antenna offering much better reception, there continued to be network errors resulting in connection timeouts with this setup.

Iridium offers software meant to improve connection speeds through data compression and to stabilize satellite-to-satellite handoff, and the brief testing with the directly attached antenna involved tests with and without Iridium's software. The Iridium software works by intercepting data sent to a standard TCP port, compressing it, and retransmitting it using an Iridium-hosted server as a proxy. As a result the software is only effective on standard ports, specifically port 25 for Email. Due to difficulties with antivirus and firewall software in the first phase of Responder, transfer of email from the Responder unit has used the non-standard port 26, complicating use of Iridium's software. Tests using Iridium's software were conducted using transmission of email using the standar port, 25.

Email transmissions with incident attachments fared no better with the Iridium software than without. While the data connection remained active, Iridium's software occasionally dropped its connection to the server, indicating some sort of network error. More extensive testing needs to be conducted to identify the causes of these network errors that result in timeouts and dropped connections. Also, more research is required to identify more effective antenna and cable solutions for the Iridium phone.

Inmarsat

Unlike Iridium and GlobalStar, Inmarsat uses geostationary satellites, which are placed at a much higher altitude and stay at a single location relative to the Earth's surface. This means that locations that have coverage will always have coverage from the same satellite, but locations without coverage won't ever have it.

The entry cost for Inmarsat is higher than GlobalStar or Iridium at $2160 and up for the receiver and $200 for the 12-volt charger. Service prices are based on the amount of data downloaded monthly: $65/month for 10MB, $130/month for 20MB, and $459/month for 100MB. Inmarsat also offers faster data rates than either of the other two satellite solutions: 240kbps up, 384kbps down. That means about two minutes to send a 196KB incident document.

The Inmarsat system works well with a standalone Responder unit: it's a one-piece device that provides an Ethernet port to connect directly to the ToughBook. A web browser interface provides the aiming parameters (azimuth and elevation), and an audible tone assists in fine tuning. After becoming familiar with the system it could be set up and online in around 5 to 10 minutes, including the time required for the system to register with the network.

Coverage in the Bozeman area is acceptable, but more research is necessary to estimate coverage in remote areas of California, particularly in canyons.

Cellular

WTI researchers spent a significant amount of time gathering information about cell coverage in the state of California using the Responder hardware. This information can be used to quantify the effectiveness of cellular communications in the Responder application and justify the need for further research to find a viable satellite alternative. All information was collected in conjunction with site visits and general in-field testing of the Responder system during Phases 1 and 2 of this project, and in conjunction with another related project. All told, the project team covered over 2600 miles of state and federal highways in California recording cellular signal strength and testing system performance during the time period from 2004 and 2007. See Figure 1 for roads covered. See Figure 2 for cellular service along these roads. See Figure 3 for cellular service on roads covered in Northern California. Not only do these maps show the extensive testing that was done by the project team in California, but also the relative amount of underserved locations in which cellular service is poor or unavailable, and where satellite service would be necessary for full system use.

Figure 1: Roads Covered in Testing the Responder System

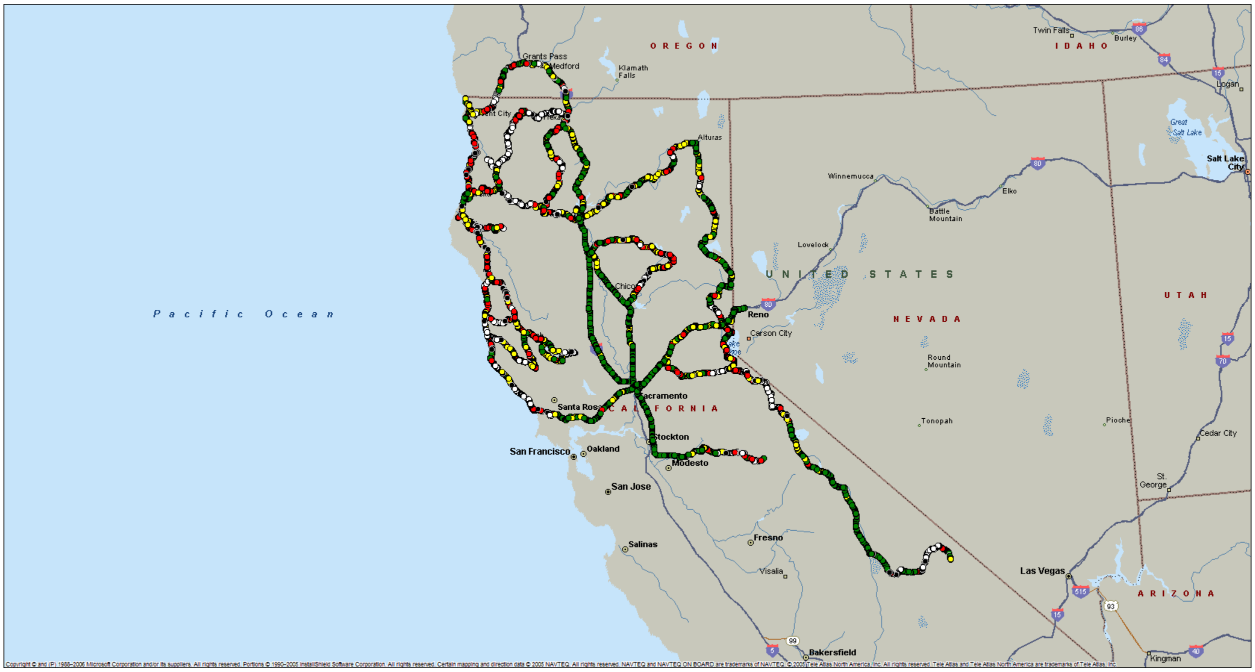

Figure 2: Cellular (CDMA) Service. Green = good, Yellow = fair, Red = poor, White = no service

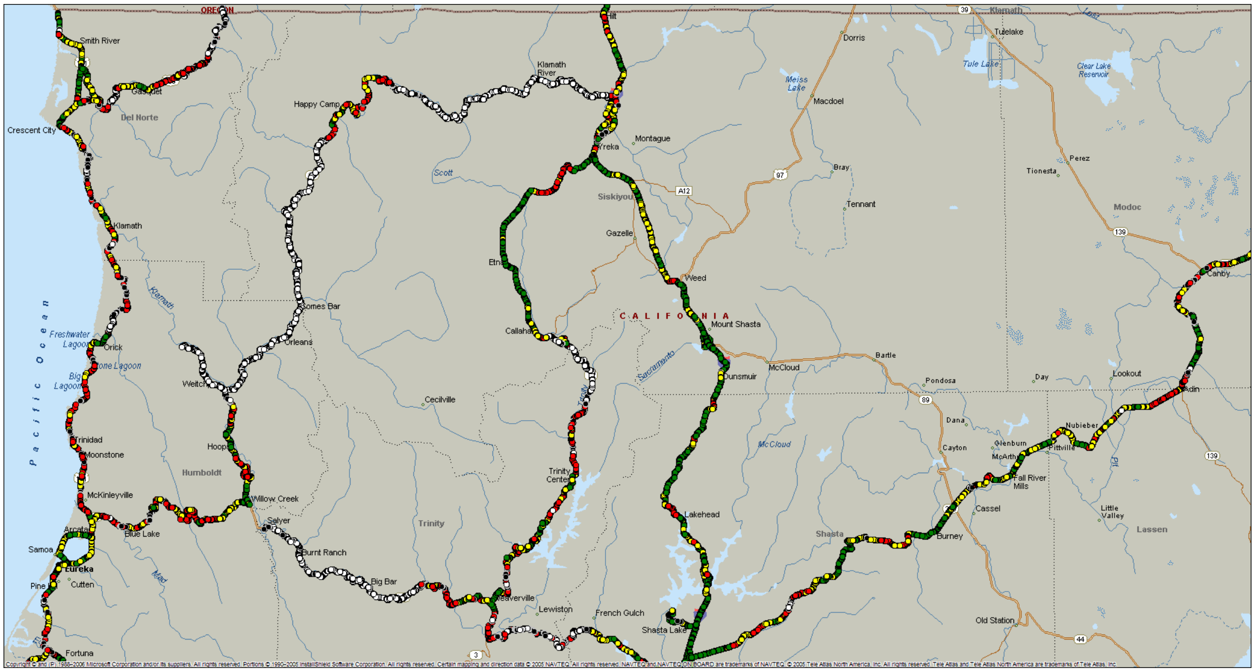

Figure 3: Cellular (CDMA) Service in Far Northern California. Green = good, Yellow = fair, Red = poor, White = no service

Complete System, Hardened for Vehicle Use

During this phase of the Responder project, two communication boxes were assembled that combined satellite capability, cellular modem, GPS, and a wireless router into a single hardened case. An additional box was built for demonstrations that include Iridium and GlobalStar satellite modems, as well as the cellular modem, GPS, and a wireless router to connect to the ToughBook. The demonstration box combined several lessons learned from building and maintaining the other two communications boxes. The demonstration case has a clean look with all the cables and devices hidden, but they are still easily accessible for troubleshooting and maintenance.

The first two communication boxes are shown in Figure 4 and Figure 5. The demonstration box is shown in Figure 6.

Figure 4: Responder03 Communication Box

Figure 5: Responder05 Communication Box

Figure 6: Demonstration Box

User Guide

A user guide describing functionality and usage of the Responder system was provided on laminated sheets and included with each of the pilot systems. The guide details all the aspects of the Responder system, including how to use it to generate an incident report, and a few frequently asked questions and general maintenance guidelines. More in-depth management and administration tasks are detailed in the System Management and Maintenance Guide.

System Management and Maintenance Guide

A basic system management guide detailing initial configuration and regular maintenance duties was written for administrators of the pilot units. The guide describes initial installation of the Responder software, the location and content of various configuration files, and regular maintenance tasks and schedules to keep the Responder system in working condition.

4. PILOT TESTING

Pilot testing in the second phase of the Responder project consisted of the distribution of four Responder units to various Caltrans districts. Two of the Responder units were coupled with a communication briefcase, which included a satellite modem; the other two were standalone units consisting of a ToughBook and camera. Distribution and transfer of the units between districts was coordinated by the Caltrans program manager, Mandy Chu.

For the purposes of evaluation, a survey was given to each user of the system, usually in written form but in some cases verbally. Questions on the survey were divided into seven sections: the incident organizer, incident email, communications, general utility, hardware deployment in vehicles, cost, and ease of use. Open ended, rather than yes/no, questions were used to encourage more detailed responses in hopes that the information could be applied to improvements to the software.

Pilot testing was unsupervised; testers were left to use the Responder unit in whatever way they thought it useful. In June of 2008, the units were returned to WTI for updates and refitting. During that process the incidents on each unit were archived, providing more information on how each unit was used.

5. EVALUATION

Pilot testers' evaluations of the Responder units and software indicated a generally favorable impression of the system. The concept was seen as valuable and effective, though the actual implementation received a few criticisms. Many of the complaints and suggestions from the first phase of Responder and the field test led to improvements to the software during the second phase.

Incident Organizer

Comments regarding the ease of use of the Incident Organizer were generally positive, though there were many suggestions for improvement. Some users wanted more detail for each incident and suggested checkboxes, enlarging the description field, and postmile support, among other things. Several testers said that the aerial maps were outdated and suggested getting new imagery. Photos and sketches were seen as the most useful features of the program as they can be used to convey much more information about the scene than can be relayed over the phone or radio. As a testament to the ease of use of the system, users generally didn't think an embedded help system was necessary, nor did they read the users manuals included with the system.

Incident Email

The email system was seen as a critical component of the system, although lacking in features. Several improvements to the software came from the comments regarding the email system, including making the initial text email optional and adding the capability to send to several recipients. The photos and sketches included with the email were accepted as visually adequate, despite the loss of quality due to attempts to minimize the email size.

Communications

The Responder unit was seen as an effective way to communicate with other responders or the TMC. The primary complaint was the unreliability of GlobalStar satellite service in remote areas. Where cellular communication was available the unit performed satisfactorily, but satellite service was intermittent at best and it was difficult to get an email through between service interruptions.

General Utility

Respondents saw a wide array of uses for the Responder system within the scope of DOT-related applications. Suggested potential users included superintendants, maintenance supervisors, bridge crews, storm damage response teams, and HazMat managers. Responses regarding the amount of time at an incident spent using the Responder unit varied from no more than 15 minutes to as much as 30 percent of the total time spent at an incident site.

Hardware Deployment in Vehicles

Most users wanted the Responder units to remain portable outside the vehicle, either because they share the unit or because they don't want the availability of the Responder system tied to the availability of the vehicle. Users suggested providing a docking station or mount to which the Responder could be attached, but from which it could be easily removed. The size of the ToughBook was deemed acceptable, though there were several complaints about the small size of the keyboard.

Cost

Regarding the feasibility of the $6000 price tag, the pilot users felt the unit was effective enough to justify it. Table 5 shows the number of units requested by each district that participated in the pilot test.

Ease of Use

All the participants agreed that the system was reasonably easy to use, but there were still complaints. The camera shipped with the Responder unit uses a manufacturer-supplied battery pack, and one user requested that a camera be provided that uses standard AA or AAA batteries. There were also complaints about the GPS being inaccurate or not getting a location fix, a situation that required an application restart. A button to restart the GPS was added so that the application didn't need to be restarted.

Other Comments

There were several comments regarding the naming of incidents and the sorting of the previous incidents list when opening a previous incident. The new naming scheme involves the date, postmile, and location of the incident, and can be sorted either by the date and time or by the name of the incident. Also, incidents can now be closed, which greatly shortens the list of incidents that can be selected in the Open New or Select Saved Incident dialog. The group of respondents in the Bay Area wanted integration of the Responder software with their already deployed Bay Area Incident Response System (BAIRS). Also, training was seen as necessary for users that use the system infrequently, and training in usage guidelines was suggested as a way to make sure the system is used as effectively as possible.

In a subsequent, separate inquiry initiated by the Caltrans Project Manager, Districts were asked how many units they would anticipate deploying, if available. Table 5 shows the responses. Not all districts responded.

Table 5: Requested Responder Units by District

District	Cell-only	Satellite and Cell Communication Box
1		5
2		12
4	12	8
6		6
7	5	1
8		3
9		2-3
10	10	14
TOTAL	**27**	**51-52**

With the desire for nearly 80 units, these results demonstrate an apparent need for the system in Caltrans.

6. OUTREACH

Throughout Phase 2, numerous outreach efforts were conducted. Generally, this was done through industry-recognized conferences. Following is a summary of Phase 2 outreach efforts:

Three presentations in relation to Responder were given at the National Rural ITS conference (NRITS) in August 2006: "The Redding Responder Project: Computing and Communication in the Middle of Nowhere;" "The Redding Responder Project: Mobile Data Communication Challenges in Remote Rural Areas;" and "The Application of Systems and Software Engineering Process Models for Development on Small to Moderate-Sized ITS Projects: WeatherShare and the Redding Responder Projects." These presentations were very well received, and served as early outreach for the project. The Caltrans project champion (Jeff Kiser) was in attendance at these presentations. (Note that Ian Turnbull replaced Jeff Kiser as project champion when Jeff departed Caltrans.) Great interest was expressed in the project from representatives from Arizona, New Mexico, Washington State, Alaska and Canada.

A poster session was presented at TRB 2007 in Washington, D.C., as part of ongoing outreach for the project. Doug Galarus and student intern Justin Krohn presented at the poster session.

The Responder system received notoriety at the ITSA America Annual Conference in Palm Springs in early June 2007, being named one of three finalists as "Best New Product, Service or Application." Although it did not win the award, there was great exposure from the proceedings and opening session. Responder was also highlighted as one of three projects presented at the Caltrans VII showcase. Responder was presented in both a moderated session and a poster session under the title, "The Redding Responder Project: Computing and Communication in the Middle of Nowhere." A number of contacts were made with other states who are interested in the project through the ITSA events. A two-minute video was produced in conjunction with the finalist designation.

In a separate outreach effort, WTI was invited to participate in an outreach effort held in conjunction with the Association of Public Safety Communications Officials International (APCO) 73rd Annual Conference and Exposition in Baltimore, Maryland, in August 2007. In conjunction with the APCO conference, a five-minute video was produced by a professional production team in London and shows a simulated incident (hazmat spill) in Caltrans District 2. It was presented at the conference on big screen displays and in conference hotels. WTI received professional copies of the DVD for re-distribution and future outreach efforts, and the video is also available for download on the APCO-TV website and the WTI website.

The state of Vermont expressed interest in the Responder system at ITS America in June 2007. Separate from Caltrans project time and funding, WTI submitted a proposal to Vermont for further development and testing of Responder in Vermont. If this proposal had been successful, it would have been the first application of Responder outside of Caltrans and would benefit the Caltrans project in general by providing further support for the system. However, we subsequently learned that the Vermont contact was unable to secure state funding for the effort (he obtained federal funding, but could not find the needed state match). We have not given up entirely on this opportunity, but it is delayed at best.

Caltrans nominated Responder for the AASHTO Technology Implementation Group's Technology Ready for Implementation. Unfortunately, the project was not accepted for this submission.

Further outreach included:

- July 2008: AASHTO, Subcommittee on Maintenance, etc., Monterey, CA
- August 2008: AASHTO, Subcommittee on Systems Operations and Management, Special Committee on Wireless Technology Annual Meeting, San Francisco
- October 2008: Caltrans Statewide TMC/ TMS meeting
- March 2009: Region III RDMHS meeting in Red Bluff

Finally, the Responder project was included with other Caltrans demonstrations at AASHTO 2009 in Palm Desert in October 2009.

7. CONCLUSION

During the course of the Phase 2 effort, a number of deliverables were produced, including:

- Final Report
- Quarterly Reports
- Documentation for FSR
- Long Term Maintenance and Management Plan
- Final User Guide
- System Management and Maintenance Guide
- Pilot Testing Summary Report

These deliverables were combined into single reports in several cases and the documents produced are:

- Redding Responder Phase 2 Pilot Testing Summary and Evaluation Summary
- Responder System Management and Maintenance Guide and Long Term Maintenance and Management Plan
- Responder Phase 2 User Guide and Training Materials Redding Responder Business Case and Documentation for Caltrans FSR
- Responder Phase 2 Final Report

These reports, along with the pilot responder systems that were developed, are the primary products of this research and development effort. A third phase is scheduled to begin in 2010, to further efforts for corporate deployment of the system. One of the biggest tasks in the upcoming phase will be facilitating a contract production of a responder system by a third-party contractor, as proof that the system can be procured by Caltrans.

There is no doubt that the usefulness of the Responder system has been proven within this phase. Users have nearly unanimously expressed their support for the project and system in general. With that said, several challenges faced in this phase deserve mention because they are critical to future success of the system. First of all, technology is a key to success, and the technology needs to provide users with a robust and current hardware and software experience. When the system was first developed in Phase 1, it was built on Windows XP which, at the time, was relatively new and state of the art. Work in Phase 2, with an emphasis on rapid deployment for pilot testing, continued on that same platform and the system continued to be robust, but it became less and less current in the process. At the end of Phase 2, Windows XP is approaching end of support from Microsoft, with Windows Vista and Windows 7 as newer versions of the Microsoft operating system. While this observation is somewhat less important in regard to system functionality and basic operation, the reality is that end of support causes procurement and maintenance and support challenges. It is the intent of the project team to update the software (and hardware) in Phase 3 to operate on Windows 7 to mitigate these challenges.

While such software challenges are solveable by upgrading and perhaps modifying the system source code, a particular hardware/communictions challenge has proven to be significant. Specifically, the GlobalStar system has sufferred from steadily declining service quality through the duration of Phase 2. Originally selected for value, performance, and particularly for service availability in nearly all areas including in the presence of canyons, mountains and other irregular terrain, GlobalStar service has degraded to a point where it is nearly unusable even in locations with a totally clear view of the sky. There is still a chance that GlobalStar will overcome their current problems after bringing a new satellite constellation online, but that is a prolonged and very expensive process. In turn, and as documented in this phase, the project team investigated alternatives including offerings from Iridium and Inmarsat. And, it appears that Inmarsat may be most viable. However, its use comes with a challenging restriction – there must be a clear view of the southern sky in the direction of one of the Inmarsat satellites. Further, antennas much be directed towards those satellites. In the absence of very expensive, auto-positioning antennas, this process will make the system at least somewhat more challenging to use. At the same time, the system will offer greater bandwidth, which will be of benefit.

Given the challenges associated with satellite service, one might question whether it is necessary and worth the trouble and expense when cellular networks continue to expand their coverage and capability. The answer gathered through interaction with users on this project is a resounding yes. Even users in the most urban areas – Los Angeles and the San Francisco Bay area – reported areas where there is no current or planned cellular service, and indicated that the satellite component would be of use to them. The communication side of the project, including both cellular and satellite, will continue to be an area where ongoing research, development and testing is necessary.

Aside from technical challenges, a number of institutional issues have surfaced in this phase, particularly in regard to an attempted expanded deployment in District 4. A number of issues including procurement challenges, staff support capability, staff turnover including loss of a local project champion, and other issues that were beyond the control of the project team caused what should have been a successful and rapid deployment to become a failed effort. In conjunction, it is natural to wonder whether it would have been better to pursue prospects for contracted, commercial assistance for system integration and subsequent maintenance. This too will be investigated in Phase 3.

Finally, the prospect of deploying the system on other platforms, particularly on a smartphone platform, has been of interest from early on in this project. With the proliferation of smartphones including Apple iPhones and Google Android devices and the multitude of applications available, it seems that the time has come for associated development on such a platform. In fact, one could argue that the time was right for this several years ago. The advantages include using a device already carried by staff – their phone – as well as lower cost. Much of the capability required for the system is available in smartphones today including GPS, camera, annotation via touch or stylus, Internet connectivity for maps and weather information, etc. However, the problem of service gaps in the cellular networks, as mentioned above, would continue to be a problem. There are several ways to address that, though. There is at least one provider at present offering a smartphone with integrated cellular and satellite data service. Further, it may be possible to use wi-fi connectivity to connect to a hotspot served by satellite service. Inmarsat offers several modems that provide this capability. The project team sees this area, smartphone development, as perhaps of most benefit for subsequent research and development.