Redding Responder Phase I Final Report

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TABLE OF CONTENTS

1. LIST OF TABLES

2. LIST OF FIGURES

3. EXECUTIVE SUMMARY

The Redding Responder Study was initiated as a component of the Redding Incident Management Enhancement (RIME) Program. The goals of the RIME program are to leverage technology and communications deployments for emergency communication providers in the RIME region by evaluating agency requirements, providing migration paths and improving incident management. The RIME region consists of 19 counties in northern California, which cover nearly 30% of the State's area, approximately 25% of the State's State Highway Lane Miles, and less than 4% of the State's population. RIME organizations include Caltrans District 2, Caltrans Division of Research and Innovation, Norcal EMS, California Department of Forestry and Fire Protection, and other local and state agencies.

The Redding Responder Study was sponsored by the Caltrans' Division of Research and Innovation. The Western Transportation Institute at Montana State University was contracted to conduct research and development comprising the study. Research and development was conducted to address the needs of Caltrans District 2, based in Redding. While targeted specifically at the needs of Caltrans District 2, consideration was given to prospective needs of other RIME agencies and other Caltrans districts, including those in urban areas. Research and development was conducted over a two-and-one-half year time period.

The premise behind the Redding Responder Study is that the collection and transmission of digital photographs and other incident information will enhance incident management and help to clear incidents more quickly. Secondary benefits include those associated with the development and implementation of a systematic methodology for collecting and documenting incidents for future analysis and training. The principal challenges include overcoming limited communication capability in the RIME region and achieving a desired ease of use necessary to make such a system usable in the field. While off-the-shelf hardware and software products exist to solve related problems, such products do not adequately address these principal challenges without further integration and development.

Specific situations in which the product of this study would be used include rockslides, landslides, mudslides, earthquakes, severe weather, and other events in which roadways would be damaged or obstructed. Such events are common in District 2, particularly during the wet months of fall, winter and spring. Use for traffic accidents and during wild land fires would also be likely.

A Project Process Model was developed to incorporate aspects of the Systems Engineering approach, as exemplified by the "Vee" Model and the Spiral Model for Development, which is commonly used to minimize risk in the development of complex systems. The resulting process model is consistent with the Caltrans' Stages of Research Deployment. Specifically, a sequence of prototypes was developed to refine the project concept, elicit requirements and feedback throughout the project, and evaluate technologies and techniques for use. With each "iteration," Caltrans was presented with the next version of the product, and feedback was elicited to determine necessary modifications and additional requirements. Feedback was documented and incorporated into subsequent development. Three early iterations were conducted for the purpose of concept refinement prior to development. A fourth iteration was conducted to develop and evaluate a laboratory prototype to demonstrate the concept, test hardware and software, and elicit feedback. A fifth iteration was conducted to develop and evaluate a controlled field demonstration prototype, a fully functional system that could be used in a limited capacity in the field.

The concept of the prospective system resulting from concept refinement was:

> A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

The associated objectives were to:

- Create and provide the information elements, framework and pilot deployment of an information collection system centered on the information needs of District 2 field units and Redding TMC for transportation management and incident response/clearance, and of relevance to other emergency response organizations. The incident information collection system will include capabilities for collection of incident images, facilities for annotating images and maps to describe incident scope and severity, incident GPS location, as well as form-based information as deemed appropriate by District 2.
- Create and provide the information elements, framework, and pilot deployment of an incident support information system based on the needs of District 2 field units and Redding TMC, and of relevance to other emergency response organizations. The incident support information system will include capabilities for downloading maps and aerial photos, weather conditions, and other support materials related to the incident and its location.
- Provide the necessary hardware and communications infrastructure for the exchange of at-scene information collected via the information collection system and the distribution of incident support information to responders as described for the incident support system. The communications system will provide the means to exchange information between District 2 field personnel at the scene and Redding TMC, and will be capable of incorporating other emergency response organizations. In Responder vehicles this will consist of a mobile data terminal (ruggedized Tablet PC), a satellite or satellite/cellular combo phone; Internet data connectivity kit including cabling and software and providing GPS hardware with computer connectivity, and a digital camera with computer connectivity. The incident information collection system and the incident support information system software will reside on and interface with this equipment to facilitate the collection of information and transmission of data to and from the incident scene.

This concept and three associated objectives would be addressed by a single integrated system.

The resulting controlled field demonstration prototype consists of integrated hardware and software to satisfy these objectives as a "proof of concept." Hardware components include a rugged Tablet PC, a weather-proof digital camera, a GPS, a cellular modem, and a satellite modem/phone. The Tablet PC is mobile within and outside a vehicle, and communicates with the GPS and modems via an 802.11 wireless connection. The camera is a standard digital camera. The GPS, cellular modem, and satellite modem/phone are integrated within a single case encapsulating cables, power, antennas and other devices necessary for interconnection and wireless access.

Software components include a custom-developed Responder application and associated drivers for the various hardware devices. The Responder application is location-aware, determining location from the GPS and using that location to automatically pre-populate incident information and to pinpoint the incident on a street map, an aerial photo and a USGS topographic map. Digital photos can be uploaded from the camera and added to the Incident Organizer, the organizational structure within the Responder application used for collecting and saving incident information. Photos and maps can be annotated using the Tablet PC pen, and free-form sketches can be drawn to depict further incident information. Weather information specific to the Responder location can be downloaded and displayed by executing a single command. The Responder location is used to automate the process of requesting and retrieving weather information, freeing the end user from manually navigating to it. Similarly, incident information is automatically organized and optimized for storage into a Microsoft Word document, which is automatically transmitted as an email attachment to the TMC upon request. The application determines whether to use cellular or satellite for transmission, dependent on signal strength and availability.

There were several key areas of focus for research on this project. First and foremost, it was desirable to elicit and understand District 2's needs and to accommodate those needs in a system that was easy to use. In other words, research was conducted to make the system both useful and usable. The second research focus area involved determining ways to maximize the use of resources, particularly limited bandwidth and storage capacity. It was necessary to determine what information could be stored locally on the Tablet PC and what information could be downloaded on the fly. It was also necessary to determine how to most effectively upload information from the Responder system to the TMC. The third focus area involved determining the limitations of communication systems and how to optimize their use in light of these limitations. In particular, it was desirable to determine the impact of terrain on satellite communications and the necessary signal strength requirements for effectively using cellular data communications.

Through the iterative, spiral process, requirements and feedback were elicited throughout the study, and feedback was used to form and test the system user interface. Emphasis was given to ease of use, and the resulting system has been judged as easy to use through a number of demonstrates as well as hands-on testing.

Resources were maximized to deliver mapping and weather information to the application in an efficient and timely manner. It was determined that maps had to be stored locally on the Tablet PC rather than downloaded. Map "tiles" were selected and stored to only cover roadways, rather than all areas in northern California, reducing the amount of storage space required for maps. Weather information was aggregated and compressed for download where possible to minimize download time. Web services were used as data sources to eliminate the download of unnecessary information such as images and links that are common in web pages. Weather information was downloaded using location information gathered from the GPS and mapping utilities, freeing the user from memorizing URLs and navigating through subsequent links to drill down to specific weather information.

Satellite and cellular communication was studied in general and particularly in the RIME region, as well as in remote areas of Montana. Over 1200 miles of California state and federal roadways were systematically driven in the RIME region, to collect signal strength measurements and evaluate performance. Extensive site studies were conducted in which signal strength readings were collected and data transmission tests were carried out. It was discovered that cellular performs well with strong signal strength readings, but does not perform well even with apparently moderate signal strength readings. Thus, cellular signal strength readings must be strong in order for cellular to be used by the system. Satellite performance degrades with greater obstruction of the sky. Extensive data was collected and a model was developed to simulate satellite signal strength and coverage dependent on site "horizon profiles," which model the obstruction of the sky at a site due to terrain. Through analysis of collected data and through extensive simulation using the model, it was determined that dropped connections are sure to occur with significant obstruction of the sky, particularly obstructions above 30 degree angles of elevation. But, "re-dials" can be used to reestablish connections and send moderate sized data with a reasonable chance of success. Software can be made to automate this process, alleviating the end user of related monitoring, decision making and manual reestablishment of connections.

The controlled field demonstration prototype was successful in demonstrating a "proof-of-concept" that such a system could be developed and made usable and useful by Caltrans responders in the RIME region. Subsequent research and development is necessary to harden the system and make it field-ready for production use. Caltrans is proceeding with a second phase of the Responder study, within which the system will be developed and tested further, with the goal of preparation for production use. Phase 2 is scheduled to begin in the December 2005 – January 2006 timeframe, and will be conducted over two-and-one-half years.

4. BACKGROUND

4.1. Redding Incident Management Enhancement Program

The Redding Responder Study is a component of the Redding Incident Management Enhancement (RIME) Program. The RIME Program was initiated to "leverage the institutional relationships and technology/communications deployments of the Redding District in a manner that[1]:

- incorporates the specific mission and function of each emergency service provider so as to improve the overall and specific activities within the incident management environment;
- provides the means for the appropriate evaluations based on the overall RIME Program and the individual requirements of the participating agencies from a functional and operational perspective;
- provides the means for the institutional and technology migration plan for both the District and other rural regions of California."

4.2. Initial RIME Participants

The following organizations were identified for initial participation in the RIME program:

- American Medical Response
- Anderson Fire Protection District
- Burney Fire Protection District
- California Department of Forestry
- California EMS Authority
- Caltrans District 2
- Caltrans Division of Research and Innovation (Caltrans DRI)
- Mayers Memorial Hospital
- Mercy Medical Center
- Northern California EMS, Inc. (NORCALEMS)
- Redding Medical Center
- Redding Police Department
- Shasta Area Safety Communications Agency (SHASCOM)
- Shasta County Sheriff's Office
- Shasta Lake City Fire

[1] From RIME Overview, Greg Cross, WTI, 2002

- Shasta Lake Fire District

4.3. RIME Region

The RIME region (Figure 1) consists of counties in Northern California that are serviced by Caltrans Districts 1, 2 and 3, with the exception of El Dorado, Sacramento and Sierra counties.

District 1 provides services for Del Norte, Humboldt, Lake and Mendocino counties.

District 2 provides services for Lassen, Modoc, Plumas, Shasta, Siskiyou, Tehama, Trinity and portions of Butte and Sierra counties.

District 3 provides services for Butte, Colusa, El Dorado, Glenn, Nevada, Placer, Sacramento, Sierra, Sutter, Yolo and Yuba counties. El Dorado, Sacramento and Sierra counties are not considered part of the RIME region.

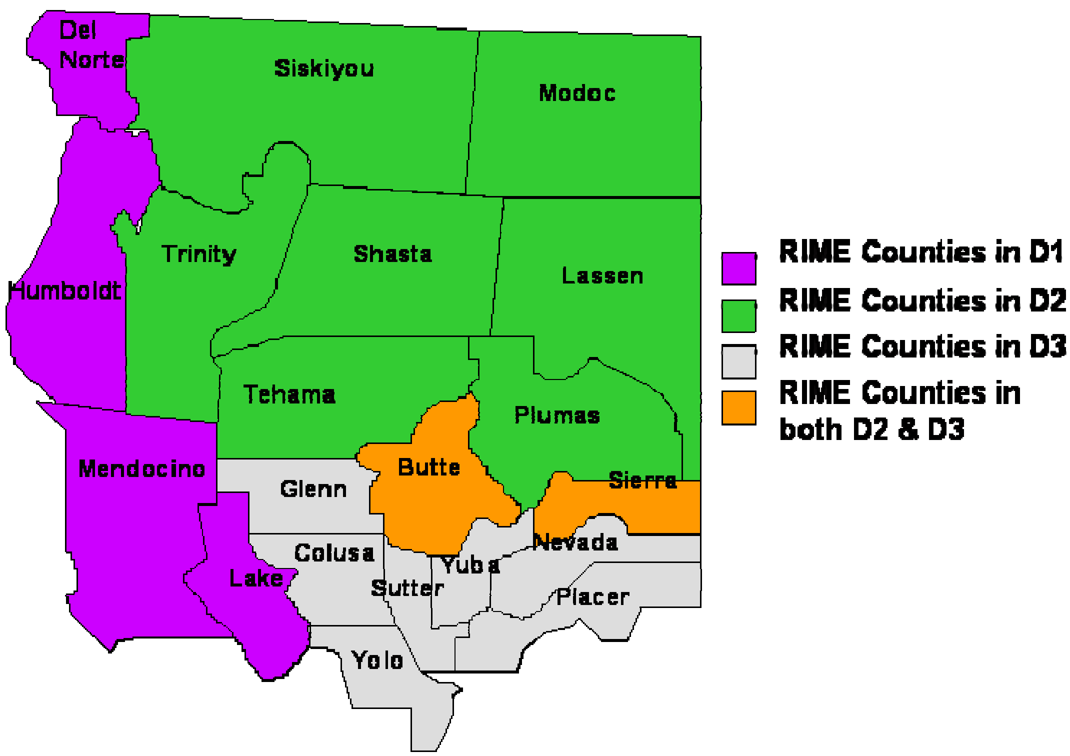

Figure 1: RIME Region

The RIME region is geographically diverse, including portions of the Central Valley, the Pacific Coast, the Sierra Mountain Range, and the high desert-plateau bordering Nevada. Elevation ranges from sea-level to over 14,000 ft above sea-level.

Approximately 90 miles of Interstate 80 from the Nevada border west nearly to Sacramento and over 250 miles of Interstate 5 from Sacramento to the Oregon border fall within the RIME region.

The RIME region is generally rural, with the exception of the cities of Redding, Chico, Yuba City and the suburbs of Sacramento. Table 1 shows populations, areas and state highway statistics for the counties in the RIME region:

Table 1: Statistics[2] for Counties in the RIME Region

County	2004 Population Estimate	Area (square miles)	2004 Population (per sq mi)	1998 State Highway Centerline Miles	1998 State Highway Lane Miles	1998 AVMT (in millions)
Butte	212,968	1,639	129.9	181.1	432.7	609.7
Colusa	20,339	1,151	17.7	114.8	301.2	405.4
Del Norte	28,351	1,008	28.1	91.4	229.1	157.9
Glenn	27,488	1,315	20.9	110.3	281.6	307.2
Humboldt	128,529	3,572	36.0	335.9	950.7	687.5
Lake	64,446	1,258	51.2	135.8	301.4	293.3
Lassen	34,661	4,557	7.6	303.5	641.1	296.2
Mendocino	88,551	3,509	25.2	381.0	896.8	656.6
Modoc	9,599	3,944	2.4	177.6	359.5	89.6
Nevada	97,660	958	101.9	129.5	364.3	629.2
Plumas	21,359	2,554	8.4	181.8	385.7	172.6
Shasta	177,816	3,785	47.0	311.4	838.5	1,052.4
Sierra	3,490	953	3.7	97.6	204.9	65.6
Siskiyou	44,891	6,287	7.1	349.5	878.3	558.6
Sutter	86,760	603	143.9	83.6	214.6	385.3
Tehama	60,075	2,951	20.4	206.3	515.3	538.1
Trinity	13,671	3,179	4.3	200.9	412.5	119.7
Yolo	184,364	1,013	182.0	177.9	553.5	1,130.8
Yuba	64,631	631	102.4	64.4	160.1	265.6
RIME	**1,369,649**	**44,867**	**30.5**	**3,634.0**	**8,921.9**	**8,421.2**
California	**35,893,799**	**155,959**	**230.1**	**15,209.67**	**50,261.42**	**155,399.08**

AVMT = Annual Vehicle Miles of Travel

While covering nearly 30 percent of the State, the RIME region accounted for less than 4 percent of California's population in 2004. (If Butte, Nevada, Sutter, Yolo and Yuba counties are excluded, then the resulting region accounted for only 2 percent of the population and over 25 percent of the State's area.)

In 1998, the RIME region included slightly less than 24 percent of the State Highway Centerline Miles, nearly 18 percent of the State Highway Lane Miles, and a little over 5 percent of Annual Vehicle Miles of Travel (AVMT).

[2] Source: U.S. Census Bureau: http://quickfacts.census.gov/qfd/maps/california_map.html, http://www.census.gov/popest/counties/tables/CO-EST2004-01-06.xls)

California Department of Transportation: http://www.dot.ca.gov/hq/tsip/tsidoc/shwydata/archives/TABLE3_3_AVMT.xls, http://www.dot.ca.gov/hq/tsip/miles.htm

4.4. Proposed RIME Projects (2002)

Five proposed pilot public safety projects, including Redding Responder, were identified initially within the RIME Program. These proposed projects are described below:

4.4.1. WeatherShare

The WeatherShare project will integrate the remote weather information collection systems operated by the Redding District and the California Department of Forestry so that the information may be shared between the agencies and other emergency service providers in the region.

4.4.2. EMS/Incident Management At-Scene Data Collection

To improve patient outcomes, enhance the 'real-time' information available to emergency room physicians and to improve emergency medical services data for post event analysis, the project will deploy at-scene EMS data collection systems that will incorporate the means to provide the data to the receiving hospital's emergency room.

The project will also incorporate the implementation of a rural hospital status tracking system for enhanced emergency dispatching and routing.

4.4.3. EMS/All Event Training

To enhance the overall response and at-scene safety of emergency service personnel, the project will develop and implement an EMS/bioterrorism/weapons of mass destruction training program for EMS personnel with a training module created and provided to the Redding District's maintenance personnel.

4.4.4. Rural Critical Surface Transportation Infrastructure Monitoring

Throughout the Redding District are numerous transportation system management devices that employ at-scene power and communications systems. This project will investigate systems and technologies that employ existing remote power and communications systems for the monitoring of critical rural surface transportation infrastructure, i.e., bridges, tunnels, passes, etc. The types of systems that may be of value in monitoring rural transportation infrastructure may include acoustic detection with video confirmation or other systems.

4.4.5. Redding District Incident Management Responder Study (Redding Responder)

To enhance the collection and delivery of 'real-time' incident information, a study will be conducted to investigate, analyze and make recommendations on an electronic data collection and communications system for Redding District maintenance personnel. The concept is that the maintenance personnel would use the system to provide information to the traffic management center, track and inventory at-scene equipment and materials provided and record data for post incident analysis.

4.5. Funded RIME Projects and Status

Two of the five proposed projects, WeatherShare and Redding Responder, were funded by Caltrans DRI, and initiated in May 2003. Both projects will conclude Phase I research and development in December 2005. With each project having demonstrated a successful "proof-of-concept," Caltrans DRI has funded subsequent Phase II research and development to begin immediately after the conclusion of Phase I. Phase II research and development will prepare the products of these projects for prospective statewide production deployment, thus focusing on a greater service region and for an expanded group of prospective users. WTI will be the contractor for Phase II of both projects.

While it was not a stated requirement or objective, efforts have been made and consideration has been given to integration of these two projects where appropriate and feasible.

4.5.1. Responder Phase I

4.5.1.1. RIME Organization Involvement

Caltrans District 2 and Caltrans Division of Research & Innovation have served as lead organizations for this effort and have provided primary guidance and feedback. Other member organizations such as NORCAL EMS and California Department of Forestry have expressed interest in the study and have been involved in several related discussions and demonstrations. WTI has conducted research and development for this study.

4.5.1.2. Overview

Phase I of Redding Responder is the subject of this document and is described subsequently.

4.5.2. WeatherShare Phase I

4.5.2.1. RIME Organization Involvement

Caltrans District 2 and Caltrans Division of Research & Innovation have served as lead organizations for this effort and have provided primary guidance and feedback. Other member organizations such as NORCAL EMS, California Department of Forestry, CHP, and SHASCOM have participated actively as stakeholders and have helped in establishing requirements and conducting evaluation. WTI has conducted research and development for this project.

4.5.2.2. Overview

The Phase I WeatherShare system integrates surface weather readings from nearly 700 weather stations in Northern California. Data is imported from the California Data Exchange Center (CDEC); MADIS, a repository of Western U.S. weather information housed at the University of Utah; NOAA's Meteorological Assimilation Data Ingest System (MADIS); and Caltrans RWIS stations.

Currently, data from 11 Caltrans RWIS stations is present in the system. WeatherShare integrates these stations with the 600+ other stations, providing far greater coverage of the region than with RWIS alone. This added data can also be used to verify data from RWIS stations.

The system provides multiple views of data. Public, unauthenticated access allows users to view data by sensor type (temperature or wind, or both), by station type, and by station detail. Map layers can be toggled on and off to show or hide detail such as roadways, water features and county boundaries. Authenticated access allows users who have been granted logins to customize their default view by storing preferences. These users also have access to non-public data such as Caltrans RWIS pavement temperatures, as well as historical data and quality control checks.

Authenticated users have the capability of setting alerts, which are triggered when user-defined thresholds are crossed. For instance, an alert could be set to show wind speeds that exceed 30 miles per hour. Stations with readings for which that threshold has been exceeded would blink on the WeatherShare display to alert the user to this condition. If the user were a TMC operator, they might then activate a changeable message sign to indicate a high-wind warning.

By providing a single source for this information and the ability to customize the display of the information, the system gives users a single, user-friendly access point to surface conditions relevant to operation of roadways.

5. INTRODUCTION

5.1. "A Picture is worth a Thousand Words"

At the heart this study is an apparently simple question and associated problem:

Question: "There's a rock in the road. How big is it?"

Problem: How do you convey this information to someone who isn't there, looking at the rock alongside you?

Solutions to this problem depend on the means you have to communicate the answer. If you are communicating by voice alone, then phrases like, "bigger than a breadbox" and "smaller than a Volkswagen" could be used. But, such answers don't necessarily convey an accurate "picture." Even when coupled with measurements such as "six feet wide, four feet deep and five feet tall," the picture isn't complete partly because rocks aren't prisms, but also because further information is needed. Natural follow-up questions include "What is the composition of the rock?" "Are there other rocks in the road?" "Where did the rock fall?" "Is there an immediate risk of other rocks falling?" "Can traffic be allowed to pass?" "What equipment should be used to clear the rock?" The person at the scene may not be capable of answering these questions, let alone conveying the answers efficiently by voice. Ultimately, an expert or multiple experts may need to "see" the incident to assess the situation and proceed in identifying and mobilizing the resources necessary to clear the incident. But, it may take a long time for an expert to travel to the scene of the incident, particularly if it occurred in a remote, rural location.

So if it's a challenge to bring the expert to the incident, perhaps it's necessary to bring the incident to the expert. It is now common for maintenance crews and other prospective first responders to carry and use digital cameras to document incidents and their clearance. If the responders could immediately transmit digital photographs from an incident scene, then decisions could be made within minutes, and appropriate resources could be identified and dispatched, resulting in faster incident clearance.

As the saying goes, "A picture is worth a thousand words." Perhaps pictures can be used to convey what is very difficult with words alone.

As an example, consider the "rock in the road" shown in Figure 2:

Figure 2: Photograph[3] - Topanga Canyon Boulder

The "rock in the road" shown in this picture is actually a huge boulder that fell on Topanga Canyon Boulevard near Malibu in Southern California on January 10th, 2005 following heavy rains. The boulder and subsequent clearance efforts received attention from the National press for several days.[4]

While this example is out of the ordinary, it demonstrates several key benefits of the use of digital photographs to document an incident. The photograph in Figure 2 conveys more information about this incident than the statement, "There's a huge boulder in the middle of Topanga Canyon Boulevard!" The photograph shows this and gives an indication of where on the road the boulder is. People familiar with the area would recognize the curve and sign in the photograph, and could visualize the location of the boulder accordingly.

If care is taken in selecting photograph scenes and multiple photographs are used, then more information can be effectively communicated. The photograph in Figure 3 gives a better indication of the size of the boulder. It's not quite as tall as a telephone pole, but close. Judging from the crew and truck in the foreground, the boulder is approximately if not more than 18 feet tall, nearly three times the height of one of the crew members. With the crew and truck included in the photograph, any viewer will immediately recognize the magnitude of the incident. Furthermore, it can be seen that the boulder is wider than it is tall. Thus, it may be blocking at least one lane of the road.

[3] Source: California Governor's Office of Emergency Services, Photos by Robert Eplett
http://www.oes.ca.gov/Operational/OESHome.nsf/0/EF8986565A9A84FF88256F89006774D4?OpenDocument

[4] Source: NPR: http://www.npr.org/templates/story/story.php?storyId=4285622&sourceCode=RSS

Figure 3: Photograph[5] -Topanga Canyon Boulder

The photograph in Figure 4 shows that the boulder totally covers one lane, and protrudes into the second lane.

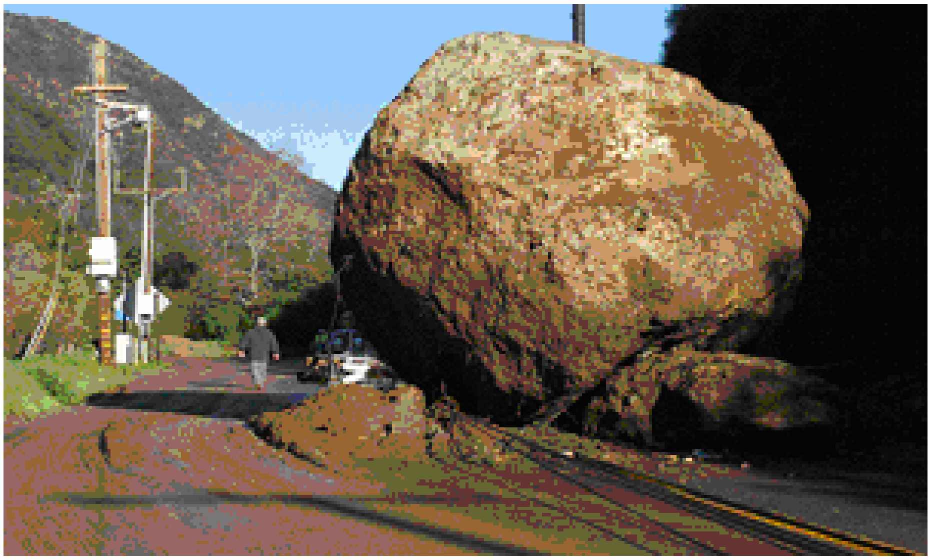

Figure 4: Photograph[6] - Topanga Canyon Boulder

Certainly these photographs convey a great deal of information about the incident that would immediately be valuable to department of transportation personnel.

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[5] Source: California Governor's Office of Emergency Services, Photos by Robert Eplett
http://www.oes.ca.gov/Operational/OESHome.nsf/0/EF8986565A9A84FF88256F89006774D4?OpenDocument
[6] Source: California Governor's Office of Emergency Services, Photos by Robert Eplett
http://www.oes.ca.gov/Operational/OESHome.nsf/0/EF8986565A9A84FF88256F89006774D4?OpenDocument

5.2. Caltrans District 2 “Rocks in the Road”

While the boulder incident in Topanga Canyon was extraordinary, “rocks in the road” are common in California, especially in District 2 and the rest of the RIME region.

5.2.1. SR-70 Rockslide in Butte County

5.2.1.1. Background

The press photographs in Figure 5 show a rockslide on California State Route 70 in Butte County approximately 75 miles southeast of Redding, which occurred on the evening of February 25th, 2004. The text in Figure 6 was published in a press release regarding this incident on February 26th, 2004. This incident and its location have been used as samples throughout the Responder study.

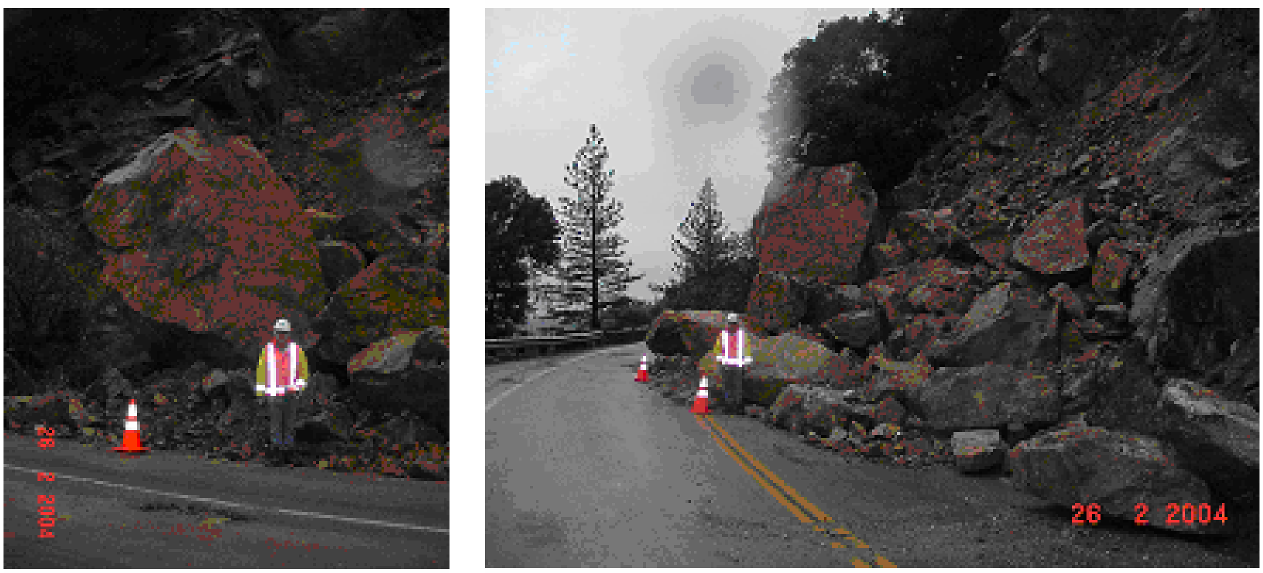

Figure 5: Press Photographs[7] - SR-70 Butte County Landslide

[7] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/archives.htm, http://www.dot.ca.gov/dist2/images/Photos/butte1.jpg, http://www.dot.ca.gov/dist2/images/Photos/butte2.jpg

Emergency Slide Removal on State Route 70 Butte County

REDDING – The California Department of Transportation (Caltrans) will begin immediate emergency road work to remove soil and rocks, some measuring more than 15 feet in diameter from State Route (SR) 70 in Butte County. The slide occurred February 25, 2004 at approximately 7:40 p.m. near Lake Oroville, 1.5 mile west of Pulga. The roadway is open to one-way traffic control and it is anticipated that it will reopen to normal traffic at 8 p.m., Friday, February 27, 2004.

The slide includes more than 200 yards of material, much of which are large pieces of rock, some weighing well over 200 tons. Explosive devices will be used in the slide removal, and during the blasting operations, the roadway will be completely closed for up to 20-minute intervals.

In order to complete the blasting process, more than 40 holes must be drilled into the rock. Drilling will begin this afternoon and continue through the night. Beginning Friday morning the slow process of blasting will be completed in small sections to limit the amount of rock that is dispersed. Extra precautions will be taken due to the location of a major electrical transmission line just below the blast area. Caltrans personnel are handling the removal process with the exception of the drilling. Certified Blaster, Mark Vukich, who is a Caltrans Maintenance Supervisor, will conduct the blasting and other Caltrans maintenance staff will remove the roadway debris.

Figure 6: Press Release[8] - SR-70 Butte County Landslide

As indicated by the photographs and the press release, this landslide had an impact on traffic and required a significant clearance effort. In fact, the road wasn't totally cleared until Saturday, February 28th, the day after the anticipated re-opening stated in the press release. Difficult weather conditions persisted, making the job even more difficult.

Not only was it a challenge to clear the incident, it was challenge getting the photos shown in Figure 5 to the outside world. The nearest place from which these digital photographs could have been transmitted is the Pulga maintenance yard, which is only 1.5 miles east of the incident location. But, because of the weather, phone lines were out at Pulga. And, even if phone lines had not been out, it was estimated that it would have taken as long as 15-20 minutes for transmission of each photograph. So, these and other photographs taken at the scene were not transmitted until the maintenance supervisor returned to Quincy, which is 55 miles to the east, on February 26th. Photographs were sent electronically to the Maintenance Manager, the Public Information Officer, and dispatch in Redding.

Communication challenges were also encountered while making arrangements to secure equipment including an air track. It was necessary for the maintenance supervisor to drive to

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[8] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/archives.htm
http://www.dot.ca.gov/dist2/pdf%20files/04-026nr.pdf

Concow, approximately six miles to the southeast, for cellular coverage, to make calls to arrange for this equipment. An estimated 4-6 hours total were lost due to back and forth trips to call to various blasting companies, leave messages, retrieve voicemail messages, and respond to those messages. An attempt was made to use dispatch as an intermediary so that the maintenance supervisor could use radio to talk to dispatch who, in turn, could talk to the blasting companies, and facilitate communication between the maintenance supervisor while at the scene, and the blasting companies. But, the blasting companies were reluctant to use the process. Thus, they had to wait until the maintenance supervisor returned to Concow and could answer questions directly via cell phone. This process was acknowledged to be vulnerable to miscommunication, but it was the best means under the circumstances.

Figure 7 shows the relative location of the incident, indicated by a camera icon; and Pulga, Concow, and Quincy, marked by phone icons to indicate where phone service was, or would have been used had lines not been down, during this incident. (The exact location of the incident was latitude 39.77616N and longitude 121.45572W.)

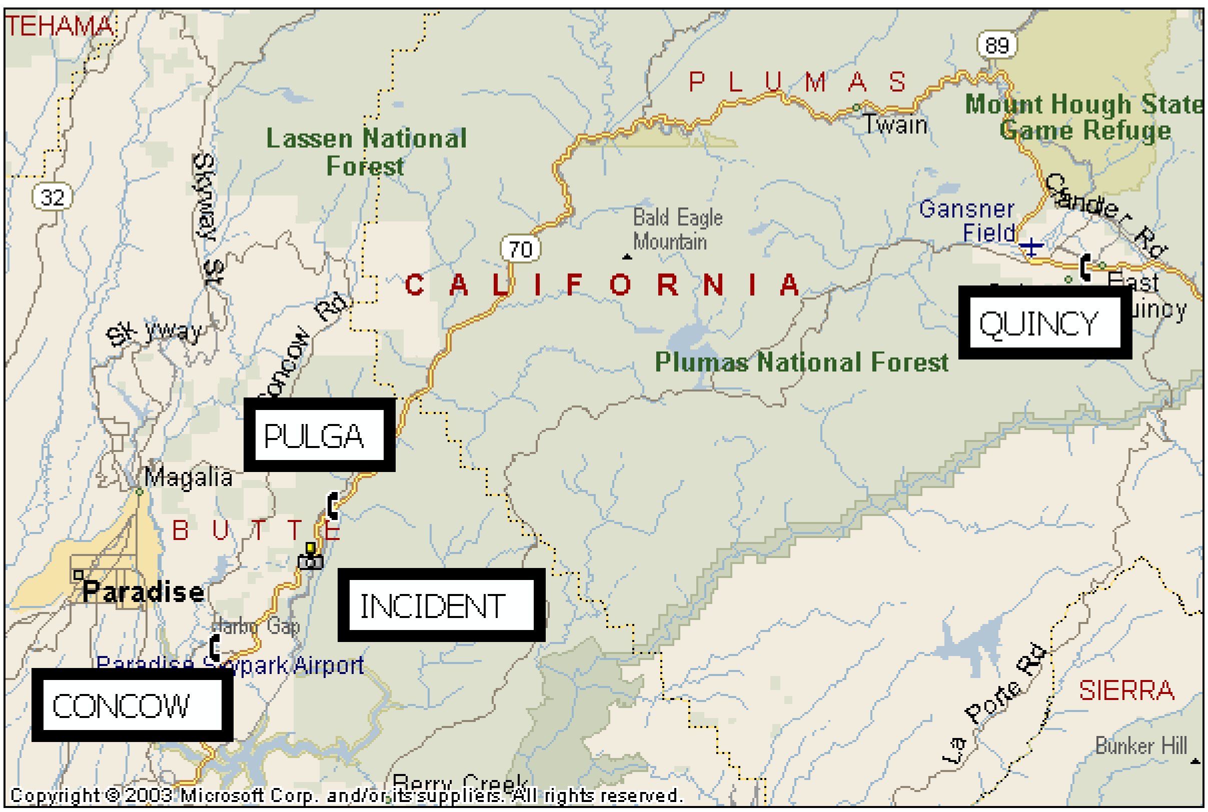

Figure 7: SR-70 Butte County Landslide Location

Direct voice communication from the incident scene to blasting companies, had it been available, would certainly have been of benefit. Beyond that, the capability of immediately transmitting incident photographs that had already been taken at the scene, may have expedited this process and helped to more readily answer questions about the incident. Aside from getting information to the blasting companies, photos would have helped Caltrans staff who had not yet arrived at the scene to confirm details such as the need for a drilling rig.

This is not to say that early transmission of photographs would have solved all problems. There will always be unanticipated delays or events. But, it was estimated that under ideal circumstances, the incident could have been cleared by noon on February 27th as opposed to noon of the 28th. The transmission of photographs alone could have helped to achieve this.

5.2.1.2. Photographs from the SR-70 Incident and Assessment

The photographs in Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12 reveal a great deal of information about the incident and clearance progress. Note that the photographs were not all taken at the same time. The first three (Figure 8, Figure 9, Figure 10) show the incident location prior to clearance efforts, and the fourth (Figure 11) and fifth (Figure 12) were taken during clearance efforts.

Figure 8: Incident Photograph[9] – SR-70 Rockslide in Butte County

[9] Source: Caltrans District 2

Figure 9: Incident Photograph[10] – SR-70 Rockslide in Butte County

Figure 10: Incident Photograph[11] – SR-70 Rockslide in Butte County

[10] Source: Caltrans District 2
[11] Source: Caltrans District 2

Figure 11: Incident Photograph[12] – SR-70 Rockslide in Butte County

Figure 12: Incident Photograph[13] – SR-70 Rockslide in Butte County

[12] Source: Caltrans District 2
[13] Source: Caltrans District 2

The Caltrans District 2 Maintenance Manager provided the following observations and assessment that would have been derived from these photographs alone:

The first three photos (Figure 8, Figure 9, and Figure 10) *show:*

- *The size of the slide*
- *Kind and type of rock*
- *Road blocked, but open to one way traffic control*
- *Rock too big to move with equipment, so we will need to blast*
- *Too many rock to drill by hand, so we will need to rent the track drill*
- *We will have to make a ramp for the track drill so it can drill the one large rock*
- *The person give perspective to size of the rock*
- *The large rock is over 200 tons*
- *We will need to mobilize our blaster, air compressor and drill, long term traffic control, let PIO know what's happening, rent light plants and a track drill*

The last two photos (Figure 11 and Figure 12) *show:*

- *Size of larger rock*
- *Pavement damage*
- *Progress of work*

He further remarked that:

Better (or additional) *photos would have shown:*

- *The face of the hillside above the slide*
- *A better shot of the surrounding area*
- *Major power lines just below slide area, a concern when blasting*
- *A major railroad below the slide area, a concern when blasting*

Taking these photos wasn't a problem, and their usefulness is apparent. What is at question is whether an efficient and reliable means can be identified to collect, prepare and transmit them and other vital data from the incident to other individuals and agencies that could use this information to help those at the scene to clear the incident. Those who would benefit from this information include, but are not limited to:

- The Maintenance Supervisor, from Quincy, prior to arrival at the incident scene
- Blasting, Drilling and Other Companies in various locations who would be contracted to help clear the incident
- The Public Information Officer in Redding
- The Maintenance Manager in Redding
- Traffic Management Center (TMC) Staff in Redding
- Dispatch in Redding

5.3. Other District 2 Incidents

The SR-70 Butte County incident from February 2004 was not uncommon for District 2. And, the challenges faced could have been worse. This incident occurred relatively close to "civilization". The rest of the Feather River Canyon, from this incident's location nearly to Quincy is rugged and remote, facing severe challenges due to terrain and distance from populated areas:

> *The Feather River Canyon is especially prone to rock slides due to the steep canyon walls. Nearly every year, rock slides big enough to warrant an emergency construction contract are necessary. "We work very hard at trying to keep State Route 70 open with minimum delays, but when large rocks begin to fall we have to do whatever it takes to stabilize the situation", said Russ Wenham, Deputy District Director for Caltrans in Redding.*[14]

Several typical incidents encountered by Caltrans District 2 in the Winter are documented by press releases and photographs in Appendix I – CALTRANS District 2 Incidents. Three of these incidents occurred along SR-70, another on I-5, and another on SR-299. The SR-70, Butte County incident is neither isolated, nor unique to area.

[14] Source: Caltrans Press Release – Rockslide, SR-70, Plumas County, 1/22/2004, http://www.dot.ca.gov/dist2/pdf%20files/04-007nr.pdf

5.4. Solution: Build or Buy?

Research was conducted in this study to solve the problem of how to effectively and efficiently use technology to collect and convey information that answers questions such as "How big is the rock in road?" On the surface, it may appear that this problem had already been solved by existing technology. In part, it had. Digital cameras, portable computers, and satellite modems were already in use in remote rural areas, even by Caltrans, and came to mind immediately for use in solving this problem. But, as we delved further into the problem, its complexity and associated challenges became apparent.

Take for example the SR-70 Butte county incident. Recall the observation that even if phone lines had been working at the Pulga maintenance yard, it would have taken 15-20 minutes to transmit each photograph. Given this performance concern regarding an admittedly slow land-based telephone line, imagine the concerns regarding an even slower satellite data connection.

To address this problem, one might suggest reducing the resolution of the photographs and then compressing them. This can be done using a variety of software packages and might even make it possible to transmit multiple photographs in the same amount of time it previously took to transmit one. But, an additional software package would now be needed to compress the photographs. Anyone familiar with such packages realizes that they are not always easy to use, even for this simple task. So, in exchange for photographs that can be more readily and efficiently transmitted, workers must be familiar with such a software package and it must be pre-loaded on their computers. And, if they forget how to use it, they may spend as much time trying to remember how to resize and compress photographs as they would have otherwise spent attempting to transmit the originals.

Other seemingly small tasks present equally significant challenges to the worker using this equipment. For instance, when at the maintenance yard, the worker might connect their computer to a telephone line and use a corresponding dial-up connection (DUN). When in the field, they would need to remember to use a separate DUN corresponding to a satellite modem. This task, combined with the prerequisite of connecting cables between the computer and satellite modem would require time and could potentially cause a great deal of frustration.

In addition, other useful information could be collected at the scene of an incident, including basic location information, and assembled as part of an "incident record." Further tools such as a GPS would be useful in gathering this information, ideally in an automated fashion.

It can be seen how a seemingly simple "system" for collecting and conveying incident information can quickly become complex and difficult to use, particularly if the needs of the prospective end-user are not taken into account. Thus, it was determined that this study should proceed with research and development to:

- Determine District 2's needs in regard to this problem.
- Conduct research of prospective technologies in an objective manner.
- Apply research to integrate technologies into a proof-of-concept system that addresses District 2's needs.

These tasks would be conducted in an iterative fashion using Systems Engineering principles to assure that the right system was built using the right technologies.

6. METHODOLOGY

To best facilitate the research focus and proof-of-concept development nature of this project, a generalized Systems Engineering approach using a Spiral / Iterative Process Model was followed. This process is consistent with Caltrans' "Stage of Research Deployment."

6.1. Systems Engineering Approach

A Systems Engineering approach, as illustrated by the "Vee" Model in Figure 13, was taken in designing and developing the Redding Responder Phase I proof-of-concept system. A Systems Engineering approach increases the likelihood that the system will work, satisfy customer needs, and meet acceptable cost and schedule constraints.

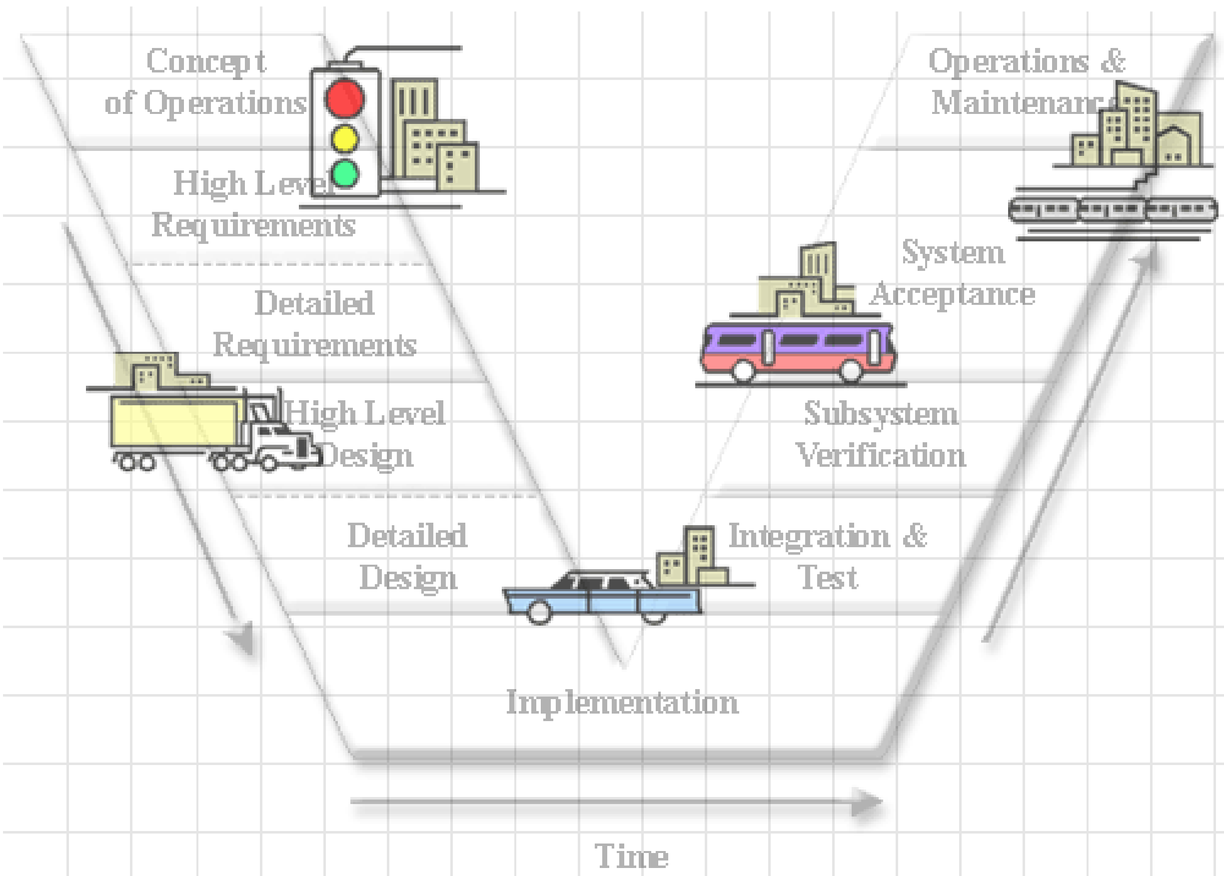

Figure 13: "Vee" Model for Systems Engineering

6.2. Spiral / Iterative Process Model

Within the context of the systems engineering approach, the spiral model for development (Figure 14) was followed to iteratively produce prototype systems, culminating in the Phase 1 proof-of-concept system. Feedback was solicited, reviewed and incorporated into subsequent development, with redesign conducted as necessary in each iteration.

This iterative approach allows prospective users of a system to provide input throughout the development process, by testing new and proposed functionality and interfaces before they are finalized. The end result is a system that better meets the needs of users in terms of both usability and utility. The Responder proof-of-concept system has been developed with an emphasis on ease of use and usability.

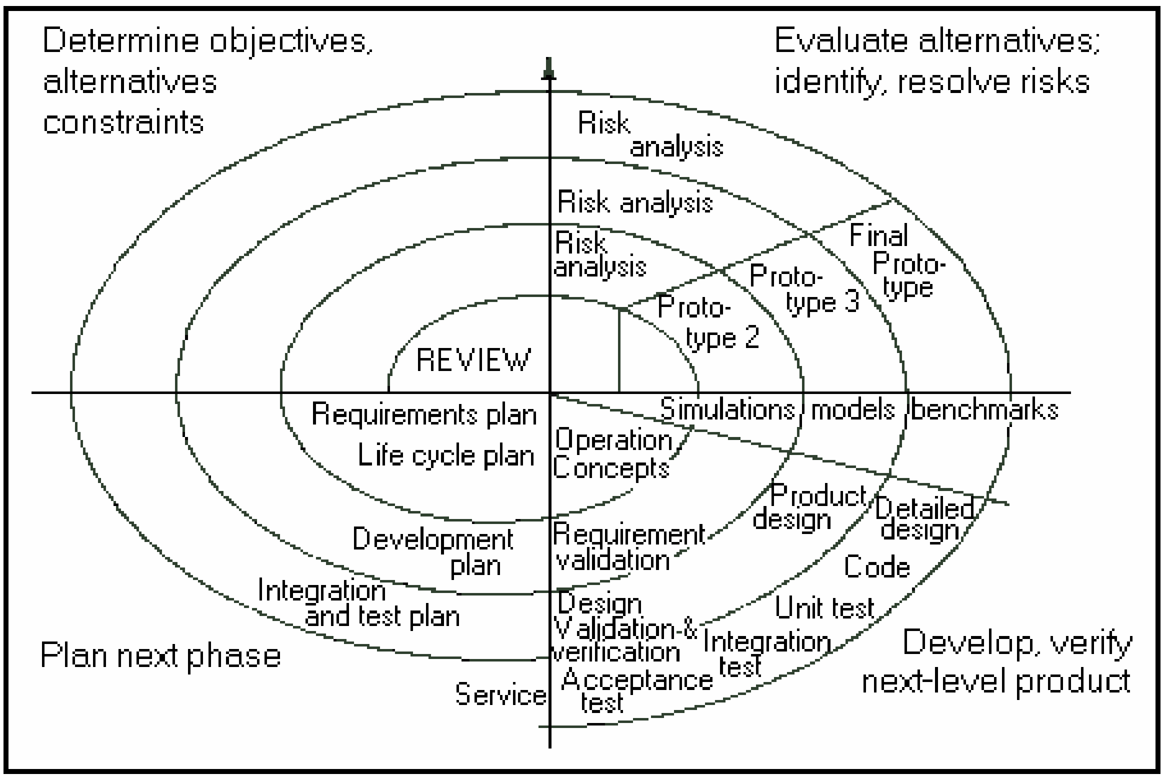

Figure 14: Spiral Model for Development[15]

The spiral model for development is an iterative process model and is often associated with rapid prototyping.

[15] Source: A Spiral Model of Software Development and Enhancement, Barry W. Boehm, TRW Defense Systems Group, May 1988, IEEE Computer

6.3. Caltrans' Stages of Research Deployment[16]

The Caltrans Division of Research and Development has identified five stages of research (development and) deployment:

CONCEPT STAGE

- First steps following Problem Statement and Proposal
- Includes detailed literature search
- Involves experimental design, data collection, analysis and reporting
- Assesses results of research
- Defines barriers, to implementation (e.g.. policies. specifications, standards)
- Submits a Final Report and outlines a recommended implementation plan.
- Includes collaboration with outside agencies or other state DOTs and US DOT

LABORATORY PROTOTYPE STAGE

- Develops breadboard circuit or computer system modeling
- Demonstrates operation in laboratory setting
- May incorporate customized or one-of-a-kind components
- Assesses results
- Submits Final Report and recommends design of full-scale demonstration
- Potential end users are enlisted to support the field pilot stage

CONTROLLED FIELD DEMONSTRATION STAGE

- Prepares for full-scale testing of demonstration project
- Controlled tests at specialized facilities are observed and supported by cooperating agencies, industry and technical associations
- Potential end-users are enlisted to support the field pilot stage
- Assesses results
- Submits Final Report and recommends site/conditions for first application pilot stage

FIRST APPLlCATION (CONTRACT) FIELD PILOT STAGE

- Works with potential end-users to select site and to conduct pilot testing under real-world operating conditions
- Test specifications and standards are developed
- Research assistance given to assure proper installation and operation
- Problems are corrected and adjustments made, as necessary, to complete pilot testing
- To the extent possible, potential end-users operate the project under careful research surveillance
- Assesses results
- Submits Final Report and recommends initial sites for full corporate deployment

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[16] http://www.dot.ca.gov/hq/research/deployment_support/5_stages.htm

SPECIFICATION & STANDARDS WITH FULL CORPORATE DEPLOYMENT STAGE

- End-user(s) select site(s) and deploy the method/process/equipment using resident management, supervision, staff and contracting forces (where applicable)
- Deployment is without research supervision or direction
- On-call assistance is available upon request
- Assesses results
- Submits Final Report and recommends adoption of specification and standards

There is a general correspondence between research conducted in this study and these stages of research deployment, as illustrated in the following section.

6.4. Resulting Project Process Model

The process model followed in this study is a hybrid of the classic Systems Engineering approach and the Spiral Model for Development. The steps of the Systems Engineering approach, as identified in the "Vee" diagram, were followed in an iterative fashion as shown in Figure 15. Each process model iteration corresponds to an iteration in the Spiral Model for Development. Note that the "Need" step is conducted once, corresponding to the initial identification of need. The "System Acceptance" and "Operations & Maintenance" steps are not conducted within these iterations, but would be conducted at the point where a production system is completed. These steps will be conducted beyond this first, proof-of-concept phase.

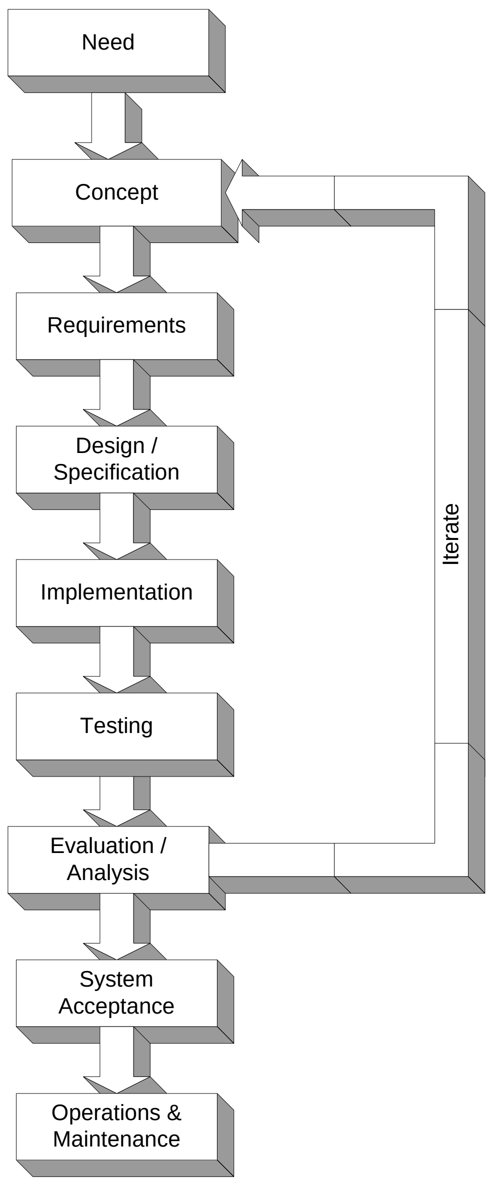

Figure 15: Project Process Model

A correspondence of the development iterations to the Caltrans' Stages of Research Deployment is shown in Figure 16. Note that the first three iterations correspond to the "Concept Stage," and are considered as concept refinement. Note also that the "First Application (Contract) Field Pilot Stage" and the "Specification & Standards with Full Corporate Deployment Stage" fall outside the scope of Phase 1, the proof-of-concept phase, and will be addressed in Phase 2.

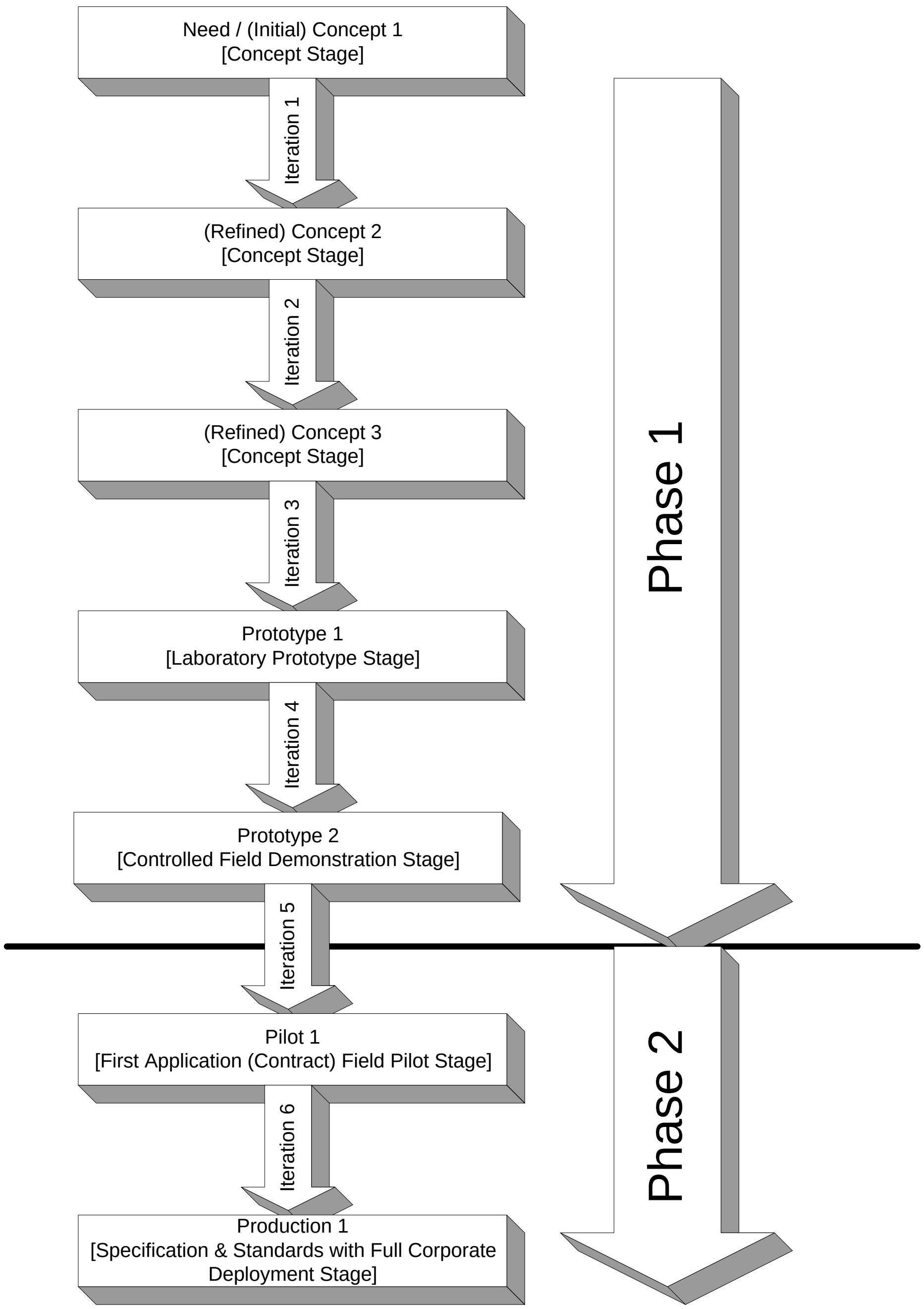

Figure 16: Correspondance to Caltrans' Stages of Research Deployment

7. STAGES OF DEVELOPMENT

The development conducted within this study is organized and described by iteration. Rather than presenting just final summary results, this method of presentation was chosen to demonstrate the process, in detail, as it was followed. Thus, it will be a resource for analysis and development in subsequent phases. Furthermore, it may be seen of benefit for application to other similar projects.

Note that certain steps were followed “in spirit” but not in a rigorous detail. For instance, the “Concept” is presented in general terms within each iteration, rather than in full detail following a standard such as that presented in *IEEE Std 1362-1998, IEEE Guide for Information Technology—System Definition—Concept of Operations (ConOps) Document.* Such rigor was not deemed necessary due to the proof-of-concept nature of this study.

Likewise, requirements and design specifications are presented as they were encountered or developed, and some that are listed will be deferred to subsequent development phases. This approach provided ample room for flexibility and creativity in development while helping to elicit and address user requirements. Furthermore, it allowed requirements and design to be specified in detail only when necessary and not prematurely.

An initial task in Phase 2 of the Responder Study will be the production of a detailed requirements and design summary along with a corresponding traceability matrix.

Each development iteration is documented with the following subsections:

<u>Time Frame:</u>	The time frame over which the iteration occurred.
<u>Overview:</u>	A brief overview of the iteration.
<u>Concept:</u>	A brief statement of the concept, including revisions as a result of the previous iteration.
<u>Requirements:</u>	A listing of requirements, including revisions as a result of the previous iteration.
<u>Design/Specification:</u>	A brief overview of design, including revisions as a result of the previous iteration, and specific stated design preferences.
<u>Implementation:</u>	A detailed description of implementation.
<u>Testing:</u>	A brief overview of testing conducted during this iteration.
<u>Evaluation/Analysis:</u>	Summaries of surveys, discussions and test results, and corresponding analysis.

7.1. Need / (Initial) Concept 1 [Concept Stage]

7.1.1. Time Frame

May 2003 – October 2003

7.1.2. Overview

The Redding District Incident Management Responder Study (Redding Responder) originated as a general concept within the Redding Incident Management Enhancement (RIME) program. This general concept required refinement, which was initiated with discussions at the October 2003 project kick-off meeting.

7.1.3. Concept

A general concept of the Redding Responder system was stated in the project description from the proposal:

> *To enhance the collection and delivery of 'real-time' incident information, a study will be conducted to investigate, analyze and make recommendations on an electronic data collection and communications system for Redding District maintenance personnel. The concept is that the maintenance personnel would use the system to provide information to the traffic management center, track and inventory at-scene equipment and materials provided and serve as a record for post incident analysis.*[17]

7.1.4. Requirements

The formalization of initial high-level and specific requirements was deferred until the next development iteration, and pending discussions at the project kick-off meeting, scheduled for October, 2003.

The following objectives[18], from the project proposal, were be discussed at the project kick-off meeting, and would form a basis for subsequent requirements:

- [The system shall] enhance the collection and sharing of incident, incident response and clearance information from a transportation management perspective and baseline incident information requirements of District 2 at-scene field unit and the Redding TMC.
- [The system shall] provide the means for at-scene District 2 field personnel for asset management and the real-time exchange of asset management information between the field unit and the Redding TMC.

[17] Source: Original Responder Proposal
[18] Source: Initial Responder Project Plan: October 2003

7.1.5. Design / Specification

Formal design and specification was deferred until the next development iteration, pending subsequent requirements definition.

7.1.6. Implementation

Implementation was deferred pending subsequent design and specification.

7.1.7. Testing

Preliminary research was conducted to identify prospective viable technologies that would be applicable to the project. In particular, it was noted that satellite would likely be the only option to provide communication coverage through District 2.

7.1.8. Evaluation / Analysis

7.1.8.1. Discussion from October 2003 Kick-Off Meeting

The following summary paraphrases discussions between District 2 personnel, the DRI project manager, and the WTI project team during the October 2003 Kick-Off meeting. The purpose of this discussion was to refine the system concept and to elicit initial, high-level system requirements.

Speaker	**Comment**
D2 Director:	*"Responder should consider EMS, fire department, and other needs, but at this stage should focus on collecting incident information needed by Caltrans"*
D2 Maintenance Manager:	*"What is the incentive for the at-scene responder to input all the incident information to a device? Time is precious. So maybe the at-scene data collection device should be automated."*
D2 Maintenance Manager:	*"Possible Use: There's a rock in the road. How big is it?"*
D2 ITS Engineer:	*"Build a mobile data terminal for use in rural areas. Incorporate 802.11 for local area communication."* *Communications is KEY in the District 2 area and the most reliable coverage (for external communication) might be the satellite phone system. Cellular phone coverage is neither 24/7 nor available anywhere in the area (due to mountainous geographical characteristics)*
DRI Project Manager:	*"Make it of use in urban areas as well."*

D2 Maintenance Manager: *"Information should flow both ways between the at-scene personnel and TMC."*

WTI Research Team: *"A Tablet PC and Digital Camera could be used to incorporate Digital Photos and other data."*

D2 Director: *"The Responder project should have a research component. (What can be learned from the project? What results can be applied elsewhere?)"*

7.1.8.2. Analysis of Discussion

This dialogue, particularly the underlined portions, provided a basis for (Refined) Concept 2, the second version of the system concept. A system would be built to facilitate the collection and transmission of incident information, particularly digital photographs. The system would be usable by Caltrans and potentially by other agencies, and various technologies would be researched in the process of building this system. Communication, particularly in the most remote areas of District 2 would be a challenge.

Further concept refinement was necessary before proceeding with development and associated research. Requirements elicitation would likely be an on-going process within the study.

7.2. (Refined) Concept 2 [Concept Stage]

7.2.1. Time Frame

October 2003 – February 2004

7.2.2. Overview

The dialogue from the October 2003 Kick-Off Meeting was used to refine the system concept. Further refinement was necessary to formulate a concept and associated plan specific enough for the Caltrans Management Team to authorize the WTI Project Team to proceed with subsequent research and development.

7.2.3. Concept

A refined concept emerged from the October 2003 Kick-Off Meeting dialogue:

> *The Responder System would consist of integrated hardware, software and data communication equipment capable of recording and transmitting incident information from the scene of incidents occurring anywhere (rural or urban) within the RIME region. It would also be capable of receiving information (data) from the outside, including the Redding TMC.*

7.2.4. Requirements

Several high-level requirements (features) were derived from the October 2003 Kick-Off Meeting dialogue in conjunction with the refined concept:

1. A system shall be implemented to collect incident information.
2. The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.
3. The system shall be deployed within Caltrans' vehicles in the field.
4. The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.
5. The system shall be easy to use.
6. The system shall automate the collection of incident information.
7. The system shall minimize the amount of time required for use.
8. The system shall transmit information to the TMC and other outside agencies.
9. The system shall receive information from the TMC and other outside sources.
10. The system shall have data communications capability in all areas of District 2.
    a. The system shall be operable in rural areas including mountainous areas.
    b. The system shall be operable in urban areas.

These features were general and would require further refinement and qualification, but they provided a framework to better formalize the system that would be developed.

7.2.5. Design / Specification

Several technologies were identified for prospective use. These technologies led to initial design specifications:

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
- The system shall use a digital camera to collect digital photographs of incidents.
- The system shall use satellite communication to provide data communication capability in mountainous areas.
- The system shall use cellular data communication to provide data communication capability in urban and other areas where cellular communication is available.
- The system shall use IEEE 802.11 –based wireless technology to implement un-tethered use in the proximity of parked Department vehicles in the field.

Design specification would evolve in subsequent iterations, and these technologies would be tested and evaluated. At this point, they were considered as likely components for the system.

To address the goal that research from this project should be applicable elsewhere, these technologies and others would be investigated not only for the sake of development of the Responder system, but also for other prospective uses. For instance, what are the limits of mobile satellite data and voice communications, particularly in mountainous areas? And, can the functionality of a Tablet PC be used to make it an easier to use field device than a standard notebook computer?

7.2.6. Implementation

A presentation and supporting documentation were prepared by the WTI Research Team to propose further refinement of the system concept for Caltrans. Approval of this proposed refinement was necessary prior to detailed research and development. The presentation and supporting materials were presented and discussed in a November 2003 teleconference between the WTI Project Team and the Caltrans Project Management Team.

7.2.6.1. Overview of Proposed Concept Refinement

Responder would be a tool for providing more effective two-way communication between responders, their managers, and other agencies. It would provide a framework for the distribution and retrieval of incident information, regardless of agency and need, and would facilitate information sharing.

Information such as weather conditions, maps and aerial photographs would be delivered automatically to responders using automatic geo-location and remote data connectivity. Access to such information would assist responders in making decisions to ensure safety and effectively manage an incident. At scene photos could be quickly sent by responders to relevant parties along with appropriate metadata such as location, time and description as well as standard forms. Maps and photos could be quickly annotated with hand-drawn sketches and sent as well. Much like a football coach diagramming a play, a responder would communicate the scope of an incident, current status, and proposed or current response plans quickly and efficiently in a manner that others can readily understand. It would not be possible or feasible to convey the same information using fixed forms or voice communications alone.

Where appropriate, electronic forms would be included and tailored to specific needs of agencies. They would be filled out on-scene and transmitted electronically, reducing the chance for error and increasing the ability to share such information with multiple users.

Responder would provide “views” both out from and into an incident, allowing those who are not on-scene to make better decisions and provide better service to those who are, while allowing those on scene greater access to information of use in managing the incident. It would provide a dynamic view of incidents located in remote rural areas where communication and access are limited.

Information could be internal and specific to the responder’s organization or external, coming from another organization or a source such as WeatherShare. Thus, Responder would complement other systems such as Computer Aided Dispatch (CAD), by providing information that is not available otherwise and by providing a blueprint for sharing such information among organizations.

7.2.6.2. A Rough Prototype

An incident scenario was presented in which there had been a collapse of a major section of roadway. Responders equipped with the prospective Responder System are at the incident scene collecting and transmitting information.

Following is an overview of this presentation:

A Picture is Worth a Thousand Words – Incident Photos

The photos in the following figures convey a great deal of information about an incident. In particular, Figure 19 and Figure 20 include points of reference – two people standing nearby and a truck parked on the other side of the incident scene – that help demonstrate the magnitude of the collapse.

Figure 17: Incident Photograph 1

Figure 18: Incident Photograph 2

Figure 19: Incident Photograph 3

Figure 20: Incident Photograph 4

None of these individual photos tells the whole story, but each provides valuable information that could be of help in managing the incident.

A Prospective User Interface and Further Functionality

By further incorporating GPS functionality and an aerial photograph to show the locations from which the incident photos were taken, a more complete overall "picture" of the incident begins to form. Sketches and labels on the aerial photograph can complement other maps in helping initial responders to assess the situation.

Figure 21 and Figure 22 show a prospective user interface that allows users to annotate aerial photos and incident photos using a Tablet PC.

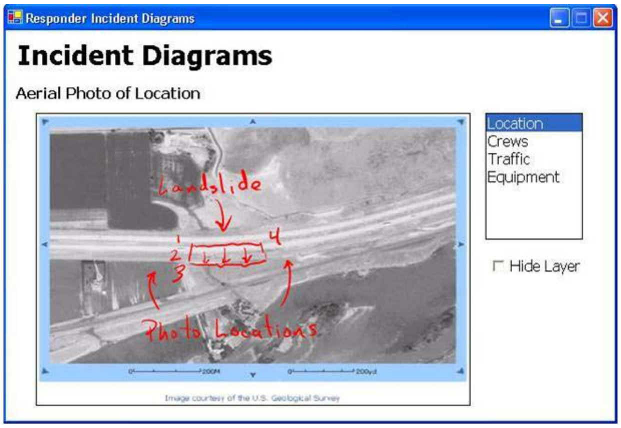

Figure 21: Hand-Drawn Annotations: Aerial Photograph

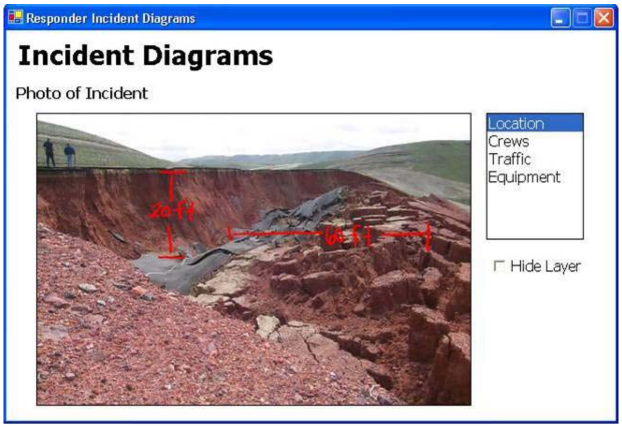

Figure 22: Hand-Drawn Annotations: Incident Photograph

Things to Note:

- Maps (road and topographic), Aerial Photos and Weather Information Enhance the Overall "Picture"
- Information is of Use to Responders, Dispatchers and Managers
- Photos and Maps can be annotated to convey even more information.
- Annotation can be added more quickly and accurately by pen than by voice.
- Annotation could be added iteratively, with information flowing to and from the scene.

An application to facilitate this would:

- allow for hand-drawn or stenciled annotations in multiple layers.
- associate location, time and other data with incident photos.
- store and present images and other data as a collection, not disparate pieces.

Further functionality could include the ability to complete electronic forms.

Flow Diagram for Prospective Responder System Use

Figure 23 shows a possible sequence of events followed in using the proposed Responder system in response to an incident. The Responder system facilitates the acquisition, exchange and refinement of information to assist responders, their managers and partners in making decisions to manage an incident.

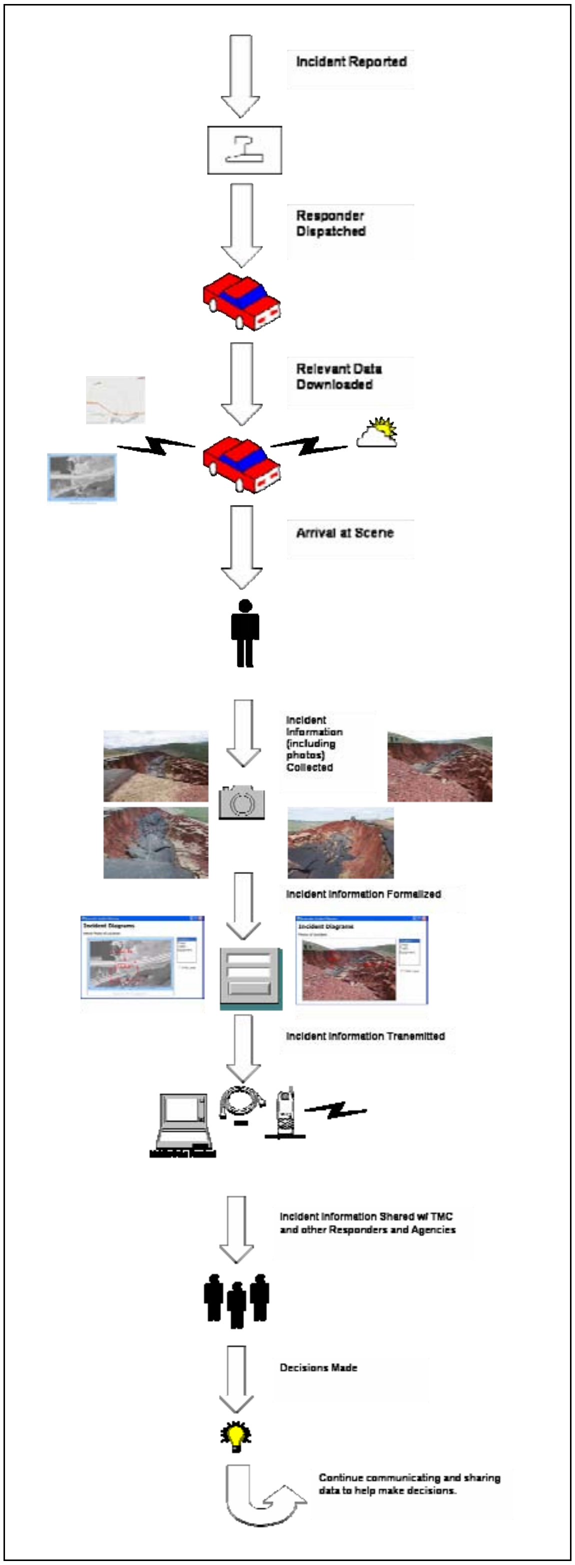

Figure 23: Flow Diagram for Prospective Responder System Use

7.2.7. Testing

Several key technologies were investigated in conjunction with the development of the mock interface screens for the refined concept. In particular, a rapid prototype was developed to test the viability of such a proposed interface using a Tablet PC and the associated software development kits (SDKs). This rapid prototype was used to create the screen shots shown in the presentation. It was determined that this option was viable and that it should be presented to Caltrans.

7.2.8. Evaluation / Analysis

7.2.8.1. November 2003 Teleconference

A teleconference was held between the WTI Project Team and the Caltrans Project Management Team on November 26th, 2003. The materials above were presented and reviewed during this teleconference. Following is a paraphrased summary:

Speaker	**Comment**
WTI Research Team:	*We propose that the system focus on a rural setting that is absent of existing data communications infrastructure. Requirements analysis should be conducted in parallel with prototype development, and multiple prototypes will be developed.*
D2 Director:	*Does a system already exist that meets the needs we've discussed?*
WTI Research Team:	*To the best of our knowledge, no, not completely. For instance, we have been made aware of the Bay Area Incident Response System (BAIRS) that is being implemented in District 4. To the best of our knowledge, BAIRS focuses on urban incident management while the proposed system would focus on rural incidents and associated challenges. Furthermore, BAIRS appears to be a customized Computer-Aided Dispatch (CAD) and Asset Management system, and that the proposed Responder system would not be redundant in that it addresses other issues such as the communication challenges in rural settings.*
D2 Maintenance Manager:	*BAIRS is a database/management/traffic management system, used to find the nearest available resources for incident management.*
All:	*It is agreed that the Responder system would not be redundant with BAIRS.*
D2 Maintenance Manager:	*The sample incident you've used (the collapsed section of roadway) demonstrates the usefulness of incident photographs, but this sort of incident would not occur often. The "rock in the road" that we've discussed previously is more representative of prospective system use.*
D2 Maintenance	*Having an inventory of incident photos is useful. Incident photos became*

Manager: *available online within Caltrans in the past year. Aerial photos of roadways are available now within Caltrans, although there is not complete coverage. These photos can be overlaid with other GIS information. The Office of Photographics in Sacramento maintains this information and they could be valuable resources for this project.*

DRI Project Manager: *Would a (notebook) computer or PDA be used in the responder vehicle?*

WTI Research Team: *We will investigate both possibilities, but a Tablet PC may be advantageous.*

DRI Project Manager: *Cell phones have the capability of taking pictures. Perhaps that is a viable option?*

WTI Research Team: *We will investigate this possibility further, but the functionality of cell phones is limited and likely won't allow for interaction with maps and aerial photos. Nor will it allow for easy annotation of Photos.*

D2 Director: *It will be a challenge integrating Responder into the Caltrans IT system. It is a good thing that the project is just a pilot.*

All: *In regard to budget and time issues, all agree that if additional project time was needed, sufficient notice (6 months) would be given. Funding will remain at the original amount.*

All: *All agree that the project plan should be modified to reflect the discussion and revised plan, and that the modified project plan would be submitted for approval prior to subsequent research and development.*

7.2.8.2. December 2003, January 2004 Review

Following the teleconference, the project plan was revised to reflect the proposed concept refinements. Several drafts were reviewed between December 2003 and January 2004. Aside from several requests and suggestions for clarification, the following comments were the only "new information" added in this review:

D2 Maintenance Manager: *Just a couple of things in regard to our equipment:*

- *We have had past experience with certain added electronic components being a problem.*
- *The added electronics have caused throttle's to go wide open or engine to die...*
- *Our equipment shop may want to hook up any power connections.*

Last but not least the system must be user friendly and simple to understand and use.

7.2.8.3. Analysis of Teleconference and Subsequent Review

The refined concept, as presented in the mock demo, was accepted by Caltrans and would be refined further in conjunction with research and development. Enough information was gathered to begin preliminary development and to proceed in gathering and formalizing detailed requirements. It would soon be necessary to survey those who would use and be most impacted by the prospective system to determine their needs and concerns.

7.3. (Refined) Concept 3 [Concept Stage]

7.3.1. Time Frame

February 2004 – May 2004

7.3.2. Overview

This iteration was the last concept-refinement iteration. Prospective users and others who would be impacted by the proposed system were surveyed to determine how they could most effectively use the system and how it could best help rather than hinder them in their jobs.

7.3.3. Concept

The concept is refined subsequent to the November 2003 teleconference to the following general description:

> A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

The objectives were revised to:

- Create and provide the information elements, framework and pilot deployment of an information collection system centered on the information needs of District 2 field units and Redding TMC for transportation management and incident response/clearance, and of relevance to other emergency response organizations. The incident information collection system will include capabilities for collection of incident images, facilities for annotating images and maps to describe incident scope and severity, incident GPS location, as well as form-based information as deemed appropriate by District 2.
- Create and provide the information elements, framework, and pilot deployment of an incident support information system based on the needs of District 2 field units and Redding TMC, and of relevance to other emergency response organizations. The incident support information system will include capabilities for downloading maps and aerial photos, weather conditions, and other support materials related to the incident and its location.
- Provide the necessary hardware and communications infrastructure for the exchange of at-scene information collected via the information collection system and the distribution of incident support information to responders as described for the incident support system. The communications system will provide the means to exchange information

between District 2 field personnel at the scene and Redding TMC, and will be capable of incorporating other emergency response organizations. In Responder vehicles this will consist of a mobile data terminal (ruggedized Tablet PC), a satellite or satellite/cellular combo phone, Internet data connectivity kit including cabling and software and providing, GPS hardware with computer connectivity, and a digital camera with computer connectivity. The incident information collection system and the incident support information system software will reside on and interface with this equipment to facilitate the collection of information and transmission of data to and from the incident scene.

7.3.4. Requirements

Requirements were further refined to incorporate items presented in the November 2003 teleconference. New requirements are listed in italics:

1. A system shall be implemented to collect incident information.
    a. *The system shall collect and store incident metadata.*
    b. *The system shall collect the incident location.*
    c. *The system shall collect the incident occurrence time.*
    d. *The system shall collect a description of the incident.*
    e. *The system shall collect incident photographs.*
    f. *The system shall collect incident sketches.*
    g. *The system shall facilitate sketches.*
        i. *The system shall facilitate sketches to annotate incident photographs.*
        ii. *The system shall facilitate sketches to annotate maps.*
        iii. *The system shall facilitate sketches to annotate aerial photos.*
        iv. *The system shall facilitate free-form sketches.*
    h. *The system shall facilitate forms.*
        i. *The system shall display forms.*
        ii. *The system shall facilitate entry of information into forms.*
    i. *The system shall store incident information as a collection, not disparate pieces.*
2. The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.
3. The system shall be deployed within Caltrans' vehicles in the field.
4. The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.
5. The system shall be easy to use.
6. The system shall automate the collection of incident information.

   a. *The system shall automatically geo-locate the responder.*
7. The system shall minimize the amount of time required for use.
8. The system shall transmit information to the TMC and other outside agencies.
9. The system shall receive information from the TMC and other outside sources.
   a. *The system shall display weather information based on the responder's location.*
   b. *The system shall display road maps based on the responder's location.*
   c. *The system shall display aerial photos based on the responder's location.*
   d. *The system shall display topographic maps based on the responder's location.*
   e. *The system shall download data to responders while en-route to and at the scene of an incident.*
10. The system shall have data communications capability in all areas of District 2.
    a. The system shall be operable in rural areas including mountainous areas.
    b. The system shall be operable in urban areas.

7.3.5. Design / Specification

Several important high-level design specifications were added during this phase (New specifications are listed in italics.).

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
    - *The system shall use a custom-developed application for data collection and recording.*
- The system shall use a digital camera to collect digital photographs of incidents.
- The system shall use satellite communication to provide data communication capability in mountainous areas.
- The system shall use cellular data communication to provide data communication capability in urban and other areas where cellular communication is available.
- *The system shall use GPS to auto-locate the responder.*
- The system shall use IEEE 802.11 –based wireless technology to implement untethered use in the proximity of parked Department vehicles in the field.

7.3.6. Implementation

No formal implementation occurred during this period. It was deferred pending survey results.

7.3.7. Testing

Research continued to test technologies for prospective use in development.

7.3.8. Evaluation / Analysis

7.3.8.1. Survey – May 2004

A survey of Caltrans D2 staff was conducted in May 2004 to elicit further system requirements. To this point, brain-storming sessions had been conducted to refine the system concept and elicit high-level requirements. The intent of this survey was elicit further, more-detailed requirements from people who would likely be directly involved with the system.

Participants

- Caltrans D2 Communications Center staff (2)
- Caltrans Superviser
- Caltrans Redding Maintenance Area Superintendent
- Caltrans, District 2 – Area Supt, Specialist, Hazmat Manager
- Caltrans Maint staff (1)
- Caltrans / Acting Supervisor

Summary

Complete survey responses are listed in Appendix II – May 2004 Survey.

Following is a summary of information, organized by category, gathered in this survey:

<u>Communications</u>

- Radio, cellular and pagers are currently used.
- There are areas where radio service is not available.
- Cellular and pager services have a lesser coverage area.
- Cellular phones from multiple service providers are used to provide greater coverage and reliability.
- Radio and cellular are valuable because they provide immediate communication, where available.
- Satellite phones have been used and provide greater coverage, but a previous vendor went out of business and units were not replaced.
- FAX is used in a HAZMAT van.

- A laptop with a cellular modem was suggested for data connectivity.
- Special antennas (YAGI) have been used to improve cellular signal strength.

Incident Support Data Provided to Responders En-Route to the Scene

- Regardless of the proposed system, improvements to radio and cell service would improve incident support.
- The following real-time information was suggested for inclusion:
  - precise location;
  - type of incident;
  - responders (including those from other agencies) en-route and at the scene;
  - traffic control;
  - equipment needed to clear, including HAZMAT;
  - quantitative information about the incident including measurements;
  - permits.

Incident Support Data Provided to Responders at the Scene

- Regardless of the proposed system, improvements to radio and cell service would improve incident support.
- The following real-time information was suggested for inclusion:
  - weather forecasts;
  - expected traffic volumes;
  - staff availability;
  - responding equipment and contract personnel and ETAs;
  - chemical information for HAZMAT;
- In general, more and better information about what has happened in regard to the incident should be included.

Incident Information Collected by Responders at the Scene

- All of the following could be collected:
  - digital photos and video for email to TMC to improve scene management including assessment of incident severity and to determine detours and closures;
  - post mile location;
  - road status including closures and associated directions of travel;
  - HAZMAT spill information including cargo, spill type and items necessary for cleanup;
  - real-time information including that listed above;

  - incident information as listed above;
- In general, more and better information about what has happened in regard to the incident should be included.

Use of Incident Photos, Aerial Photos, and Maps for Incident Management

Aerial photos could be used to:

- help determine the source of a landslide in the event of a major landslide.

Maps could be used to:

- determine or show detours, closures, and other traffic control around an incident;
- determine or show the location of command post;
- determine where to position crews and equipment;
- identify affected facilities;
- determine routes and wind directions;
- view storm and wild land fire information;
- analyze potential impact of spills.

Photos could be used to:

- show HAZMAT spills;
- show major accidents;
- show severity of incidents.

Familiarity, Comfort and Capability with Technology

In general, while not all survey participants had used the following technology, most had familiarity, comfort and capability with the following technologies:

- Cellular Phone
- Satellite Phone
- Pocket PC, Handheld PC, Palm Pilot, etc.
- Portable PC (Notebook Computer)
- Tablet PC (Computer with touch screen & pen)
- Digital Camera
- GPS Module

Use Scenarios of Proposed System

The following scenarios were identified for potential use of the system:

- landslides

- wild land fires
- HAZMAT
- earthquakes
- flooding
- storms

Willingness to Use Proposed System

Staff indicated a general willingness to use such a system with the following qualifications:

- They are only capable of operating a certain number of components at once, so caution must be used in requiring the use of additional tools.
- They would use the tool if it made them more efficient at their job.
- If it provides helpful information such as weather, product, or other support information, then it would be useful.
- If it improves communication and provides more accurate and timely information by an incident, then it will save time and money.

One staff member indicated that no time would be available for the collection and recording of at-scene information. Direct communication suffices. However, the same staff member indicated that time would be available to request and use support information.

Allowable Time for Download of Relevant Data from the TMC, Internet, etc.

- Tools may take too much time for use since many decisions are split-second decisions.
- The TMC may be the best option for information.
- When an incident scene is stabilized, then time is available, and generally not until then.
- A few minutes or a maximum of 10-20 minutes may be acceptable.
- For a HAZMAT incident, 30 – 90 minutes might be acceptable, if staff is available to use the information.

Allowable Time to Collect and Transmit Incident Data

- A short amount of time would be available to collect and transmit information to the TMC in general.
- When an incident scene is stabilized, then time is available, and generally not until then.
- Perhaps 15 – 30 minutes could be dedicated to collecting and transmitting incident data.

Use of Proposed System – Within Vehicle or Outside Vehicle

- It should be useable outside the vehicle. Limited access to equipment makes it more of a nuisance than a tool.
- Some items could be fixed in the vehicle while others should be used outside the vehicle.

- Responders are needed outside the vehicle for traffic control and other issues.
- Tools should be portable, with the ability to plug them into a vehicle.
- A response gear bag could be stored out of the way until its use is needed.
- It may be beneficial to pack items to the scene, outside the vehicle.

Additional Comments / Concerns

- The 30 minute rule applies for timely and accurate updates from field personnel.
- There should be only one primary in-field contact person to receive, request and/or disseminate information from and to Dispatch.
- Standardized Emergency Management System rules apply on all major incidents.
- A checklist for system use and procedure would be useful at the scene.
- The ability of the equipment to work in remote areas was questioned.
- Portable command posts are already used for incidents by some districts.
- These tools could be used for coordination with other agencies.

7.3.8.2. Analysis of Survey

This survey can be summarized as follows:

In regard to communications, there are areas in which there is no service. Furthermore, crews have been equipped with and have used a number of systems (radio, cellular and satellite) in attempts to provide coverage throughout the district. No single system is sufficient and the District uses whatever it takes to provide communication.

Specific and general data elements were identified for collection by responders and for use by responders at the scene of incidents. In general, the sentiment is that the more information, the better. Due to communications challenges, it is not possible to provide access to all information, so that which is provided must be prioritized. Email may be an acceptable means for exchanging certain information.

Incident photographs, aerial photos and maps could serve a variety of purposes in helping responders, dependent on the situation. Prospective use of these items and the system in general includes landslides, wild land fires, Hazmat, earthquakes, flooding and storms.

Those who were surveyed seemed comfortable with the technologies that would likely be integrated to form the prospective system.

While there appeared to be a general willingness to use the proposed system, this willingness was qualified. The system must be of benefit to the responders, or they will not use it. Furthermore, the time they have to use the system would be limited, so it must be user-friendly and efficient.

Further requirements were gathered from this survey and are listed in the next iteration.

7.4. Prototype 1 [Laboratory Prototype Stage]

7.4.1. Time Frame

May 2004 – October 2004

7.4.2. Overview

In this iteration, a laboratory prototype was developed to explore the viability of various hardware and software components, and to help elicit further, more specific requirements. The prototype was assembled using off-the-shelf hardware and software packages. While it was understood that many of these components would not be part of a production system, they were effective in facilitating development and proving viability of specific technologies.

7.4.3. Concept

The concept remains unchanged from the previous iteration:

> A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

The objectives remained unchanged:

- Create and provide the information elements, framework and pilot deployment of an information collection system centered on the information needs of District 2 field units and Redding TMC for transportation management and incident response/clearance, and of relevance to other emergency response organizations. The incident information collection system will include capabilities for collection of incident images, facilities for annotating images and maps to describe incident scope and severity, incident GPS location, as well as form-based information as deemed appropriate by District 2.
- Create and provide the information elements, framework, and pilot deployment of an incident support information system based on the needs of District 2 field units and Redding TMC, and of relevance to other emergency response organizations. The incident support information system will include capabilities for downloading maps and aerial photos, weather conditions, and other support materials related to the incident and its location.
- Provide the necessary hardware and communications infrastructure for the exchange of at-scene information collected via the information collection system and the distribution of incident support information to responders as described for the incident support

system. The communications system will provide the means to exchange information between District 2 field personnel at the scene and Redding TMC, and will be capable of incorporating other emergency response organizations. In Responder vehicles this will consist of a mobile data terminal (ruggedized Tablet PC), a satellite or satellite/cellular combo phone, Internet data connectivity kit including cabling and software and providing, GPS hardware with computer connectivity, and a digital camera with computer connectivity. The incident information collection system and the incident support information system software will reside on and interface with this equipment to facilitate the collection of information and transmission of data to and from the incident scene.

7.4.4. Requirements

Requirements were further refined to incorporate items resulting from the May 2004 survey. Note that some listed requirements are deferred to later iterations for further consideration and prospective development. New requirements are listed in italics:

1. A system shall be implemented to collect incident information.
    a. The system shall collect and store incident metadata.
    b. The system shall collect the incident location.
        i. The system shall record the precise location of the incident using latitude and longitude.
        ii. The system shall record post mile location of the incident.
    c. The system shall collect the incident occurrence time.
    d. The system shall collect a description of the incident.
        i. *The system shall record the type of incident.*
            1. The system shall record analysis of spill impacts for Hazmat incidents.
            2. The system shall record severity of incidents.
        ii. The system shall record traffic control, closures and directions of traffic in a form.
        iii. The system shall record equipment needed for incident clearance.
        iv. The system shall record incident measurements.
    e. The system shall collect incident photographs.
    f. The system shall collect incident sketches.
    g. The system shall facilitate sketches.
        i. The system shall facilitate sketches to annotate incident photographs.
        ii. The system shall facilitate sketches to annotate maps.
        iii. The system shall facilitate sketches to annotate aerial photos.

        iv. The system shall facilitate free-form sketches.

    h. The system shall facilitate forms.

        i. The system shall display forms.

        ii. The system shall facilitate entry of information into forms.

        iii. The system shall facilitate permit forms.

    i. The system shall store incident information as a collection, not disparate pieces.

2. The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.

    a. The system shall be usable by one primary field contact person for communication with dispatch.

3. The system shall be deployed within Caltrans' vehicles in the field.

4. The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.

5. The system shall be easy to use.

    a. The system shall include a checklist for use and procedures at the scene.

6. The system shall automate the collection of incident information.

    a. The system shall automatically geo-locate the responder.

7. The system shall minimize the amount of time required for use.

    a. The system shall facilitate the collection and entry of incident information in less than 20 minutes.

    b. The system shall facilitate automated transmission of incident information.

8. The system shall transmit information to the TMC and other outside agencies.

9. The system shall receive information from the TMC and other outside sources.

    a. The system shall display weather information based on the responder's location.

        i. The system shall display weather forecasts based on the responder's position.

        ii. The system shall display wind directions.

        iii. The system shall display storm information.

        iv. The system shall display wild land fire information.

    b. The system shall display road maps based on the responder's location.

    c. The system shall display aerial photos based on the responder's location.

    d. The system shall display topographic maps based on the responder's location.

    e. The system shall display the location of the command post, crews and equipment at the incident.

f. *The system shall display locations of other responders, contract personnel and equipment at the incident scene.*

g. *The system shall display locations and estimated times of arrival of responders, contract personnel and equipment en-route to the incident scene.*

h. *The system shall display staff availability.*

i. *The system shall display expected traffic volumes.*

j. *The system shall display chemical information for Hazmat spills.*

k. *The system shall display affected facilities.*

l. The system shall download data to responders while en-route to and at the scene of an incident.

10. The system shall have data communications capability in all areas of District 2.

    a. The system shall be operable in rural areas including mountainous areas.

    b. The system shall be operable in urban areas.

7.4.5. Design / Specification

Many design decisions were made in creating this prototype. These design decisions should not be considered final, and are not documented in this section. See the following implementation section for further details regarding design decisions made during this iteration.

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
  - The system shall use a custom-developed application for data collection and recording.
  - *The system shall use email as the transport for incident information.*
- The system shall use a digital camera to collect digital photographs of incidents.
- The system shall use satellite communication to provide data communication capability in mountainous areas.
- The system shall use cellular data communication to provide data communication capability in urban and other areas where cellular communication is available.
- The system shall use GPS to auto-locate the responder.
- The system shall use IEEE 802.11 –based wireless technology to implement un-tethered use in the proximity of parked Department vehicles in the field.

7.4.6. Implementation

Prototype 1 consisted of software and hardware demonstrating the functionality of the prospective system. It included equivalents of the hardware that would likely be used in a production system, as well as a functional prototype that demonstrated much of the capability of the prospective system. Not only did this facilitate demonstration and feedback, it allowed for a testing and experimentation.

7.4.6.1. Software

Required Software

The Responder application is a Microsoft Windows application, written in the C# programming language. It uses the .NET framework as well as the Tablet PC Application Program Interface (APIs). In order to use the application, the following must be installed on the Responder Tablet PC:

- Microsoft Windows XP Tablet PC Edition
- Microsoft Office 2003 (Word, Outlook)
- Microsoft MapPoint 2004
- Microsoft Internet Explorer
- Adobe Acrobat Reader
- Data Connectivity Software for Cell Phone and Satellite Phone
- Miscellaneous Drivers
- Responder Application

Following is a description of the major components of the Responder application:

Splash Screen

The Responder Application opens with a splash screen (Figure 24). This screen not only introduces the program, but also displays initialization status. Specifically, status is displayed corresponding to attempts to establish connections with the satellite phone, the cellular phone, and the GPS. The last step is to load the street map and pinpoint the location corresponding to that which is indicated by the GPS. If a connection to the GPS cannot be established, then this step is skipped. Note that street maps are preloaded on the computer as part of the Microsoft MapPoint application, so this step does not require a connection to the Internet. The program will load and will be operational even if a connection to one or all of the devices fails.

Figure 24: Prototype 1 - Splash Screen

Upon completion of initialization, the Incident Organizer is displayed.

The Incident Organizer

The Incident Organizer (Figure 25) is intended to facilitate the organization of incident information. It helps the responder to organize incident information. Tabs indicate various sections of the incident organizer. Tabs include Summary, Photos, Mapping, Sketches, Forms, Manuals, Internet, Communications and Help.

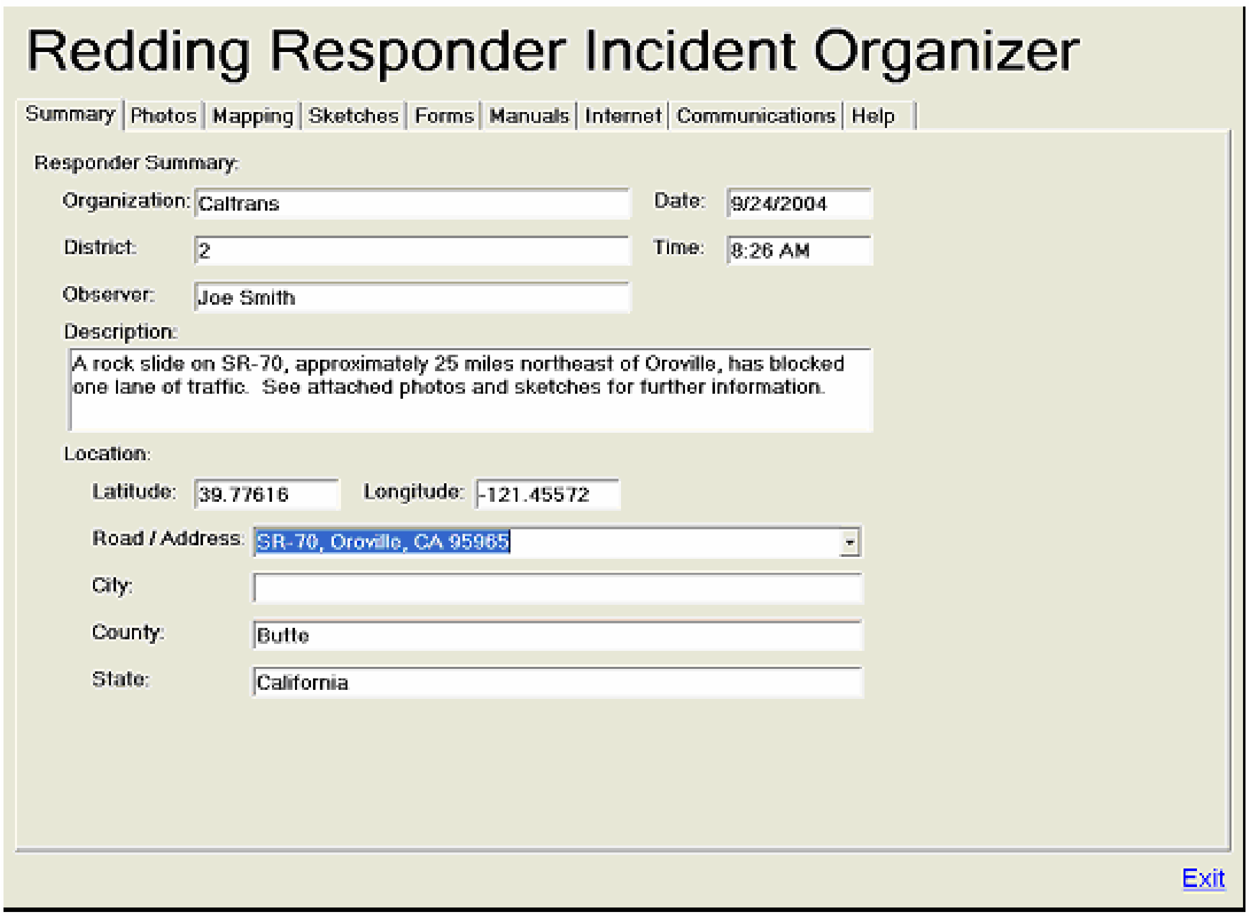

Figure 25: Prototype 1 – Incident Organizer

The initial, default tab displayed is the Summary tab (Figure 26).

Summary Tab

The Summary tab (Figure 26) includes the following fields: Organization, District, Observer, Date, Time, Description, Latitude, Longitude, Road/Address, City, County and State. The Date and Time fields are auto-populated with the current date and time. The Latitude and Longitude fields are auto-populated if communication with the GPS is established. If Latitude and Longitude are known, then Road/Address, City, County and State may be auto-populated. MapPoint is used to determine these field values. Note that the Road/Address field will sometimes correspond to the name of an actual road and other times may correspond to a region such as a National forest. A city name will be determined if the location is within a city. County and State will be determined automatically.

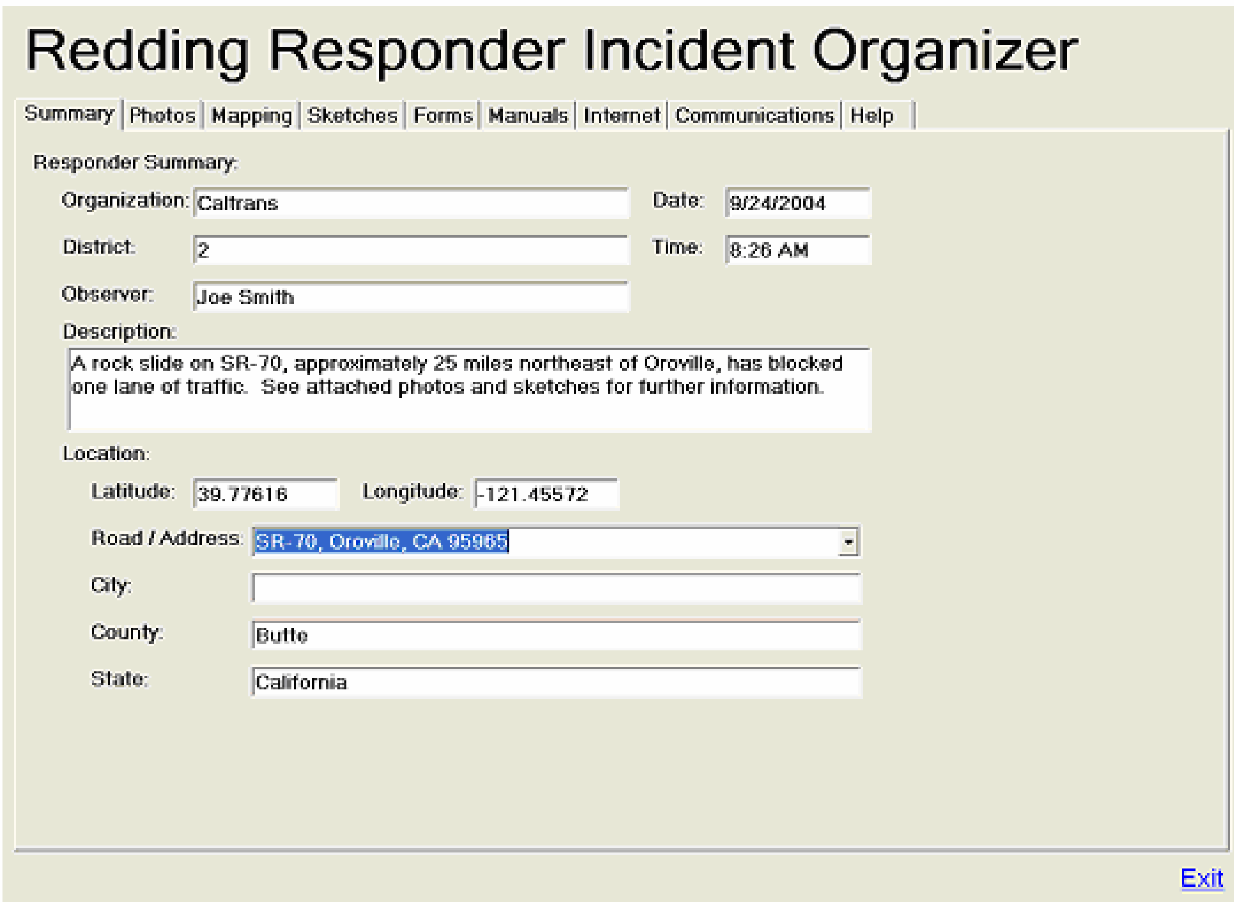

Figure 26: Prototype 1 – Summary Tab

Users can modify any of the fields within the summary tab. Input may come from either pen or keyboard input. When a user selects a field, a writing pad is displayed, upon which handwriting can be entered for automatic recognition. As an alternative, if a keyboard is available, entries can be typed. All fields other than those mentioned above are completed in this manner.

Users can switch to any other tab by selecting that tab. There is no set sequence that users must follow in entering information.

Photos Tab

Photos can be selected and added, as shown in Figure 27, to the Photos tab (Figure 28). Photos are selected and added using the standard Windows file selection form. It is necessary to navigate to the folder containing the photos. If a thumbnail view is desired, then this view must be selected manually from the view drop box.

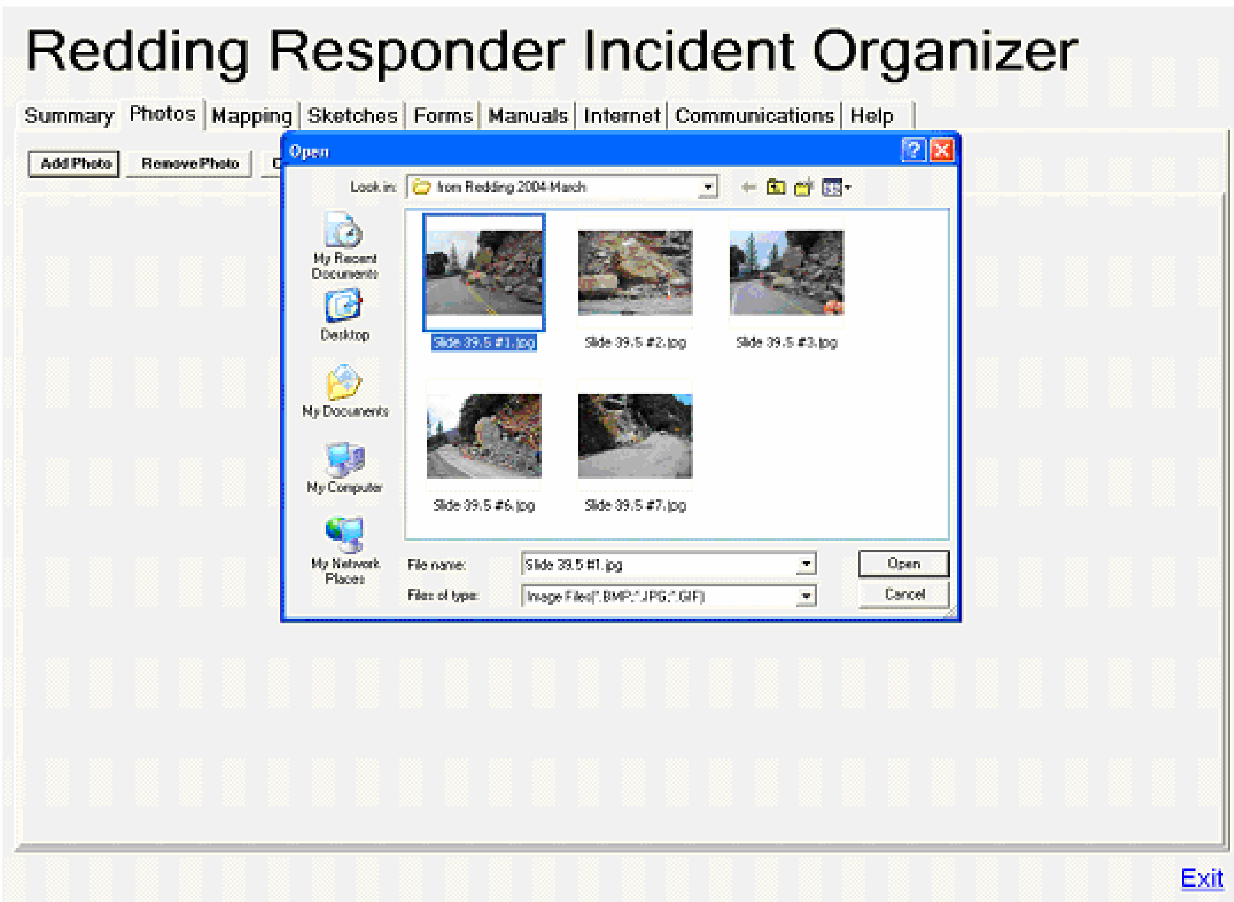

Figure 27: Prototype 1 – Adding Photos

Once selected, photos are added to and organized within the Photos tab (Figure 28). Sub-tabs are used to identify and separate the photos. Short text descriptions can be associated with each photograph.

Figure 28: Prototype 1 – Photos Tab

Photos can be copied to the Sketches tab (Figure 29) for the purpose of annotation. When this is done, a separate copy of the photograph is created, and annotation does not alter the original photograph.

Sketches Tab

The example below (Figure 29) shows how sketches can be used to add information to and clarify features visible in the photograph. For instance, the following sketch (Figure 29) shows the approximate height of the tallest boulder, indicates that one lane is open to traffic, highlights pavement damage, and shows that there are too many rocks to drill by hand.

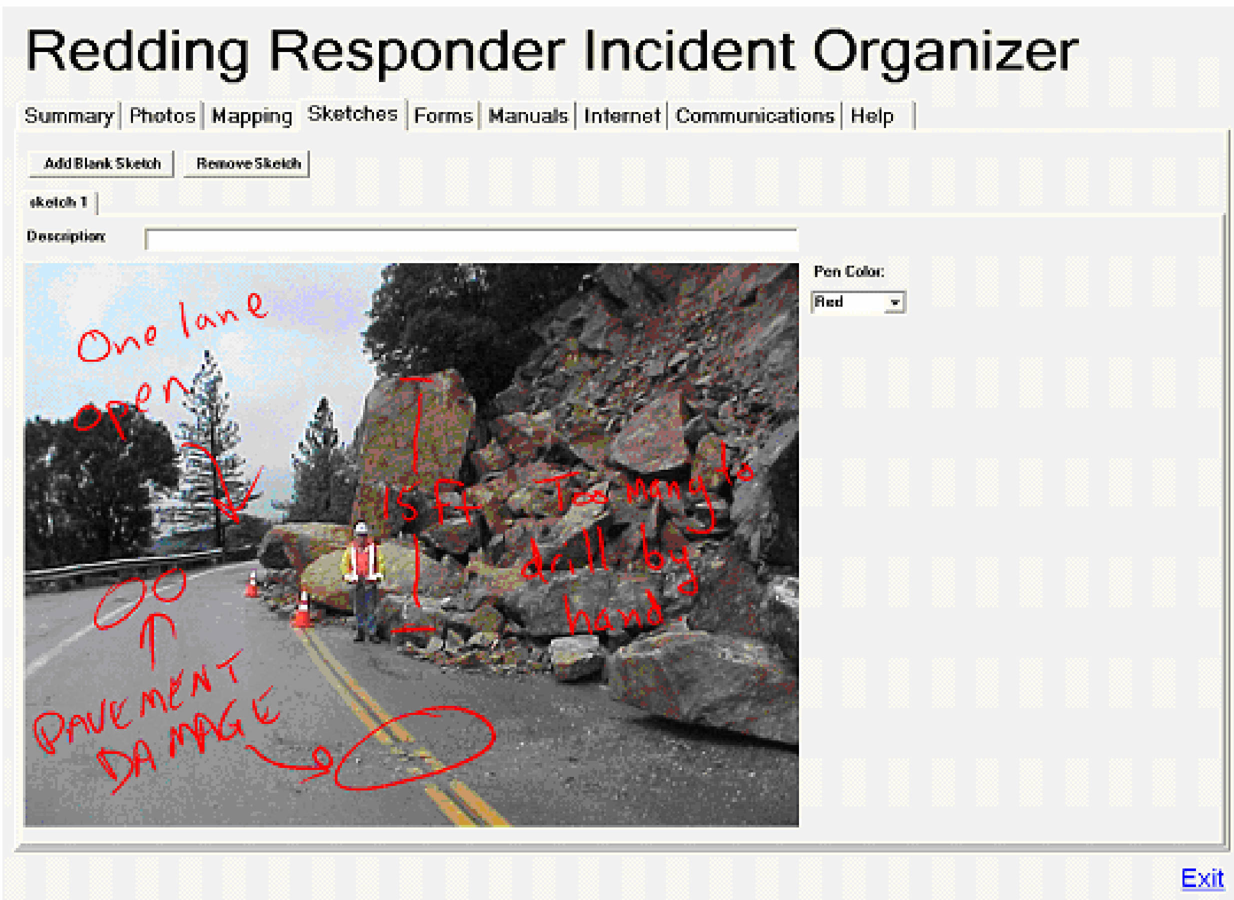

Figure 29: Prototype 1 – Sketch on a Photograph

A blank drawing pad can be created and drawn on in the same manner. Figure 30 shows a freehand sketch of the incident. Note the use of color for different features. Four colors are available for drawing and these may be selected from the Pen Color drop box.

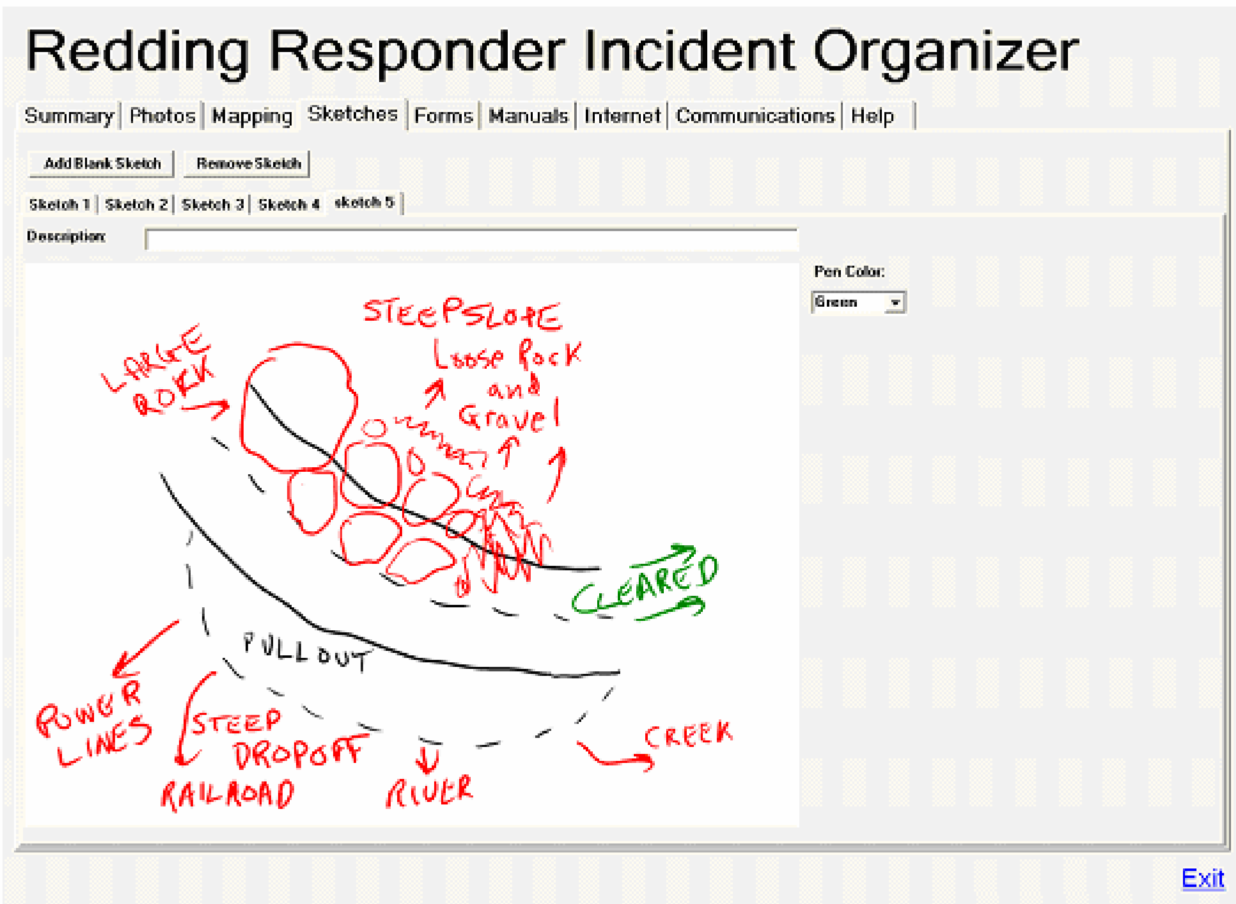

Figure 30: Prototype 1 – Blank Sketch

Mapping Tab

The Mapping tab (Figure 31) displays maps corresponding to the incident location, as specified in the Summary tab (Figure 26). A road map is automatically opened and centered on the incident location, and zoomed to the immediate vicinity of the incident. Sub-tabs are available to display an aerial photograph, a topographic map and GPS readings. Aerial photos and topographic maps are not stored locally and must be downloaded prior to viewing. This process can take up to ten minutes for each, depending on connection speed. GPS readings are automatically updated with direct readings from the GPS, assuming it is connected.

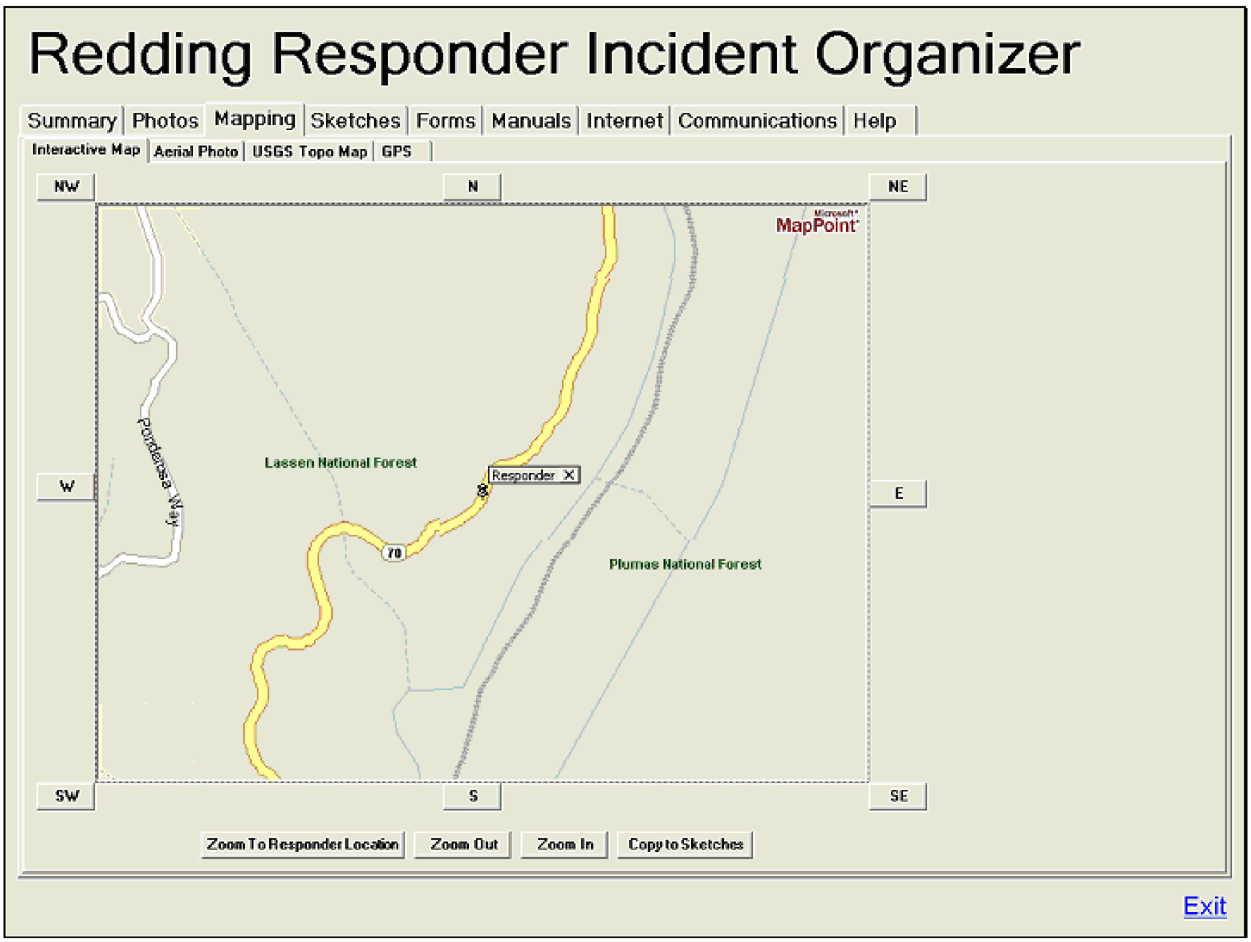

Figure 31: Prototype 1 – Mapping Tab

Forms Tab

Forms can be selected (Figure 32) and displayed for use/input (Figure 33). A sample Hazmat form is shown for the sake of demonstration.

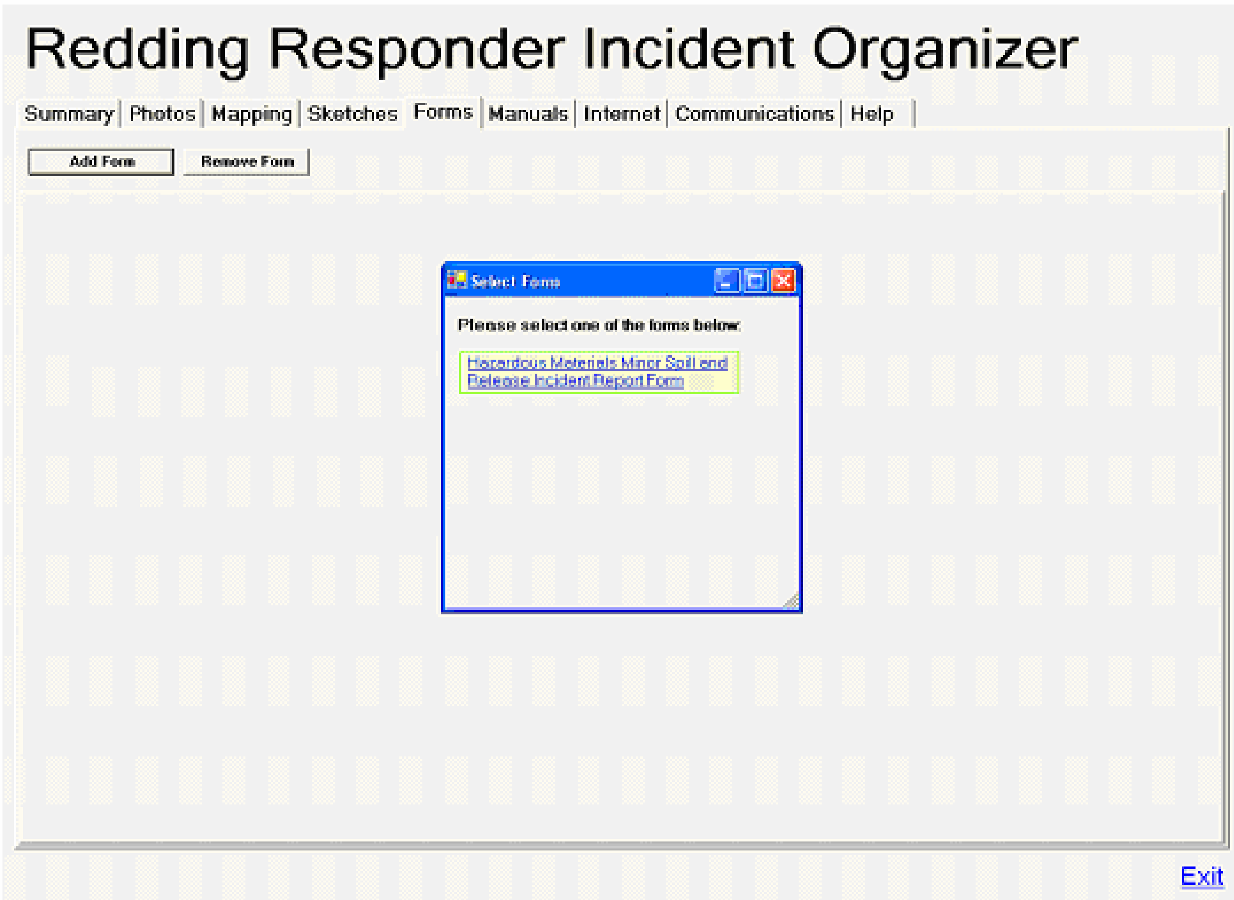

Figure 32: Prototype 1 – Selecting a Form

Note that the form is displayed in a Microsoft Word control within the application. It is not necessary to leave the application in order to complete the form.

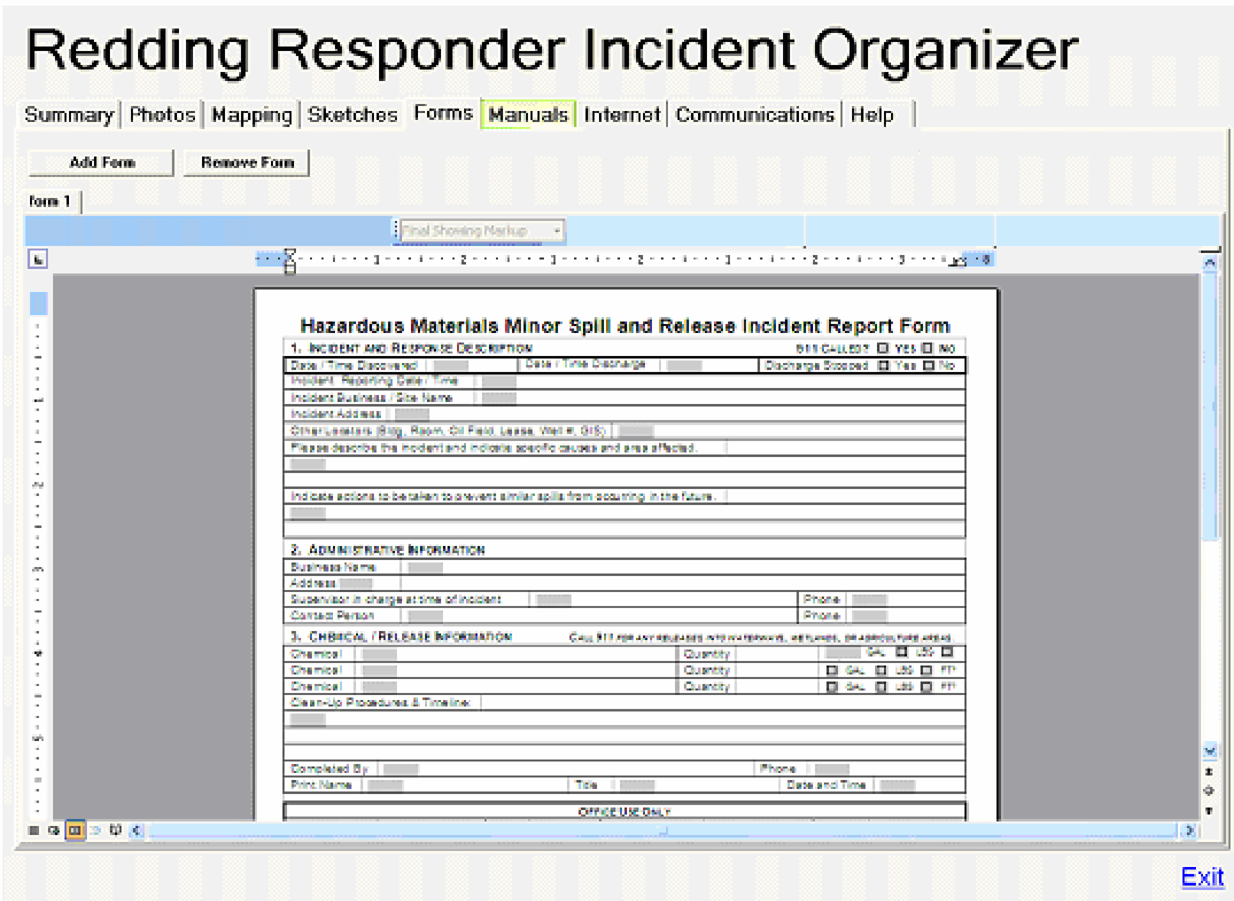

Figure 33: Prototype 1 – A Form within the Forms Tab

Multiple forms can be selected and completed within the Forms section.

Manuals Tab

Similar to forms, manuals can be selected and displayed (Figure 34). The example below shows an example manual in Adobe Acrobat format. A table of contents is shown within the Acrobat Reader window, allowing for rapid navigation.

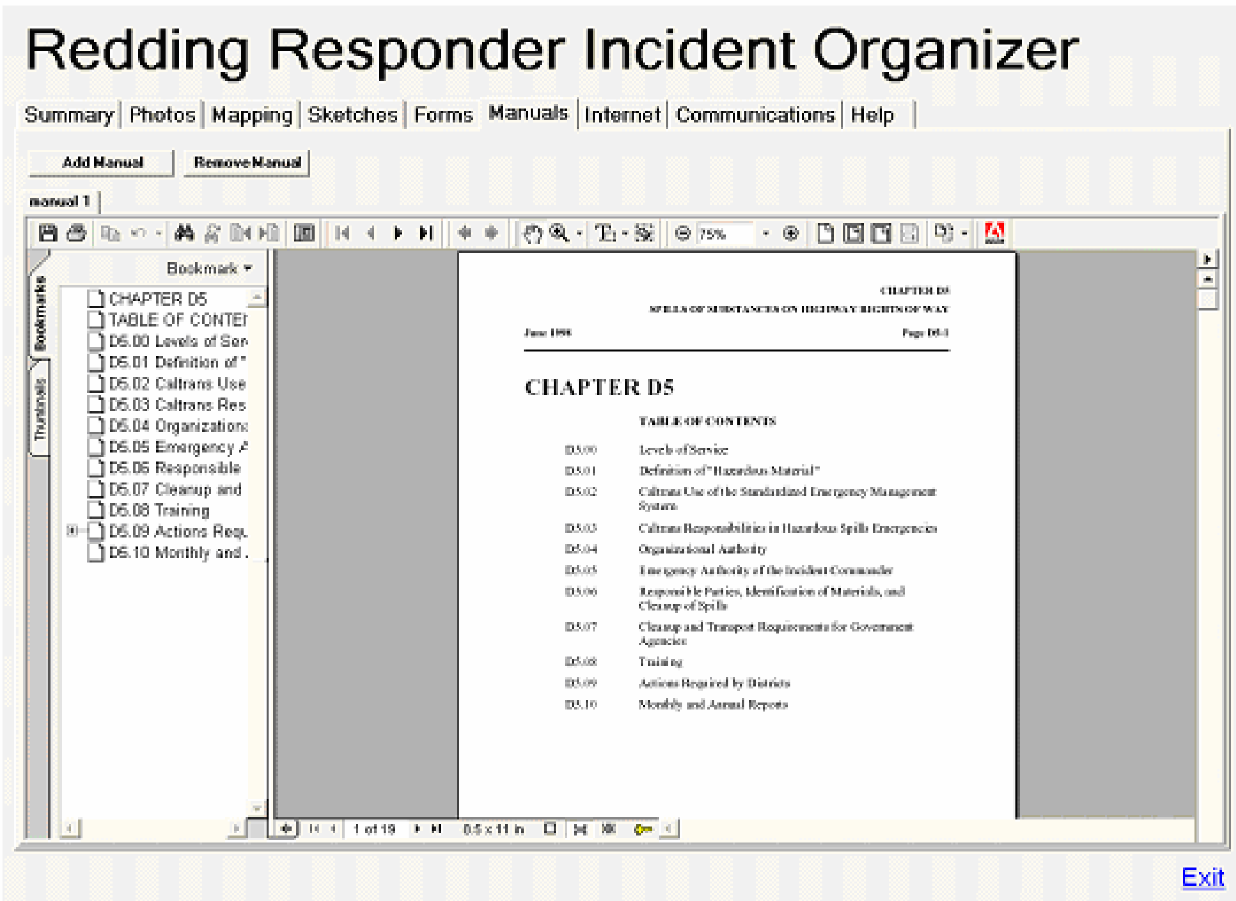

Figure 34: Prototype 1 - Manuals

Internet Tab

The Internet Tab (Figure 35) provides access to a pre-defined set of web pages. Where possible, these pages are automatically provided parameters identifying the location of the responder. Links to the National Weather Service's Digital Point Forecasts and to Caltrans' cameras are included as examples. Further pages could be added.

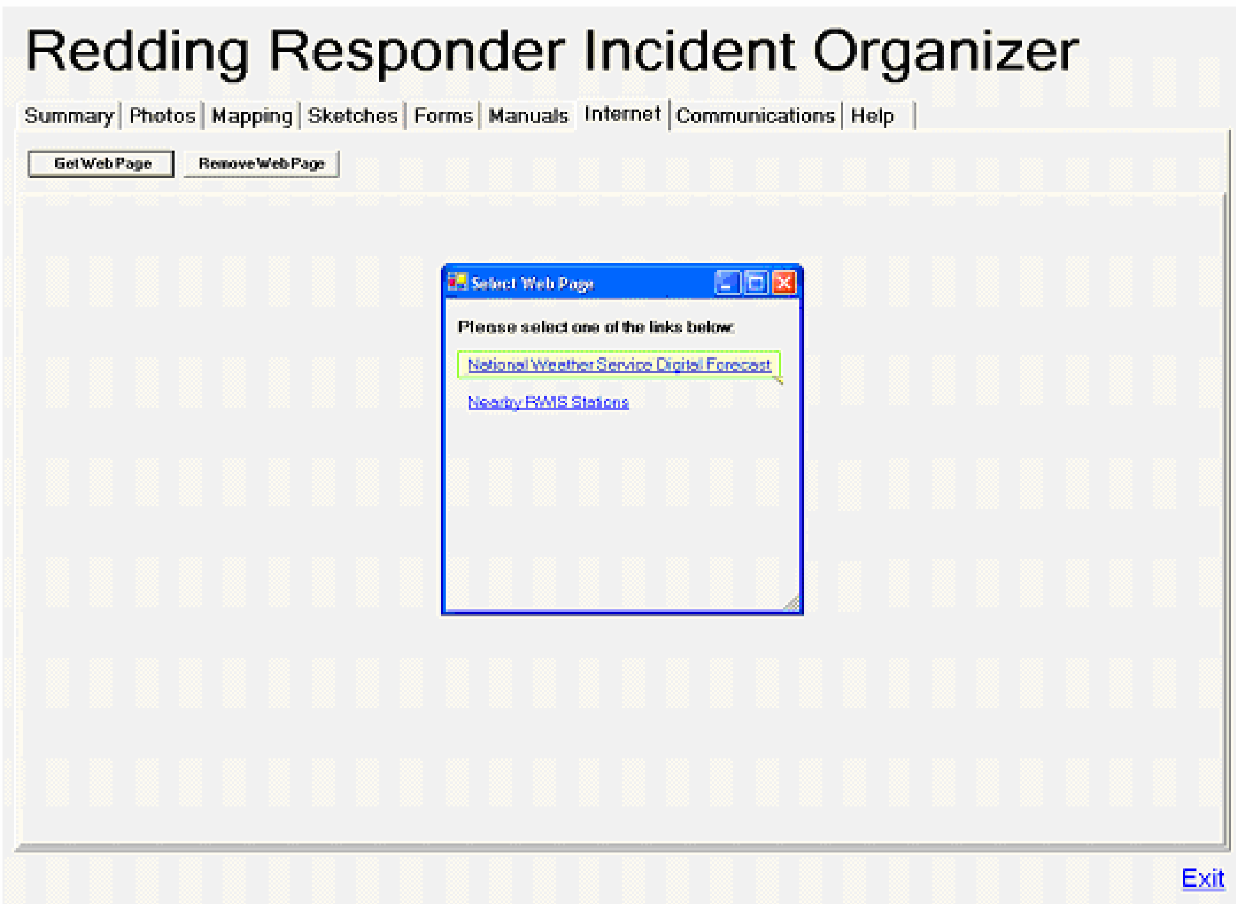

Figure 35: Prototype 1 – Internet Tab

Note that users are not given the option to enter a web page free form. They are however permitted to follow links within the page.

Figure 36 shows the result of selecting the National Weather Service's Digital Point Forecast. Note that the point forecast is given for the incident location, as identified in the Summary section (Figure 26).

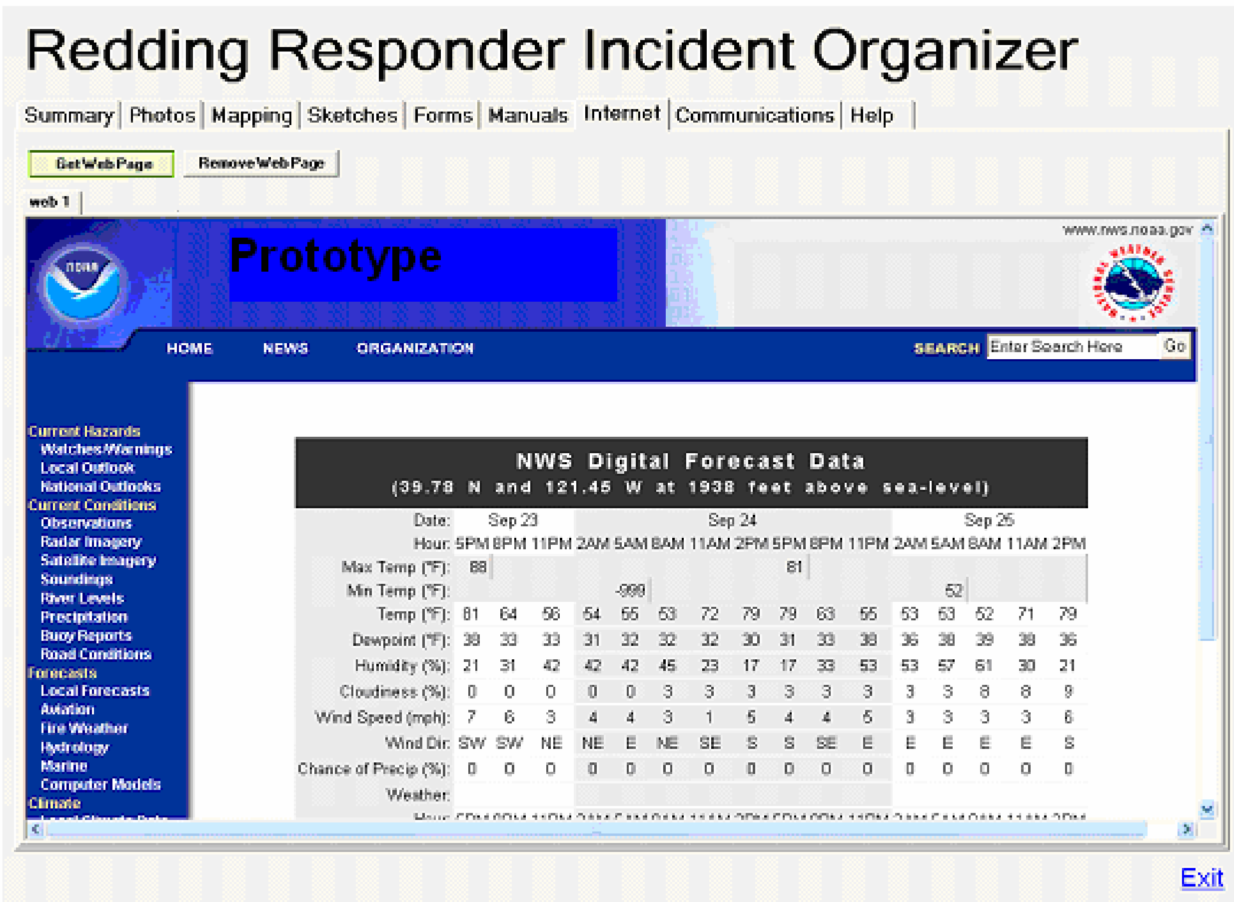

Figure 36: Prototype 1 – NWS Digital Forecast for Incident Location

Communications Tab

The Communications Tab (Figure 37) includes options for displaying status of and testing the satellite phone and the cellular phone. Signal strength and other information are displayed for each. Options are also included for "manually" establishing connections.

In addition to the diagnostic tabs for the phones, email functionality(Figure 38) is included as a sub-tab within the Communications tab.

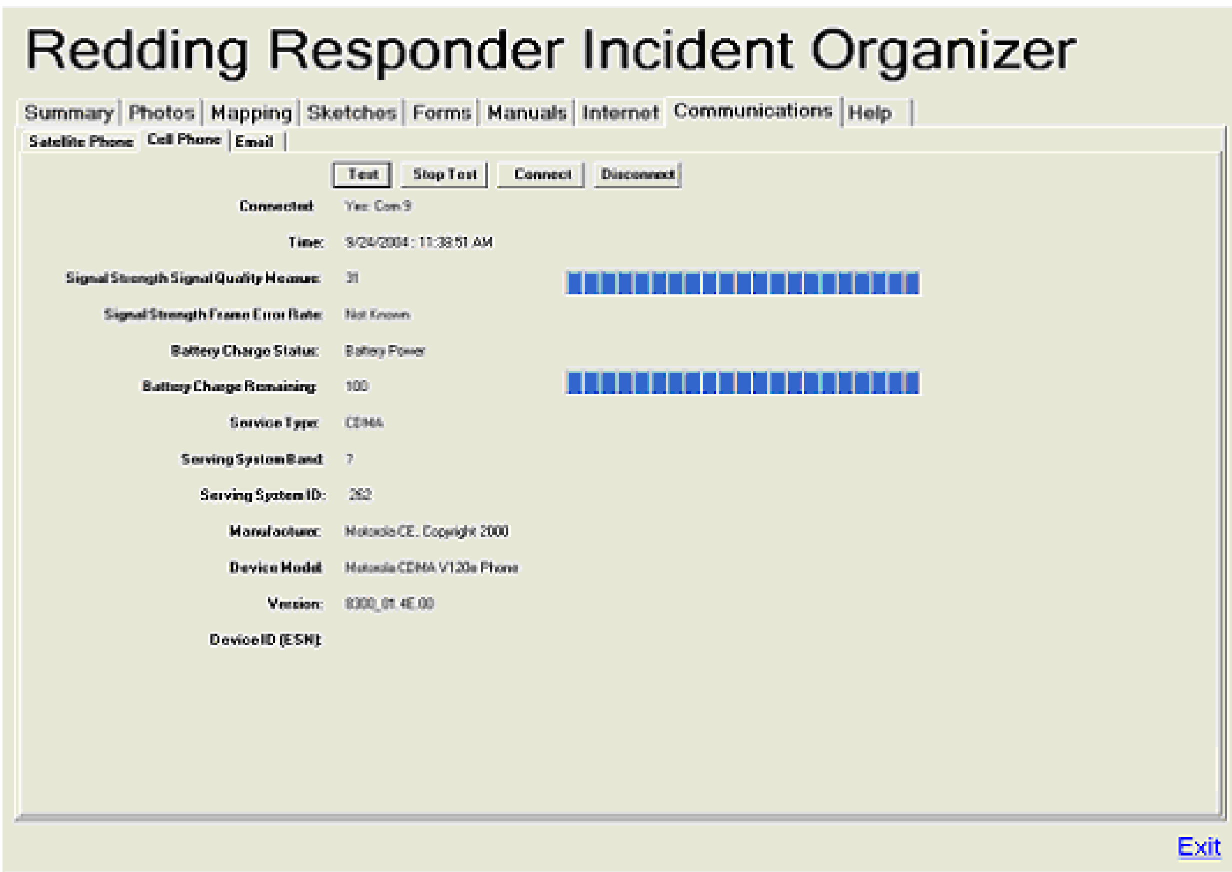

Figure 37: Prototype 1 – Communications Tab, Cell Phone Status

Email is used to communicate the incident information collected by the user to the TMC or other parties. An email attachment is automatically created to include information from the Incident Organizer. This email message is displayed for preview (Figure 38) when it is created. The user must then use the Send Email button to proceed in sending the information.

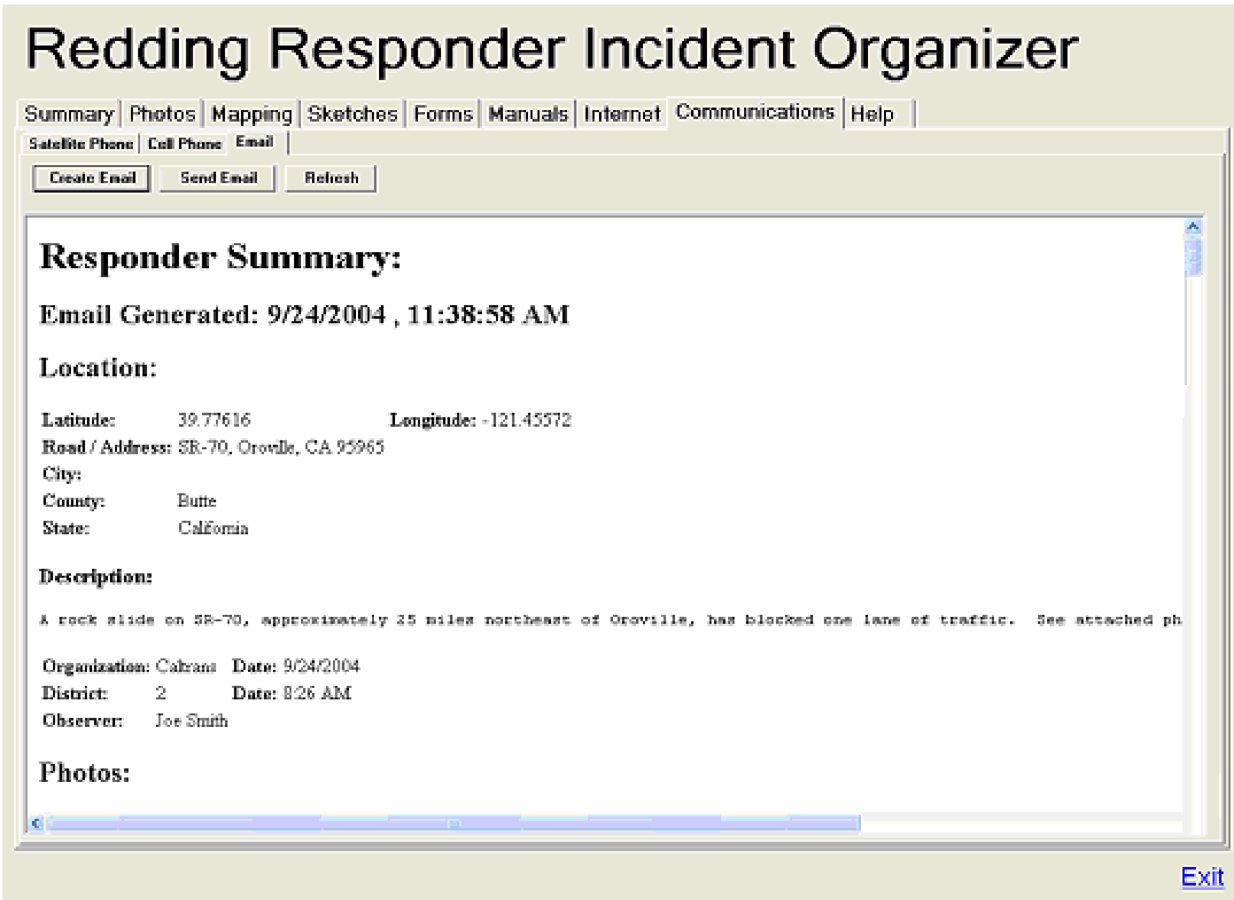

Figure 38: Prototype 1 – Incident Email Preview

When the Send Email button is selected, an email message is created in Microsoft Outlook (Figure 39). Note that a separate Microsoft Outlook window is created and displayed at this point. Several further steps must be taken to send the message. An address must be chosen to indicate who the email will be sent to. The Outlook contacts list can be used for this purpose, or the user can manually enter an email address. The user may also choose to enter further information in the subject and body of the email. When ready, the user may then press the "Send" button to send the email.

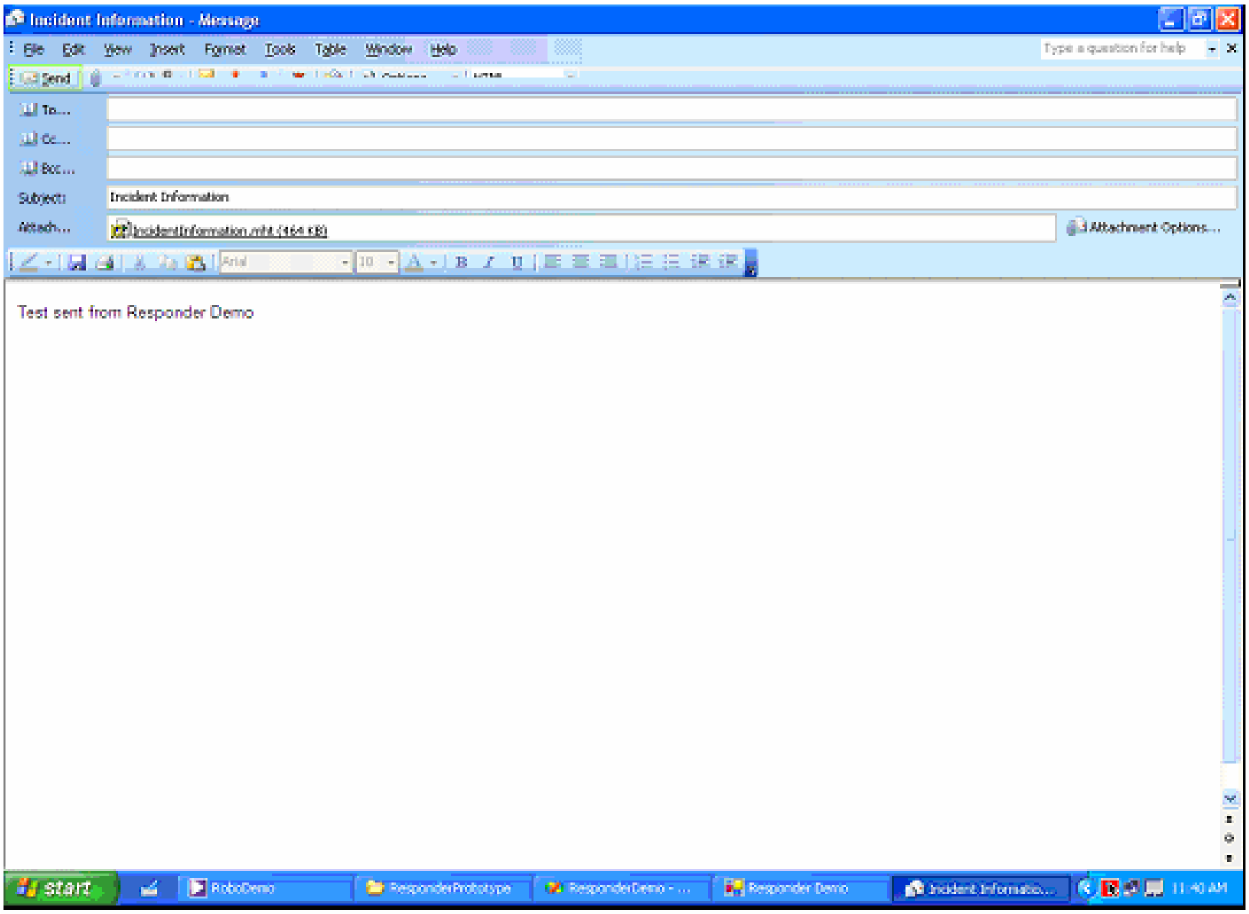

Figure 39: Prototype 1 – Incident Email via Microsoft Outlook

Help Tab

The Help tab was intentionally left blank pending further discussion regarding its need and use.

7.4.6.2. Hardware

This prototype integrates a number of separate devices. These devices are linked by wired connections, which will be replaced by wireless connections in subsequent development. In general, the devices used in this prototype are neither rugged nor modular and would not be suitable for use in a final configuration. They were chosen for the sake of proof-of-concept and demonstration, and because they were readily available at a lower cost than corresponding rugged versions of the same equipment. If this proof of concept proves successful, then equipment more suitable for field testing would be identified for subsequent development.

Hardware components of the prototype system include:

1. Toshiba 3505 Convertible Tablet PC
2. Magellan 315 Handheld GPS
3. Motorola V120 Cell Phone
4. Globalstar (Qualcomm) GSP 1600 Satellite Phone
5. OrbitOne Porta-kit for GlobalStar Satellite Phone
6. Globalstar External Antenna
7. Belkin USB Hub
8. Belkin Serial to USB Converter Cables
9. Olympus Stylus 410 All Weather Digital Camera
10. Radio Shack 300 Watt Dual Outlet Inverter
11. Surge Arrest Professional Surge Protector
12. APC Notebook Surge Protector

These hardware components are shown in Figure 40 and Figure 41.

There are many cables in the prototype system and setup is cumbersome. Furthermore, the Tablet PC must remain connected to devices, rendering it immobile, even in Tablet mode (Figure 42). Again, this configuration was chosen for demonstration of concept and availability and price of equipment. Figure 43 shows the equipment in the back of a vehicle. Figure 44 shows the satellite antenna mounted on top of the vehicle.

Figure 40: Prototype 1 - Hardware, Front View

Figure 41: Prototype 1 - Hardware, Rear View

Figure 42: Prototype 1 - Hardware, Computer in Tablet Mode

Figure 43: Prototype 1 - Hardware, Equipment in Rear of Vehicle

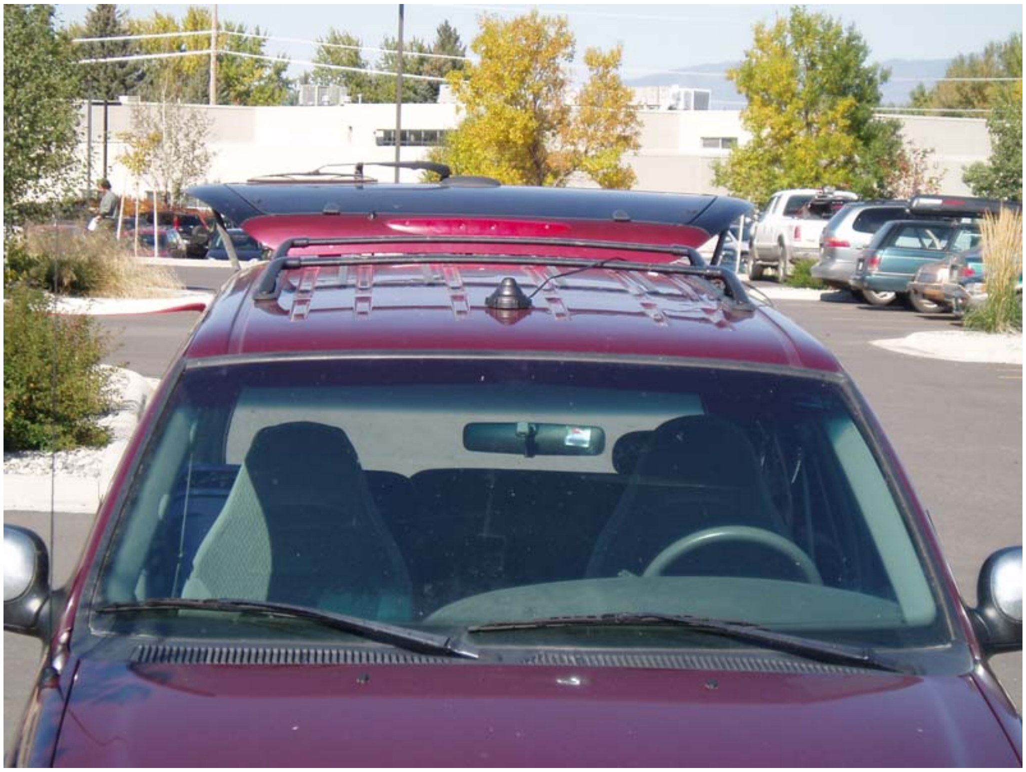

Figure 44: Prototype 1 - Hardware, Satellite Antenna

7.4.7. Testing

The software was tested throughout development and prior to demonstration primarily for performance and validation purposes. More extensive testing was conducted on the hardware, particularly the communication equipment. Testing results are discussed in further detail in the research chapter of this document.

Testing led to subsequent design decisions used in the second prototype. For instance, an email glitch that occurred during demonstration at Caltrans led to the use of a different email creation and transmission method. In addition, it was determined that it was not feasible to download maps and aerial photos, because too much time was required for their download.

7.4.8. Evaluation / Analysis

Evaluation during this iteration consisted of a survey conducted in conjunction with a demonstration of the program. Emphasis was placed on the software and its functionality.

7.4.8.1. Survey – October 2004

The Responder "Incident Organizer" user interface was presented for evaluation. The presentation consisted of a live demonstration of the prototype as well as a canned demonstration of interface functionality using RoboDemo.

The three respondents to the survey included the Caltrans Project Champion, the Caltrans Project Manager, and the D2 ITS Engineer. They were asked to rate functionality on "usefulness," "clarity," and "ease of use." A scale of poor, fair, average, good and excellent was used for rankings. Additional comments and suggestions were solicited.

Complete results are listed in Appendix III – October 2004 Survey.

A summary by survey section follows:

Summary Section

The functionality and content of this section was well-received, with rankings of "average" or above. Clarity of the section was ranked particularly high, with rankings of "good" and "excellent."

Specific issues raised were:

- Fields such as "Organization" and "District" should auto-populate.
- A field for "post mile" location of the incident, as well as direction (side of road) should be included.
- Use of the Date/Time fields needs clarification. Are these the times at which the incident occurred, when the responder reached the scene, when data was entered, or something else?

Photos Section

Usefulness and Clarity for this section received unanimous "excellent" ratings. "Ease of Use" was unanimously ranked "good," leaving some room for improvement. Note that a method for navigating to photos and selecting them had not been completely identified at this point, and several options were discussed. In particular, the ability to preview images, perhaps by thumbnail, was discussed as an option.

Specific issues raised were:

- There needs to be an easy way to retrieve photos from the camera.
- It would be nice to assign descriptions to photographs on a thumbnail page.

Mapping Section

This section received rankings of “good to excellent”. The usefulness of the information in this section was unanimously ranked excellent. Ease of use unanimously received good ease of use ratings, leaving room for improvement.

Specific issues raised were:

- Downloading this information on the fly may not be practical. It was suggested that this information be stored on the PC.
- Caltrans aerial photos (DHIPP) should be used rather than USGS aerials.
- Other Caltrans maps should be considered for inclusion, although no specific maps were identified.

Sketches Section

This section received rankings of “average to excellent”. The majority of rankings were excellent. There is some room for improvement here, although the suggestions tended to focus on user interface issues.

Specific issues raised were:

- The functionality appears to be good, but it will be interesting to see how this feature is used in practice.
- When a photograph is copied to the sketches section, its description should be copied as well.
- The buttons for adding sketches, either blank or from photograph, could be made easier to use/locate.
- Selection of photos for sketching could be done via a thumbnail page, making it possible to view the photos together and select them quickly.

Forms Section

This section received rankings of “average to excellent”, with usefulness and clarity both receiving unanimous “excellent” ratings. Ease of use received “average” and “good” rankings, but no “excellent” rankings.

Specific issues raised were:

- Both the pen and keyboard should be available for input.
- Where possible, form information that has already been entered should be auto-populated. Examples include county, route, mile post, etc.

Manuals Section

Like forms, manuals received high rankings. All rankings were “excellent” with the exception of one “good” ranking for ease of use.

Specific issues raised were:

- It would be helpful if manual pages could be bookmarked for subsequent access.
- Phone lists for Caltrans and other organizations could be included.

Internet Section

Internet functionality received high rankings, with all rankings being “good” or “excellent”. Rankings tended more towards “good” than to “excellent”, so there is room for improvement.

Specific issues raised were:

- Location awareness is desirable. For example, information access should be automated to drill down to location-specific information where possible, reducing the amount of input and interaction that is necessary from the user.
- Slow downloads would be problematic.
- Other information that could be included: CCTV images and chain control, Caltrans Road conditions web page.

Communications Section

Communications functionality received all good rankings with the exception of one excellent ranking for usefulness.

Specific issues raised were:

- Information given may be more than is needed.
- The email functionality is good.
- Email addresses should auto-populate from a user-defined list.
- There should be a way for the user to select which sketches and photos are sent.

Help Section

The help section was intentionally left blank. The hope was that it could be omitted, providing the program is intuitive and user-friendly enough so that traditional help section functionality would not be needed. No rankings or comments were given regarding the Help section.

Incident Organizer General Rankings and Comments

In general, the Incident Organizer received rankings ranging from “average” to “excellent”, with usefulness and clarity receiving unanimous “excellent” rankings. Ease of use received “average” to “good” rankings, indicating room for improvement attributable to issues pointed out in previous sections.

7.4.8.2. Analysis of October 2004 Survey

Summary Section

Relatively minor changes are required here.

The Organization and District fields should auto-populate. An initialization file could be used to accommodate multiple organizations and districts, by allowing this information to be pre-saved on the Responder computer. If the terminal was assigned to an individual staff member, then that person's name could be stored in the initialization file as well.

Fields for Post Mile and Direction could also be included. However, unlike the State, County and Road fields which are pre-populated (location-awareness), it is likely that Post Mile and Direction could not be pre-populated, given the latitude and longitude of the responder. To maximize flexibility and the potential for differences based on jurisdiction and agency, this information could be included as part of a location description.

Use of the Date/Time fields needs to be clarified. However, such use may vary by agency and could be handled by training and procedure.

These improvements should improve the rankings of this functionality.

Photos Section

The major issue with the photos section is finding an easy to use method for selecting photos from the camera. The normal, manual process for doing so is to plug in the camera and either have Windows automatically detect that the camera has been plugged in and ask the user what they want to do, or to manually navigate to the drive assigned to the camera and further navigate to the photos. Neither of these options is acceptable for this application. The former may result in undesirable action outside the control of the program. The latter requires too many steps.

As a result, the most desirable solution is one that automatically recognizes that the camera has been plugged in and automatically navigates to the location of photos and presents preview images of those photos to the user. Methodologies for doing this should be explored further.

In regard to the comment about the assignment of descriptions on the thumbnail page, that should be given further consideration, but will depend on the means chosen for selecting photos and will be deferred until that time.

The ability to manage photos on the camera needs to be addressed as well. In particular, when do they get removed / deleted? Certain cameras including the one used for the prototype appear inconsistent in how they handle timestamps associated with photos. For instance, when camera batteries are changed, the date and time on the camera need to be reset. Thus, it is not safe to assume that the camera is assigning consistent dates and times to images and, as a result, the associated dates and times can not be used as a reliable filter for what is new and what is old. A mechanism should be implemented so that users can easily remove photos from the camera. In conjunction, it should be assured that images are archived at full resolution for further use.

Inclusion of these improvements should improve the "ease of use" rankings for this section.

Mapping Section

The major issue with the mapping section is the amount of time required to download maps and aerial photos. While these items are unquestionably useful, their utility diminishes with the amount of time required to download them. Thus, efforts need to be made to pre-store this information on the Responder computer. The challenge in doing so is that these items require gigabytes of storage, and they will need to be selectively chosen to make this option feasible. For instance, if only the aerial photos and topographic maps that overlap roadways are included, then the amount of storage required would be reduced significantly.

As for the use of other maps and data including Caltrans DHIPP aerial photos, this should certainly be considered. Such maps and data should be identified for inclusion and should be analyzed in light of the requirement of storing these items on the Responder computer.

Addressing the issue of pre-storing the maps and aerial photos rather than downloading them should address ease of use concerns. Considering other Caltrans maps should address clarity issues.

Sketches Section

The major issue with ease of use of sketches appears to be that of selecting photos which will be used as sketches. There are a number of ways this could be done and different users will have different preferences. Of most importance is minimizing the amount of navigating back and forth that the users will have to do to carry out this process. While the suggestion of using thumbnails for selection is appealing, it will be deferred. It will be desirable to determine the outcome of development for selection of photos within the Photograph section first.

Copying the photograph description along with the photograph will be done.

Forms Section

The biggest issue with forms is making them easy to use. It is apparent that their usefulness is unquestioned.

There are two challenges in making forms viable. The first is having an easy means for entry of information. The second is having an easy and standard means for creating the forms. The latter problem could be addressed by using Microsoft Word or Adobe Acrobat to create forms that could be filled out electronically. Another alternative, creating a custom means for generating and displaying forms was ruled out due to the inherent complexity of such a system. While Microsoft Word and Adobe Acrobat forms certainly are viable for creation and presentation, they do not appear to be viable for providing an easy means for the entry of information. Both operate best when the user is using a keyboard, and attempting to complete forms using pen input is not viewed as viable, at least for moderately complex forms. Thus, form functionality has been deferred pending further investigation of alternative methods. Products such as Microsoft InfoPath show promise in this area.

Manuals Section

Manuals will be desirable in a final product and are certainly viable. As with forms, Microsoft Word and Adobe Acrobat formats could be used to present manuals. It is quite possible that book-marking functionality such as that requested could be implemented.

At this point, the biggest issue regarding manuals is determining which should be included. The answer to this is certainly agency-specific and requires further investigation. It would be reasonable to think that if enough manuals were included, then it would be desirable to organize them in a manner so that they could be easily browsed or searched. Pending further investigation, manuals will be omitted from the subsequent prototype.

Internet Section

As with maps, download time is a concern. However, the information addressed in this section is time-sensitive and cannot be cached on the local machine for extended periods of time. Thus, methods to improve efficiency need to be explored. Efficiency can be achieved by reducing/eliminating the amount of unnecessary information downloaded and reducing the amount of navigation required of the user. For instance, unnecessary text and graphics that are displayed on web pages for aesthetic or navigation purposes could be eliminated. Where possible, if information can be accessed using location-awareness, it will help as well.

As a result of the comments regarding this section, it was determined that such information could potentially be made more functional in nature. For instance, rather than navigating to the Internet section and requesting Weather information, there could be a Weather section with an associated “Get Weather” button. Pressing this button would entirely automate the downloading of weather information that applies to the Responder’s immediate location. Thus, the user could work on other tasks while weather information is downloaded. Web services providing weather data show promise for this purpose.

Communications Section

The comment stating that more information was included in this section than is necessary is a by-product of combining the email/messaging functionality with other communication-related diagnostic functionality that shows the status of the modems and GPS. In future versions, these functions should be logically separated, and consideration should be given to whether or not the diagnostic information is readily viewable.

Auto-population of email addresses should be considered. Beyond that, email addresses could potentially be pre-programmed so that they do not need to be entered or selected every time. To do so, an alias or group could be set up at Caltrans to receive these emails in every instance. In turn, messages could automatically be forwarded to appropriate staff. This would also address technical challenges involved in sending email messages to multiple recipients. Specifically, if sent from the Responder application to multiple addresses, the message would be uploaded from the application multiple times, increasing the amount of time required for transmission and decreasing the likelihood of successful transmission.

The use of Outlook as a means for sending email from the program presented a number of challenges. First, it was problematic in that there was no way to determine, other than by user observation, if a message had been successfully sent. Second, it was the only place in which another application's interface was invoked outside the primary application. This presented users with the potential to "get lost" in the other program's interface and find it difficult to return to the Responder application. Thus, it was desirable to find a means for automating the composition and sending of email without using Outlook.

Help Section

In the next prototype, this section will be omitted. Further evaluation will be necessary to determine if Help functionality is necessary and how it should be presented.

Incident Organizer General Rankings and Comments

In general, the Incident Organizer appears to provide an effective user interface for the Responder system. With the modifications described above, this interface could be considered near final. Goals of ease of use and user-friendliness appear to achievable.

7.5. Prototype 2 [Controlled Field Demonstration Stage]

7.5.1. Time Frame

October 2004 – May 2005

7.5.2. Overview

The prototype developed in this iteration is the final prototype of this phase of the project. The intent of this prototype is to prove that the system (hardware and system) is viable. It was understood that further development would be necessary to "harden" the system and to finalize functionality. Certain design choices would be made out of practicality, to ensure that a working system would be developed. If the system was deemed successful, then time could be devoted to resolve issues surrounding these design choices. In particular, this prototype was designed to be portable, but not hardened sufficiently for final production use in the field. The prototype was sufficient for limited field testing by Caltrans with minimal setup and training.

7.5.3. Concept

The concept remains unchanged from the previous iteration:

> A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

The objectives were remained unchanged:

- Create and provide the information elements, framework and pilot deployment of an information collection system centered on the information needs of District 2 field units and Redding TMC for transportation management and incident response/clearance, and of relevance to other emergency response organizations. The incident information collection system will include capabilities for collection of incident images, facilities for annotating images and maps to describe incident scope and severity, incident GPS location, as well as form-based information as deemed appropriate by District 2.
- Create and provide the information elements, framework, and pilot deployment of an incident support information system based on the needs of District 2 field units and Redding TMC, and of relevance to other emergency response organizations. The incident support information system will include capabilities for downloading maps and aerial photos, weather conditions, and other support materials related to the incident and its location.

- Provide the necessary hardware and communications infrastructure for the exchange of at-scene information collected via the information collection system and the distribution of incident support information to responders as described for the incident support system. The communications system will provide the means to exchange information between District 2 field personnel at the scene and Redding TMC, and will be capable of incorporating other emergency response organizations. In Responder vehicles this will consist of a mobile data terminal (ruggedized Tablet PC), a satellite or satellite/cellular combo phone, Internet data connectivity kit including cabling and software, GPS hardware with computer connectivity, and a digital camera with computer connectivity. The incident information collection system and the incident support information system software will reside on and interface with this equipment to facilitate the collection of information and transmission of data to and from the incident scene.

7.5.4. Requirements

Requirements were further refined to incorporate items resulting from the October 2004 demonstration and survey. New requirements are listed in italics:

1. A system shall be implemented to collect incident information.
    a. The system shall collect and store incident metadata.
    b. The system shall collect the incident location.
        i. The system shall record the precise location of the incident using latitude and longitude.
        ii. The system shall record post mile location of the incident.
    c. The system shall collect the incident occurrence time.
    d. The system shall collect a description of the incident.
        i. The system shall record the type of incident.
            1. The system shall record analysis of spill impacts for Hazmat incidents.
            2. The system shall record severity of incidents.
        ii. The system shall record traffic control, closures and directions of traffic in a form.
        iii. The system shall record equipment needed for incident clearance.
        iv. The system shall record incident measurements.
    e. The system shall collect incident photographs.
    f. The system shall collect incident sketches.
    g. The system shall facilitate sketches.
        i. The system shall facilitate sketches to annotate incident photographs.
        ii. The system shall facilitate sketches to annotate maps.

iii. The system shall facilitate sketches to annotate aerial photos.

iv. The system shall facilitate free-form sketches.

h. The system shall facilitate forms.

i. The system shall display forms.

ii. The system shall facilitate entry of information into forms.

iii. The system shall facilitate permit forms.

i. The system shall facilitate access to manuals.

i. The system shall organize manuals for browsing and searching.

ii. The system shall allow bookmarks in manuals.

j. The system shall store incident information as a collection, not disparate pieces.

2. The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.

a. The system shall be usable by one primary field contact person for communication with dispatch.

b. The system shall transmit incident information to a single contact.

3. The system shall be deployed within Caltrans' vehicles in the field.

4. The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.

5. The system shall be easy to use.

a. The system shall include a checklist for use and procedures at the scene.

b. The system shall automatically recognize when it is connected to a camera.

c. The system shall automatically present a preview of photographs.

d. The system shall facilitate management of photos on the camera.

i. The system shall facilitate archival of photos from the camera.

ii. The system shall facilitate deletion of photos from the camera.

e. The system shall require minimal navigation to complete operations.

f. The system shall use functional names for interface elements.

g. The system shall facilitate pre-stored configuration information and default values.

i. The system shall store default contact information (email address) for incident information transmission.

h. The system shall be designed for ease of use so as not to require embedded help.

6. The system shall automate the collection of incident information.

a. The system shall automatically geo-locate the responder.

7. The system shall minimize the amount of time required for use.
    a. The system shall facilitate the collection and entry of incident information in less than 20 minutes.
    b. The system shall facilitate automated transmission of incident information.
8. The system shall transmit information to the TMC and other outside agencies.
    a. The system shall transmit incident information to a single contact.
9. The system shall receive information from the TMC and other outside sources.
    a. The system shall display weather information based on the responder's location.
        i. The system shall display weather forecasts based on the responder's position.
        ii. The system shall display wind directions.
        iii. The system shall display storm information.
        iv. The system shall display wild land fire information.
    b. The system shall display road maps based on the responder's location.
        i. The system shall include pre-loaded road maps.
    c. The system shall display aerial photos based on the responder's location.
        i. The system shall include pre-loaded aerial photos.
        ii. The system shall include pre-loaded Caltrans' DHIPP aerials photos.
    d. The system shall display topographic maps based on the responder's location.
        i. The system shall include pre-loaded topographic maps.
    e. The system shall display Caltrans' maps.
    f. The system shall display the location of the command post, crews and equipment at the incident.
    g. The system shall display locations of other responders, contract personnel and equipment at the incident scene.
    h. The system shall display locations and estimated times of arrival of responders, contract personnel and equipment en-route to the incident scene.
    i. The system shall display staff availability.
    j. The system shall display expected traffic volumes.
    k. The system shall display chemical information for Hazmat spills.
    l. The system shall display affected facilities.
    m. The system shall download data to responders while en-route to and at the scene of an incident.
    n. *The system shall not download unnecessary information such as graphics and links.*

o. *The system shall use incident location information to identify and expedite downloads.*

10. The system shall have data communications capability in all areas of District 2.

    a. The system shall be operable in rural areas including mountainous areas.

    b. The system shall be operable in urban areas.

11. *The system shall display diagnostic information for system devices.*

    a. *The system shall display diagnostic information in a clearly separate location from other information.*

7.5.5. Design / Specification

A number of design specifications were added as a consequence of the October 2004 survey. This listing was not intended to be comprehensive, but rather to document certain items that were explicitly requested or discussed. (New specifications are listed in italics.)

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
    - The system shall use a custom-developed application for data collection and recording.
        - *The system shall auto-populate Organization and District fields.*
        - *The system shall use a location description field to indicate post-mile and direction.*
        - *The system shall automatically navigate to photograph locations.*
        - *The system shall minimize interaction required to select and copy photos and maps for annotation (sketches).*
        - *The system shall copy descriptions along with photos to sketches.*
        - *Forms shall auto-populate.*
        - *Entry shall be made using pen or keyboard.*
        - *The application shall be self-contained, with no requirement for exit or transfer to other applications for use.*
    - The system shall use email as the transport for incident information.
- The system shall use a digital camera to collect digital photographs of incidents.
- The system shall use satellite communication to provide data communication capability in mountainous areas.
- The system shall use cellular data communication to provide data communication capability in urban and other areas where cellular communication is available.
- The system shall use GPS to auto-locate the responder.
- The system shall use IEEE 802.11 –based wireless technology to implement un-tethered use in the proximity of parked Department vehicles in the field.

7.5.6. Implementation

Prototype 2 consists of software and hardware demonstrating the full functionality of the prospective system. It includes equivalents of the hardware that would likely be used in a production system, as well as a prototype that fully demonstrates much of the capability of the prospective system. Not only did this prototype facilitate demonstration and feedback, it allowed for further testing and experimentation that will ultimately benefit development of a production system.

7.5.6.1. Software

Required Software

The Responder application is a Microsoft Windows application, written in the C# programming language. It uses the .NET framework as well as Tablet PC APIs. In order to use the application, the following must be installed on the Responder Tablet PC:

- Microsoft Windows XP Tablet PC Edition
- Microsoft Office 2003 (Word)
- Microsoft MapPoint 2004
- Data Connectivity Software for Cell Phone and Satellite Phone
- Miscellaneous Drivers
- Responder Application

Note that Microsoft Outlook, Microsoft Internet Explorer and Adobe Acrobat Reader are no longer prerequisites for the application. In the event that forms and manuals are added back into the system, then Internet Explorer and Acrobat Reader will likely be needed again.

Splash Screen

The splash screen appears and functions in a manner similar to that of Prototype 1. Several wording changes have been made in the status messages to make them more user-friendly. The initialization process has been made more robust by implementing multiple connection attempts and timed-delays between attempts. As a result, the application takes more time to pass through the initialization phase, but is more likely to succeed in connecting to devices than in the previous prototype. In the testing of Prototype 1, contention issues were observed between the operating system and the application. The operating system may take up to one minute to recognize devices such as the GPS, the cellular modem, and the satellite modem. When attempts are made to connect to these devices before they are recognized by the operating system, the operating system may fail to establish the connection. The aforementioned modifications address this problem and appear to handle a wide range of circumstances including the unavailability of the devices. In all cases, the application handles the result gracefully, and proceeds in displaying the Incident Organizer, regardless of the status of the devices.

Figure 45: Prototype 2 - Splash Screen

A major addition to Prototype 2 is the ability to save incidents and open them at a later time. This functionality was necessary and planned previously. Furthermore, users can save incident information periodically as they are completing an incident record, helping them to avoid losing their work. Further investigation should be conducted to determine whether an auto-save feature would be desirable to further enhance this ability.

Complete incident information is saved on the Responder computer in XML format for each incident. Furthermore, incident images are archived at full resolution for later use. (Note again that when images are transmitted, they are re-scaled and compressed to minimize transmission time.) Time-sensitive information (such as weather reports) is not archived. Further investigation should be conducted to determine if weather reports retrieved and used by the Responder application should be archived for future reference.

At this point, the Responder application is the only application designed to read archived incident files. However, since information is stored in an open, XML format, use for other applications could be readily facilitated. For instance, it would easy to extract information for storage in a greater incident database, as was suggested in subsequent review. At this time, no mechanism or application has been identified to transfer complete incident records from the Responder computer to a central storage area. However, such transfer would be a simple process that involves copying the directory and files corresponding to an incident.

To facilitate the exchange of information, incident records can also be saved in Microsoft Word, HTML, and MHT archive formats. While not included as an option via the user interface, coding has been put in place allowing for the adjustment of resolution and quality of images stored in these formats.

Following initialization, the user is prompted (Figure 46) to indicate whether they would like to open an existing incident or if they would like to create a new incident. Incidents are identified by time and organization, and users may select saved incidents accordingly, or may choose to create a new incident.

Incident Organizer

The Incident Organizer has been restructured to include the following tabs: Summary, Mapping, Photos, Sketches, Weather, Devices and Messaging. The Forms and Manuals tabs from Prototype 1 have been removed, pending further technical and institutional investigation. Manuals will likely be added back into the application in the future. Forms may be added if technical issues with entering and saving information can be resolved. The Internet tab from Prototype 1 has been replaced with the more functional Weather tab, which will be discussed later. The Communications tab has been split into Devices and Messaging, again to clearly distinguish functionality. The Help tab has been removed pending further investigation. At this point it appears to be unnecessary to include integrated help within the application.

Saved or New Incidents

Following the Splash Screen and initialization, the user is prompted as to whether they would like to open an existing incident or create a new incident.

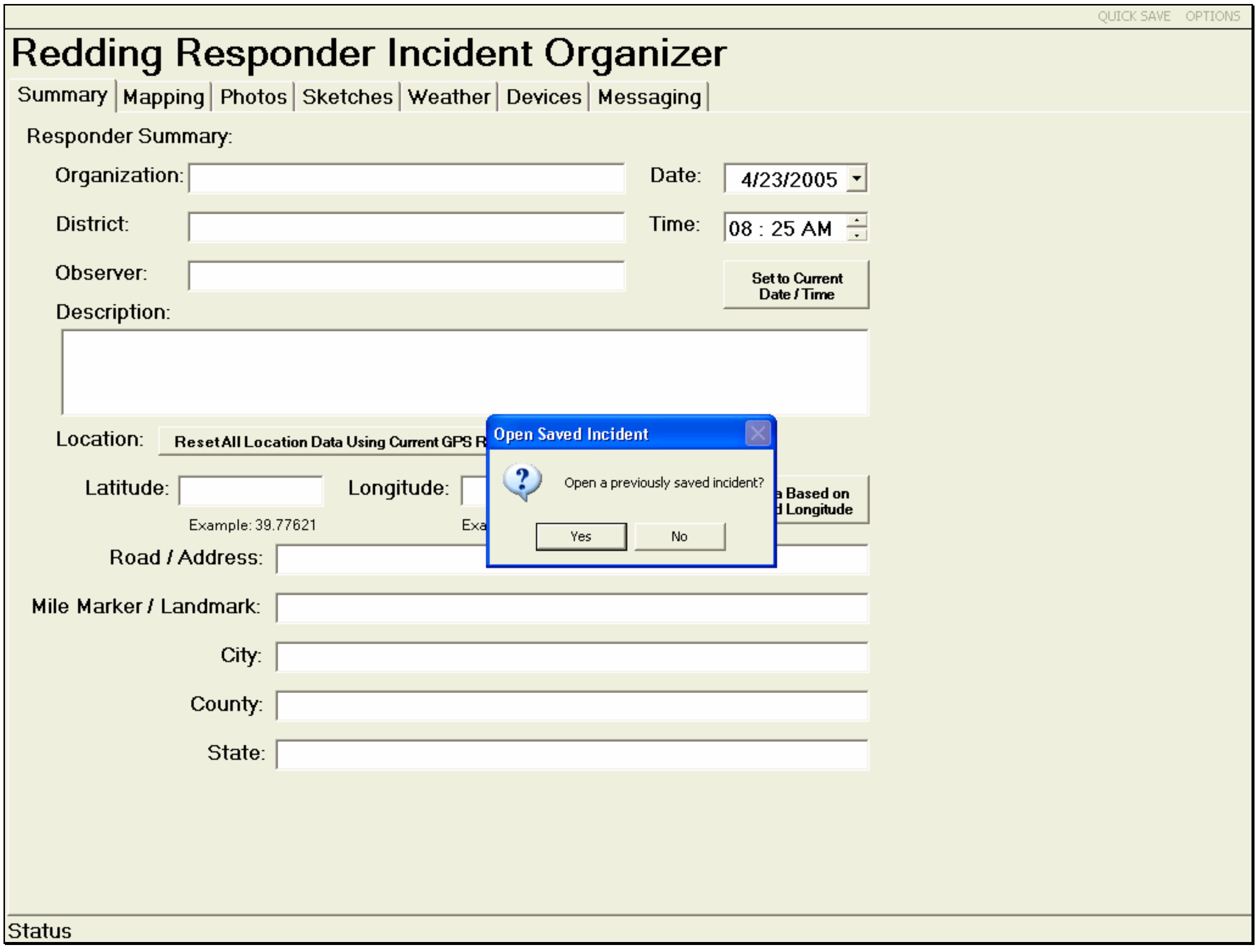

Figure 46: Prototype 2 – Open Existing or New Incident

If the user chooses to enter a previously saved incident, then that incident's information is loaded into the Incident Organizer. If the user chooses to open a new incident, a new incident record is created and fields are pre-populated, where possible.

Summary Tab

The Summary tab is similar to that of Prototype 1, with several additions:

- A Mile Marker/Landmark field has been added to further identify the incident location. This is a free-form text field that is not pre-populated. Users may enter necessary information via pen or keyboard.
- A "Set to Current Date/Time" button has been added, allowing users to reset the Date and Time fields to the current date and time. Furthermore, users can select Dates and Times using standard Date and Time dialog boxes. This modification should improve efficiency and reduce errors.
- A "Reset All Location Data Using Current GPS Reading" button has been added to allow the user to reset location information based on the current GPS reading, if a reading is available. (This button is disabled if a GPS reading is not available.) Not only will location information in the Summary section be updated, but maps will also be reset to reflect the "new" location.
- An "Update Location Data Based on Specified Latitude and Longitude" button has been added to allow the user to reset location information based on a manually entered GPS reading. This button is included partially for demonstration and testing purposes, but has the practical application of allowing the user to over-ride the GPS reading. For instance, they might be completing an incident record in a different location or even in circumstances where the GPS is not available.
- Sample format text has been included beneath the Latitude and Longitude fields indicating the proper format for entry. Entry is made using decimal degrees, and negative value for longitude indicates a longitude west of the Prime Meridian.

As in Prototype 1, the Date, Time, Road/Address, City, County and State fields are auto-populated. Auto-population of the Road/Address field is handled in a slightly different manner than in Prototype 1. Rather than automatically prompting the user to select from a list of possibilities, the field is presented as a list and the first choice is selected by default. The user may select an alternate choice or manually edit this field at any time.

The Organization, District and Observer fields are also pre-populated in Prototype 2. These fields required manual entry for every new incident in Prototype 1. Values for these fields are stored in an initialization file that is read when the application is opened. These values can be changed within the Summary tab at any time. Furthermore, information in the initialization file can be changed by a system administrator to customize them for different organizations, districts and users.

Further default information is stored in the initialization file including email addresses for the Responder and the contact to which they will transmit responder information, as well as technical information including configuration settings for the modems and GPS.

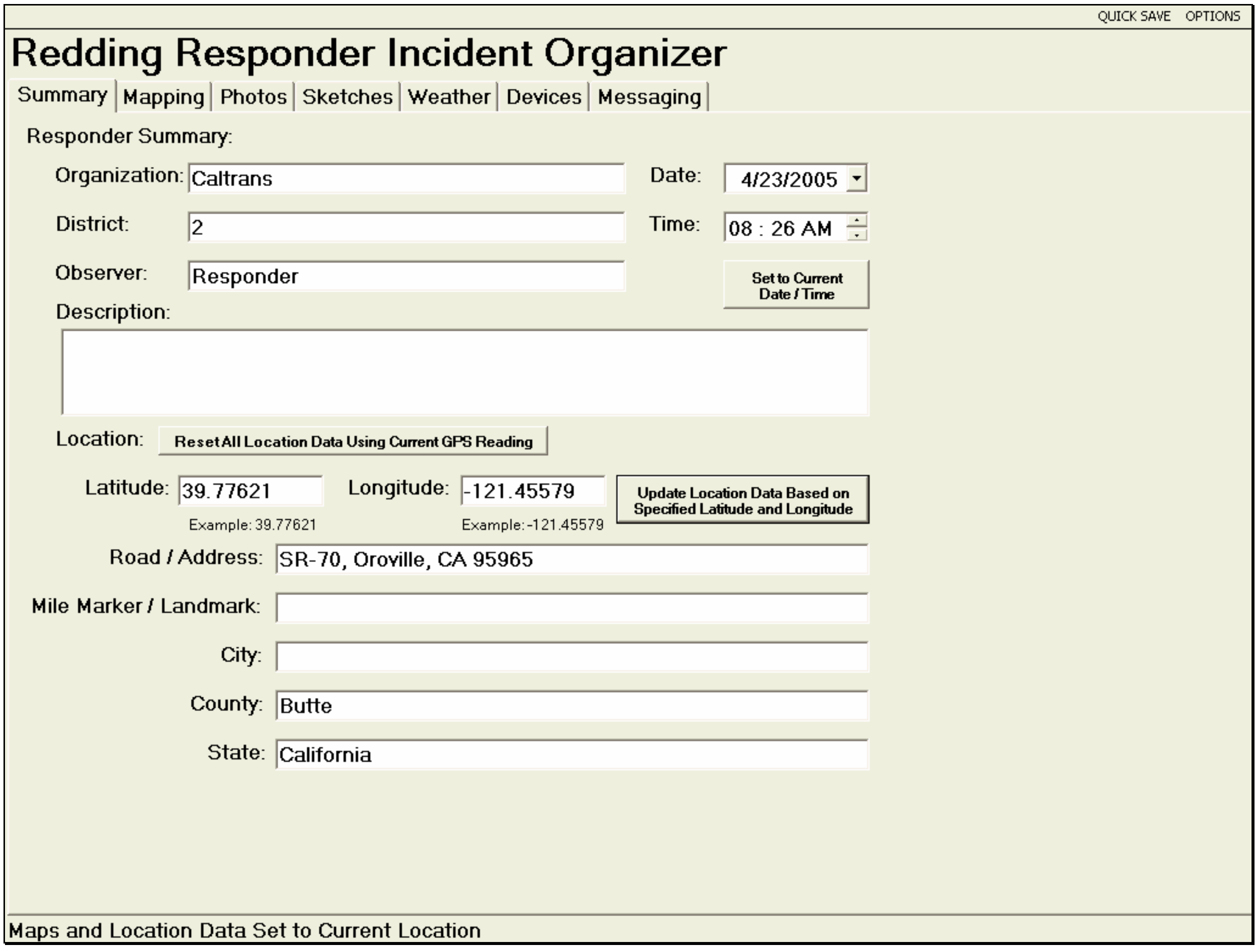

Figure 47: Prototype 2 – Summary Tab

Note that a status bar has been added to the bottom of the application. This status bar is visible within any tab in the Incident Organizer, and indicates the status of recent program activity. In Figure 47, the status bar indicates that maps and location data have been set to the current location, as indicated by the GPS unit.

Mapping Tab

Mapping functionality is similar to that of Prototype 1, with several notable modifications:

- All mapping information, including street maps (Figure 48), aerial photos (Figure 49) and USGS topographic maps (Figure 50), is stored locally on the Responder computer. These items, along with the Road Maps, are available immediately to the responder. The mechanism for storing and using these maps is described in detail later. They must be selected and stored for specific areas prior to use of the system. If an area is not "covered" by stored data, then these maps will not be displayed. An option to download them has not been included, although it could very easily be added.
- GPS readings are no longer displayed in this section. The GPS tab has been moved to the Devices tab, where it seems more appropriate and consistent with other data. If it is determined that GPS information should be included under the mapping tab, it could easily be moved back.
- At the bottom and right sides of each map, a scale is shown to help users recognize distance. Distances are shown in kilometers, but could be converted to Imperial measurement – either feet or miles.
- Panning options have been removed. It is assumed that the responder's focus will be on the immediate vicinity of the incident, and that the incident occurs on the road network. Users may still zoom in and out. (Note that aerial photos and USGS topographic maps were stored as tiles and only those tiles immediately surrounding the road network were included. Thus, a user would not be able to pan far from the road on which an incident is located and view maps and imagery.)

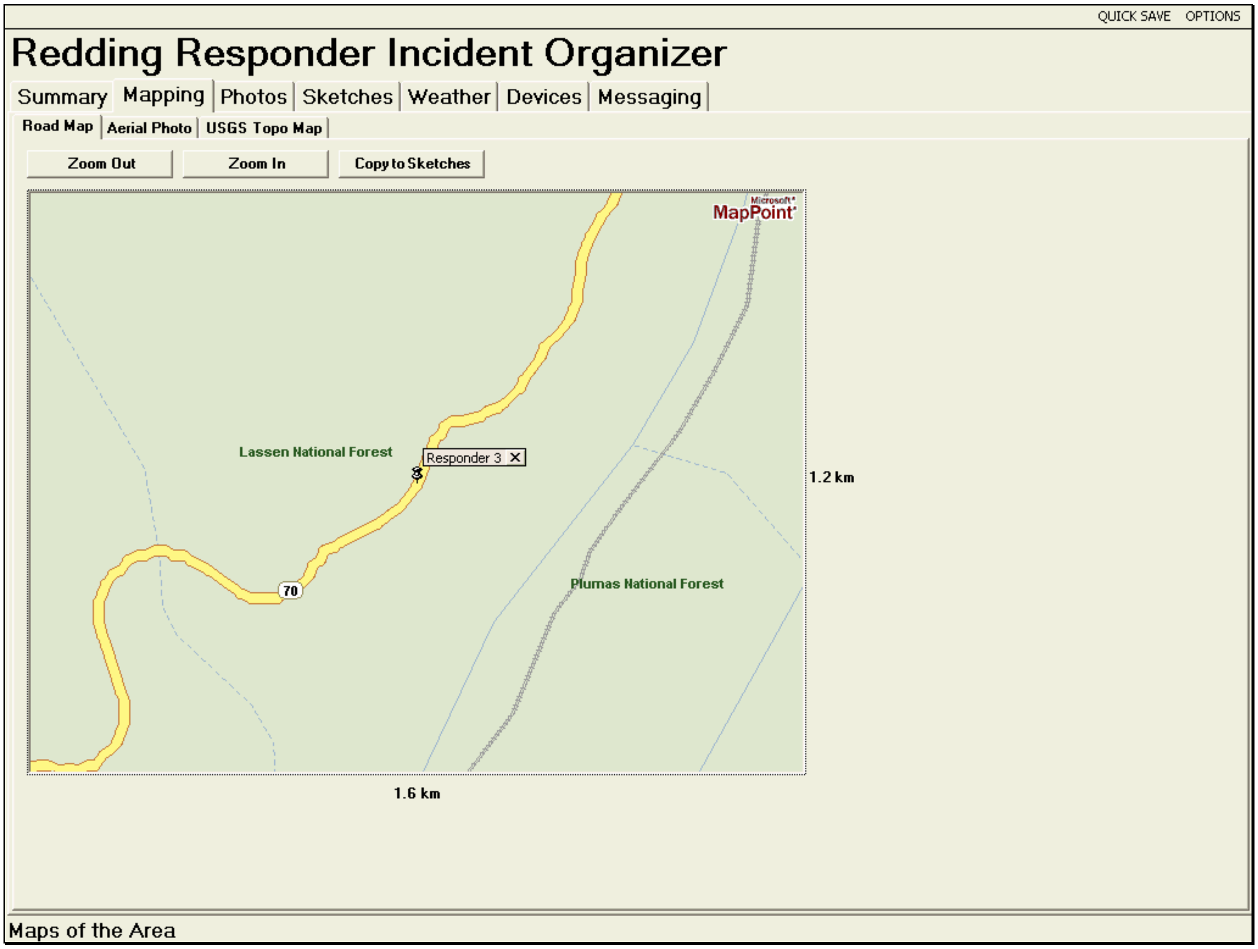

Figure 48: Prototype 2 – Mapping Tab, Road Map

Initial views of the road map, aerial photograph and USGS topographic map correspond approximately to the same coverage area, and are all centered on the responder's location, as indicated in the Summary tab. Note that due to technical complications with the MapPoint application, there is not an exact correspondence between the road map and the aerial photograph and topographic map, but the correspondence is approximate. The crosshair used to indicate the responder's location on the aerial photograph and topographic map has been removed to eliminate obstruction of detail. This indicator or an icon could be added if necessary to show the responder's location.

"Zoom In" and "Zoom Out" buttons allow the user to zoom the current map accordingly. Note that these buttons only zoom the map that is currently in view, and do not zoom the other maps.

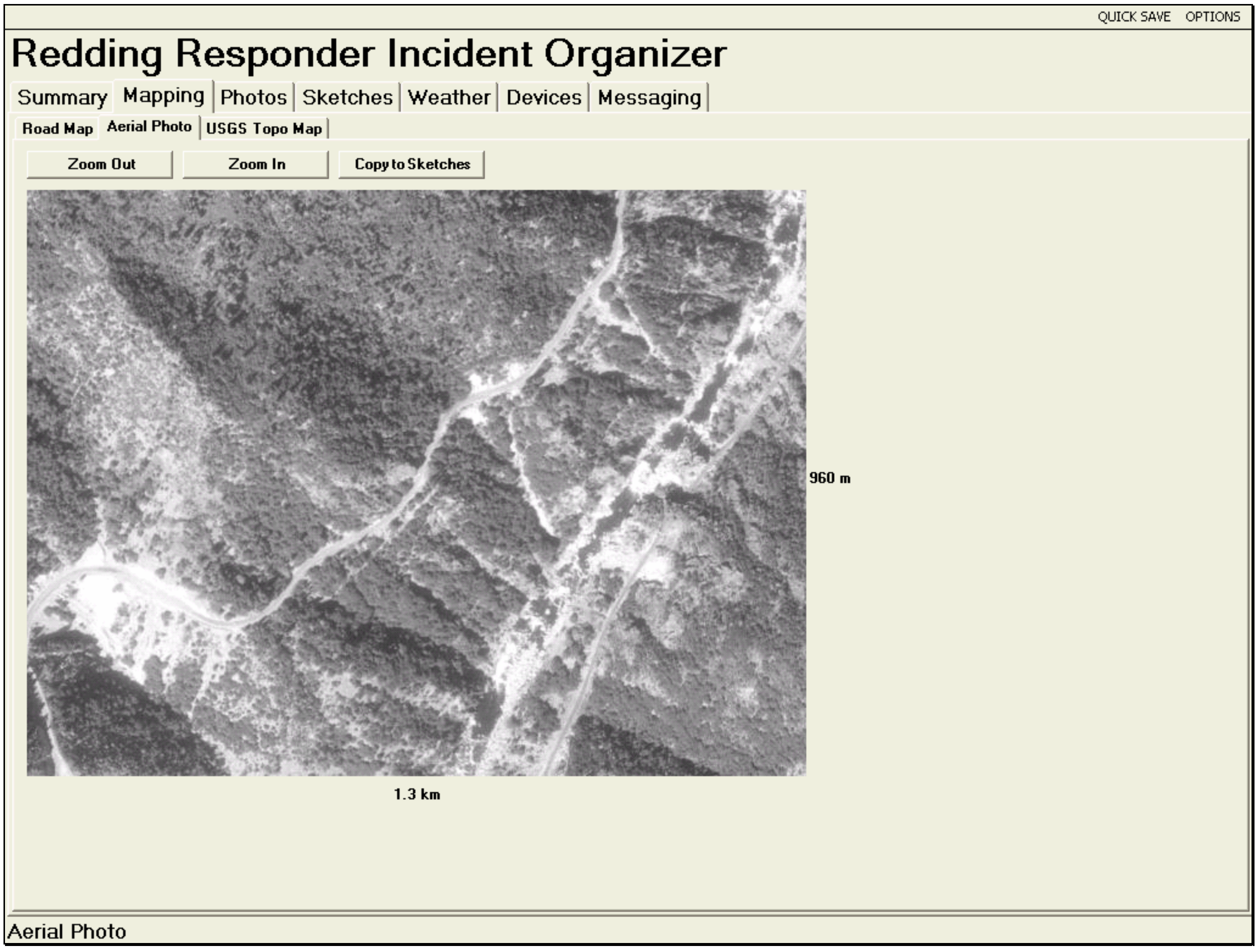

Figure 49: Prototype 2 - Mapping Tab, Aerial Photograph

Note the rough correspondence between the aerial photograph and the road map, as well as the nearly exact correspondence between the aerial photograph and the topographic map.

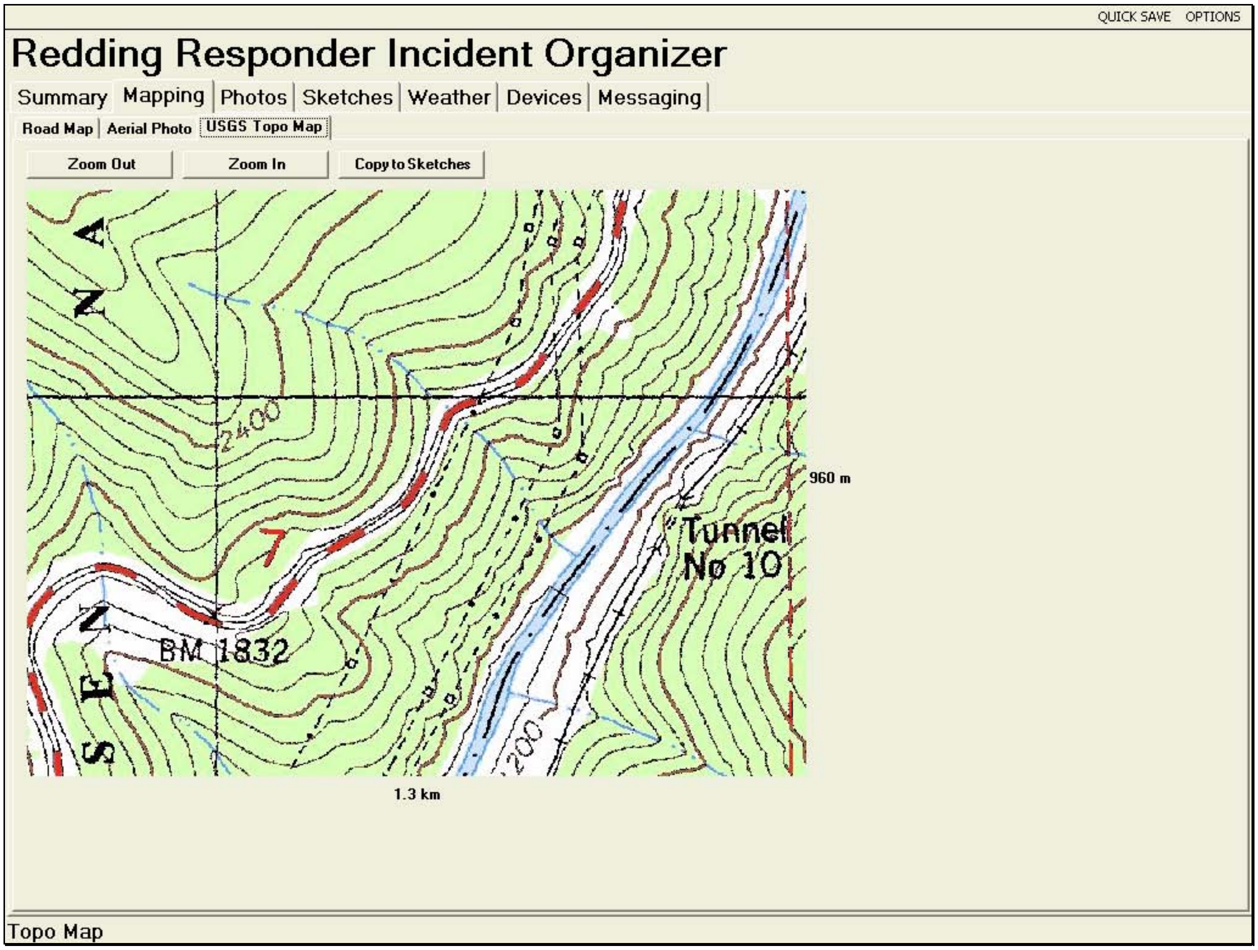

Figure 50: Prototype 2 - Mapping Tab, USGS Topographic Map

Photos Tab

While the Photos Tab (Figure 51, Figure 52 and Figure 53) remains largely unchanged, the method of selecting photos for inclusion in the Incident Organizer has changed significantly. A Photograph Selector dialog (Figure 51) is invoked when the "Add Photos" button is selected within the Photos tab. This dialog box does the following:

- Automatically connects to the digital camera and locates the path to photos stored on the camera, if it is plugged in. (This is transparent to the user, except in the event that the camera is not connected.)
- Displays a preview of each photograph individually.
- Allows the user to navigate through the photos.
- Allows the user to select photos for inclusion within the Incident Organizer.
- Allows the user to mark photos for deletion from the camera.
- Allows the user to select or de-select all photos for inclusion and/or deletion.

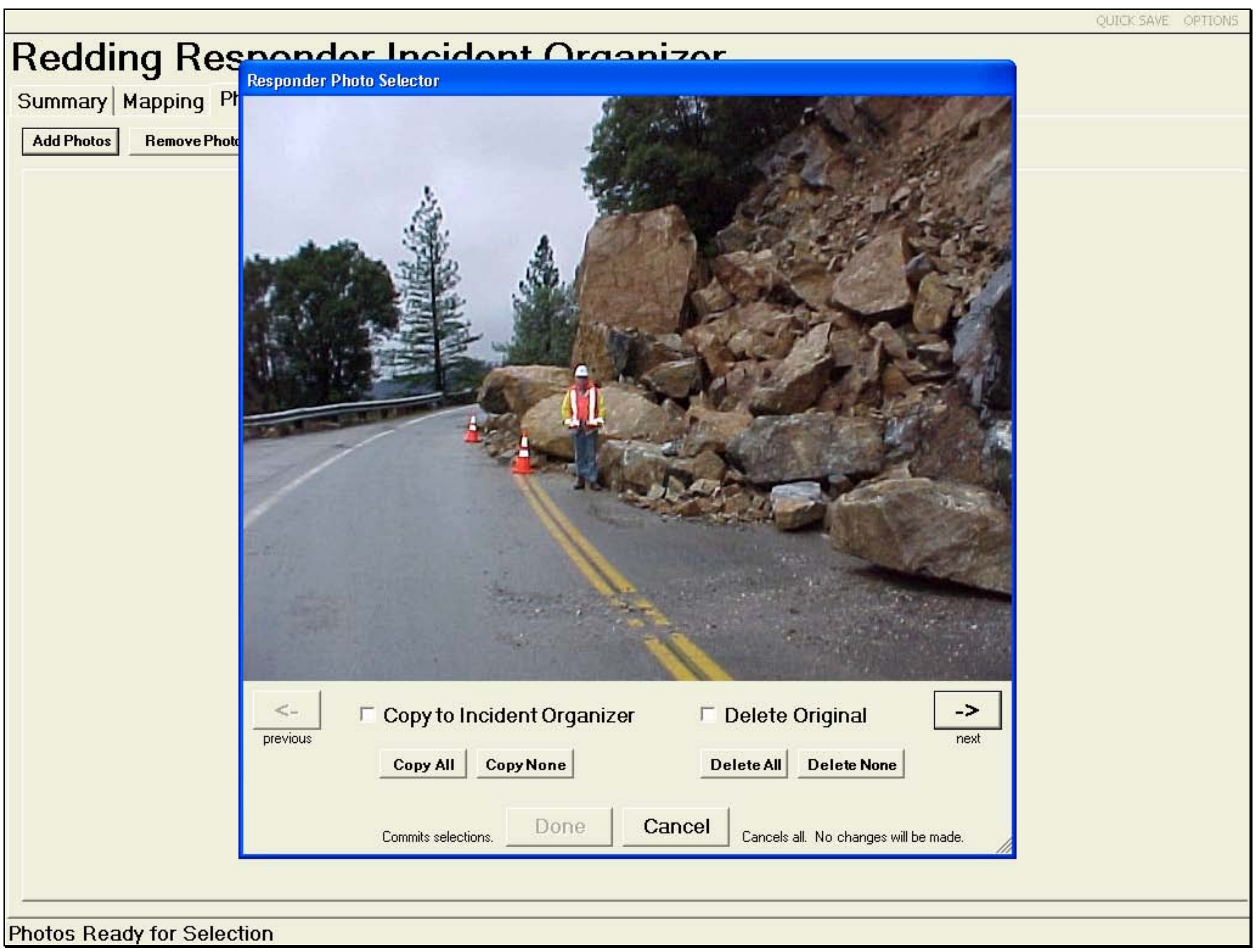

Figure 51: Prototype 2 – Photograph Preview and Selection

This added functionality allows users to more easily work with and manage photos taken with a digital camera. They no longer have to manually determine and navigate to the drive and folder corresponding to the camera, as was required in Prototype 1. They also have a means to "clean up" storage on the camera, and remove old photos that are no longer necessary. Note that this process could potentially become semi-automated if reliable timestamps were recorded by the camera for each photograph. This may become a desirable feature for subsequent selection of a camera for the system.

The Writing Pad (Figure 52) is used for entry of descriptions via the pen, and automatically appears when the description field is selected.

Figure 52: Prototype 2 – Writing Pad for Photograph Description

Note the "email" checkbox to the right of the photograph in Figure 52. This checkbox is used to indicate the inclusion or exclusion of a photograph within incident email. The intent of this checkbox is that the responder may (and should) include photos and other information that are important in documenting the incident, but are not necessary for inclusion in messages that are sent to the TMC from the incident scene. For instance, certain photos may contain redundant information and could be omitted to reduce the size of the email and minimize transmission time. Yet these same photos may show a different view of the incident scene that is useful later for analysis and documentation of the incident.

Sketches Tab

The Sketches tab was modified slightly from what was developed in Prototype 1. Specifically, the following additions were made:

- An "Erase Ink" button has been added, allowing users to erase ink that they placed on a sketch. All ink is erased from that sketch, but the underlying photograph, map or blank sketch remains. In Prototype 1, the only means for removing errant sketches was to remove the entire sketch.
- An "Email" checkbox has been included with the same purpose as that in the Photos tab, to indicate if the sketch will be included in incident email.

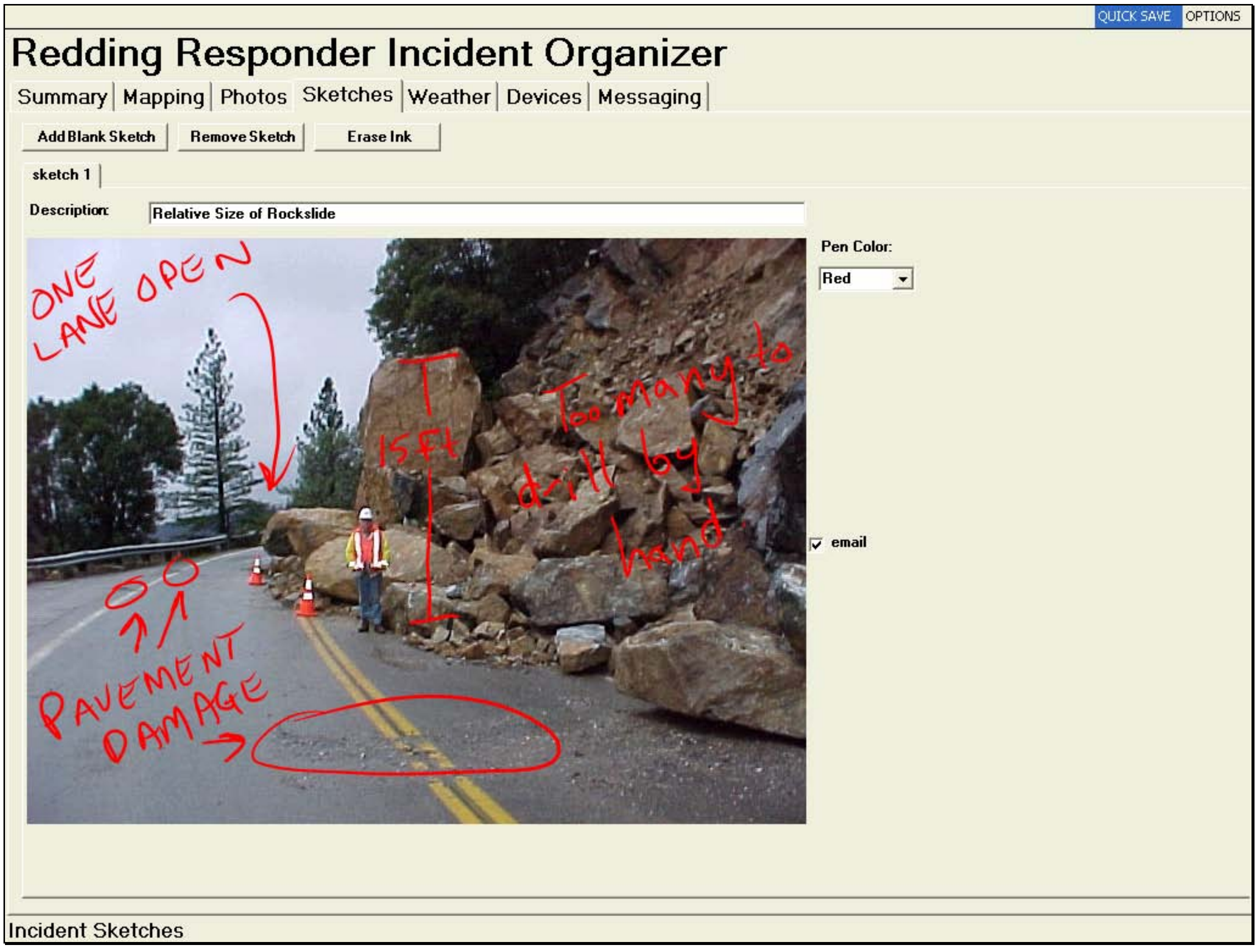

Figure 53: Prototype 2 – Annotated Photograph in Sketches Tab

Photos and all maps (road, aerial photograph, topographic) can be copied to the Sketches section and annotated using the pen. Figure 54 shows an annotated topographic map in the Sketches section of the Incident Organizer.

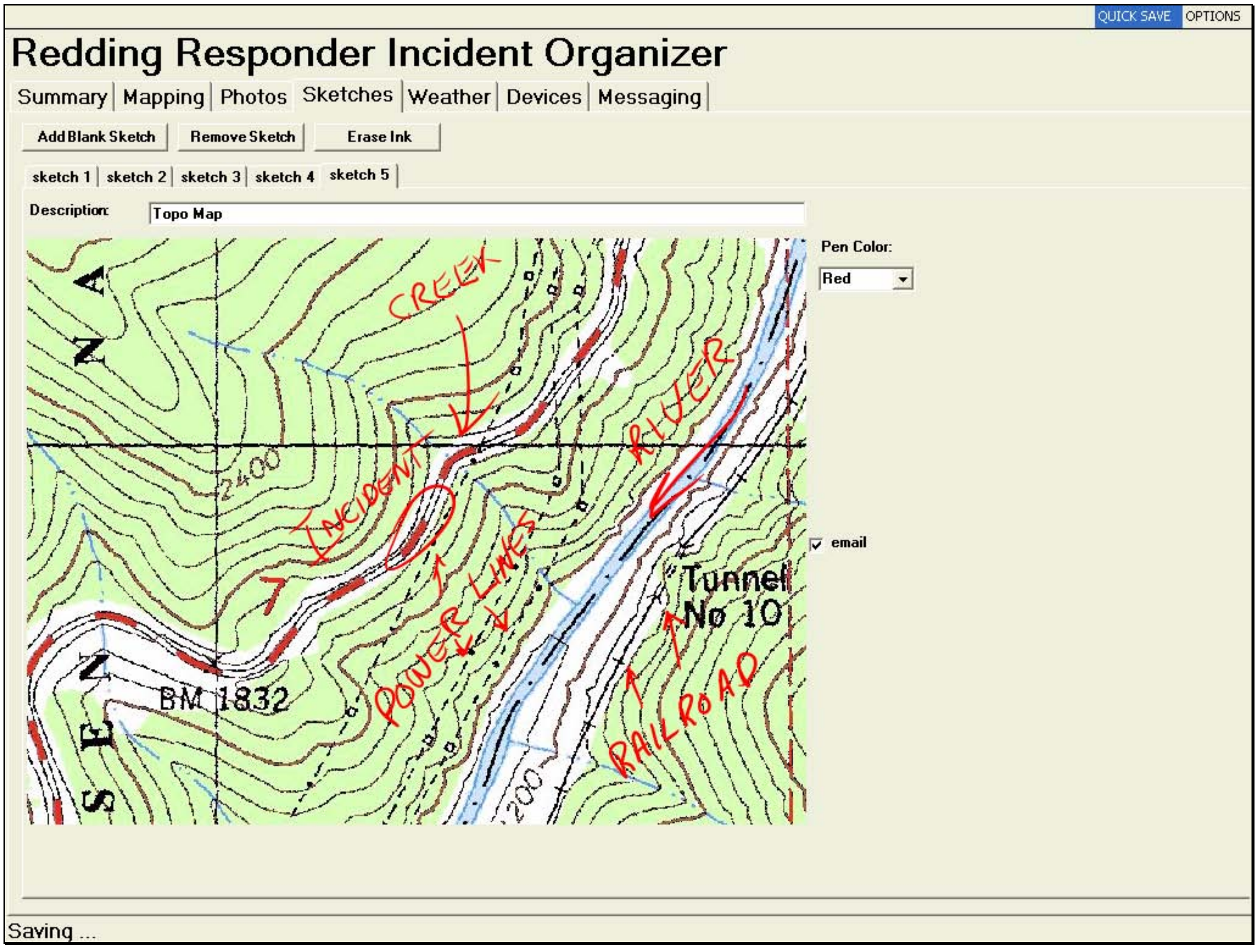

Figure 54: Prototype 2 – Annotated Topographic Map

Note the use of annotations to highlight features on the map (Figure 54).

Blank sketch functionality (Figure 55) remains the same in Prototype 2 as it was in Prototype 1.

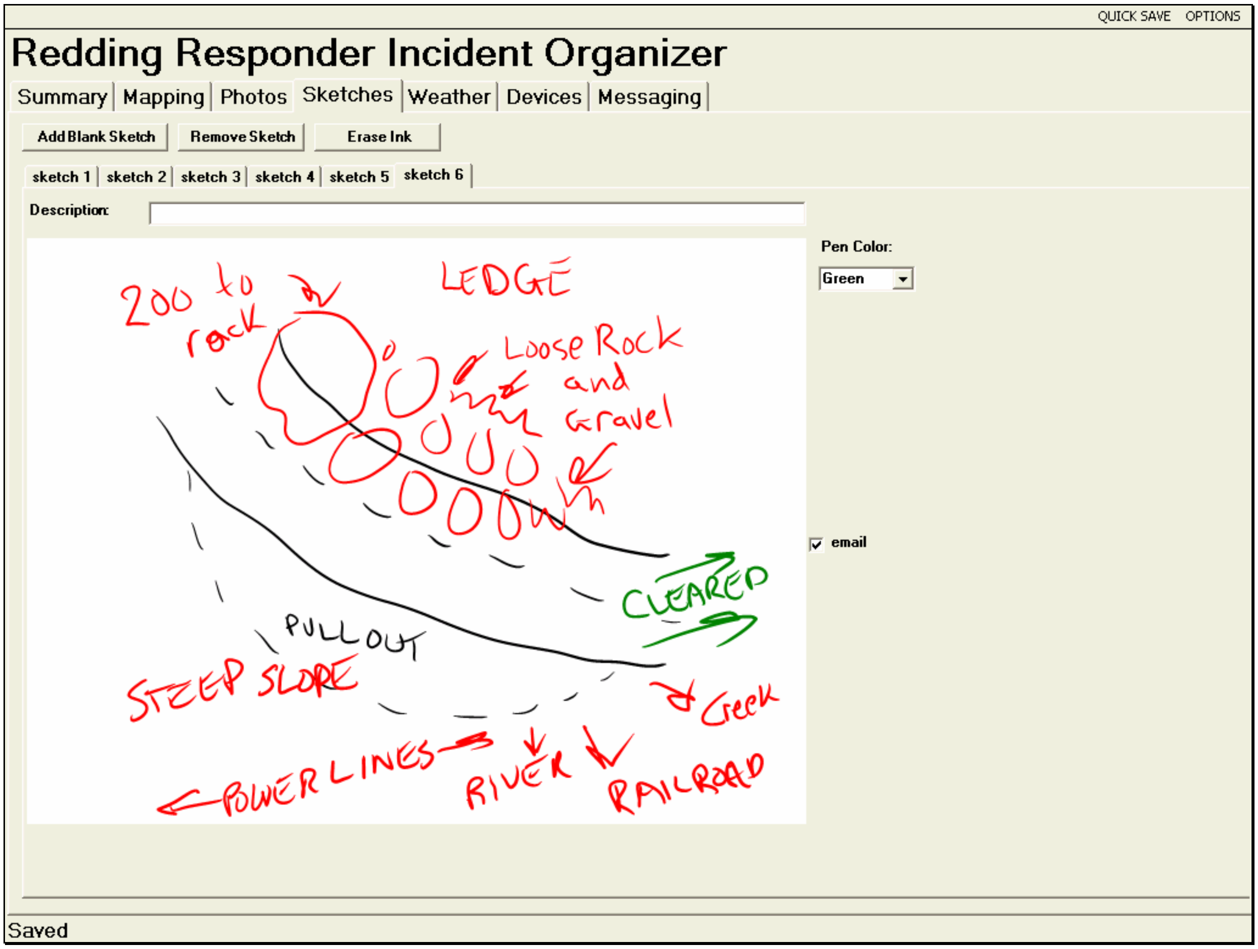

Figure 55: Prototype 2 – Blank Sketch

Weather Tab

The addition of the Weather tab (Figure 56) in Prototype 2 is a dramatic change from the mechanism for retrieving weather in Prototype 1, which required using the former Internet tab (Figure 35) to retrieve a web page containing NWS Digital Point Forecasts (Figure 36).

Now, rather than explicitly requesting a Point forecast, the user presses the “Get Current Weather” button. In turn, they are notified that getting the weather involves connecting to the Internet and may require several minutes for the process to complete. If they choose to proceed, then the system automatically connects to the Internet and downloads weather information specific to the incident location. Other than selecting the “Get Current Weather” button and confirming, the user is not required to do anything further, because the process is entirely automated.

Three types of weather information are downloaded and displayed, when available: a Point Forecast, Alerts, and Nearby Conditions.

Note that these weather reports are downloaded in text format and compressed where possible, to minimize download time. Once weather information has been downloaded, the connection to the Internet is disconnected and the weather information is automatically displayed.

The Point Forecast (Figure 56) provides hourly forecasts specific to the incident location. The latitude and longitude from the Summary section are used as parameters to a web service that retrieves this information from the National Weather Service in XML format.

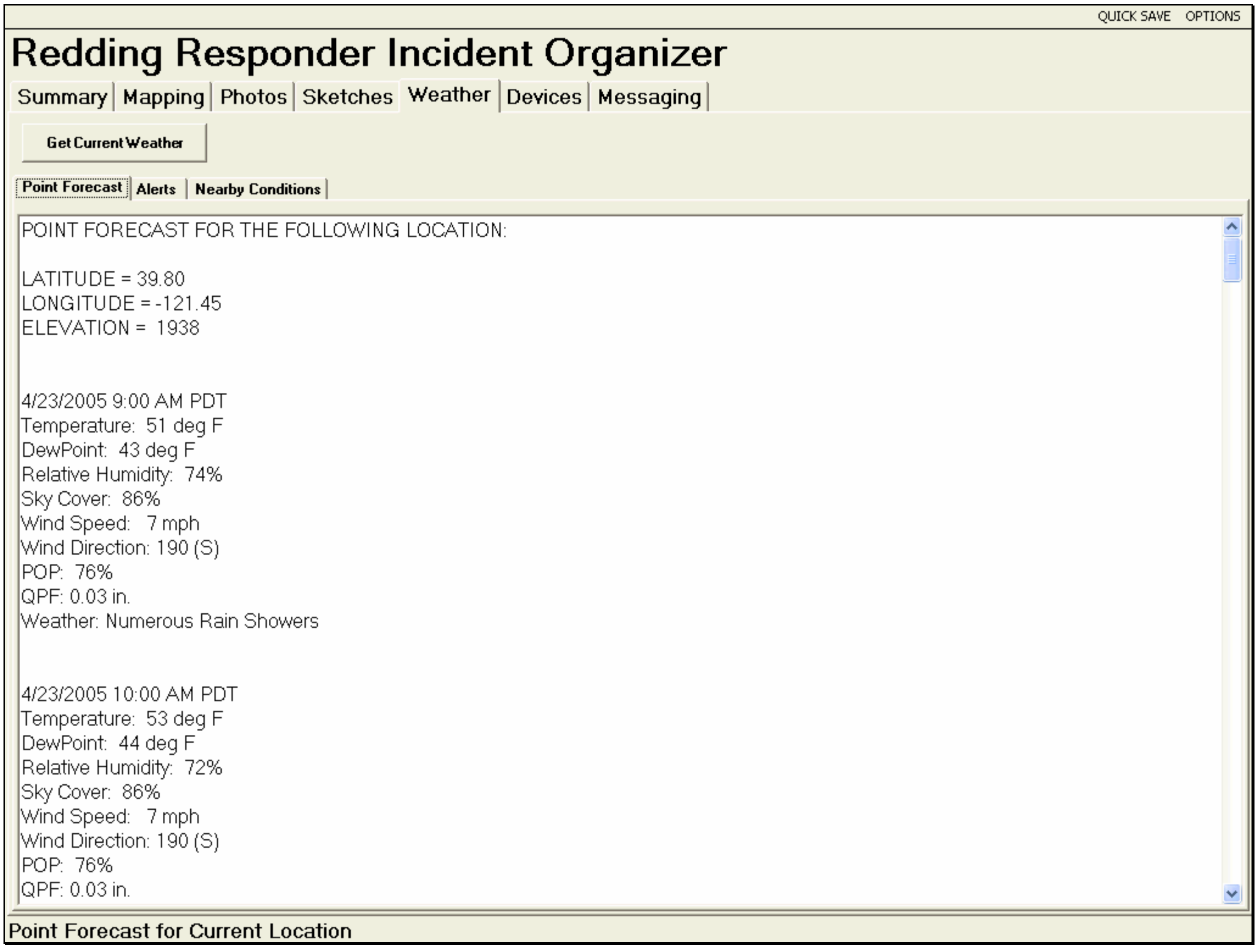

Figure 56: Prototype 2 – Weather Tab and Point Forecast

The Alerts sub-tab (Figure 57) shows weather alerts and warnings that pertain to the incident location. If alerts are present, the system will automatically display these as the top sub-tab within the Weather tab.

Figure 57: Prototype 2 – Weather Alert

The Nearby Conditions (Figure 58) sub-tab shows recent condition reports from stations within 75 miles of the incident.

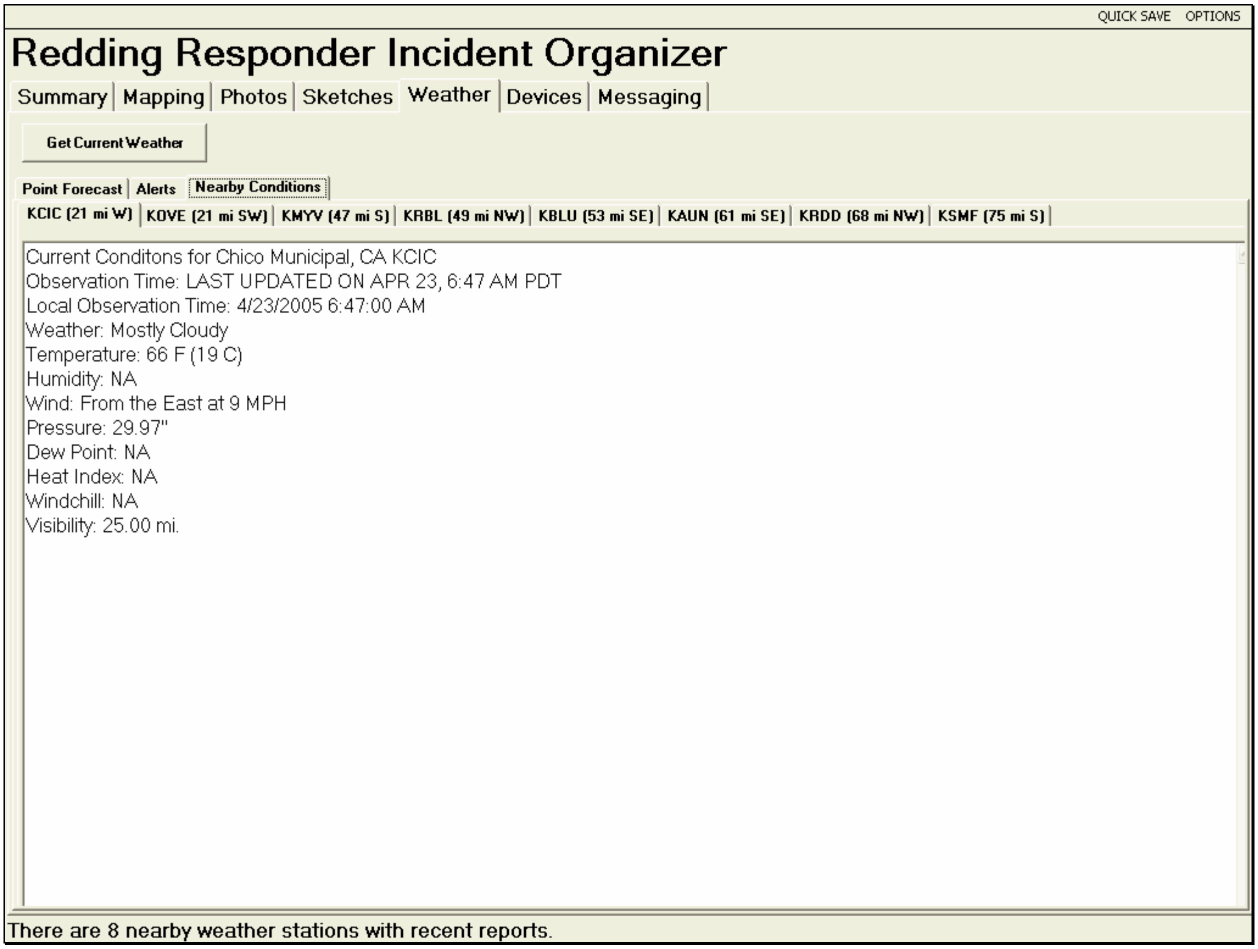

Figure 58: Prototype 2 – Nearby Conditions

Devices Tab

The Devices tab (Figure 59) has been added to include information about status of the three primary devices with which the Tablet PC must communicate: the cellular modem, the satellite modem and the GPS. This information was available in Prototype 1 under the Communications tab (cellular and satellite) and under the Mapping tab (GPS). This tab is primarily intended for diagnostic purposes. Note that a status indicator has been included to indicate if there is a current connection to the Internet. There is also a "(Re-)Connect to Devices" button, which allows the user to force the application to attempt to re-establish connections to these devices. This is useful in the event that a connection is broken or if the application is opened without having first established connects. For instance, power might not be on for the devices.

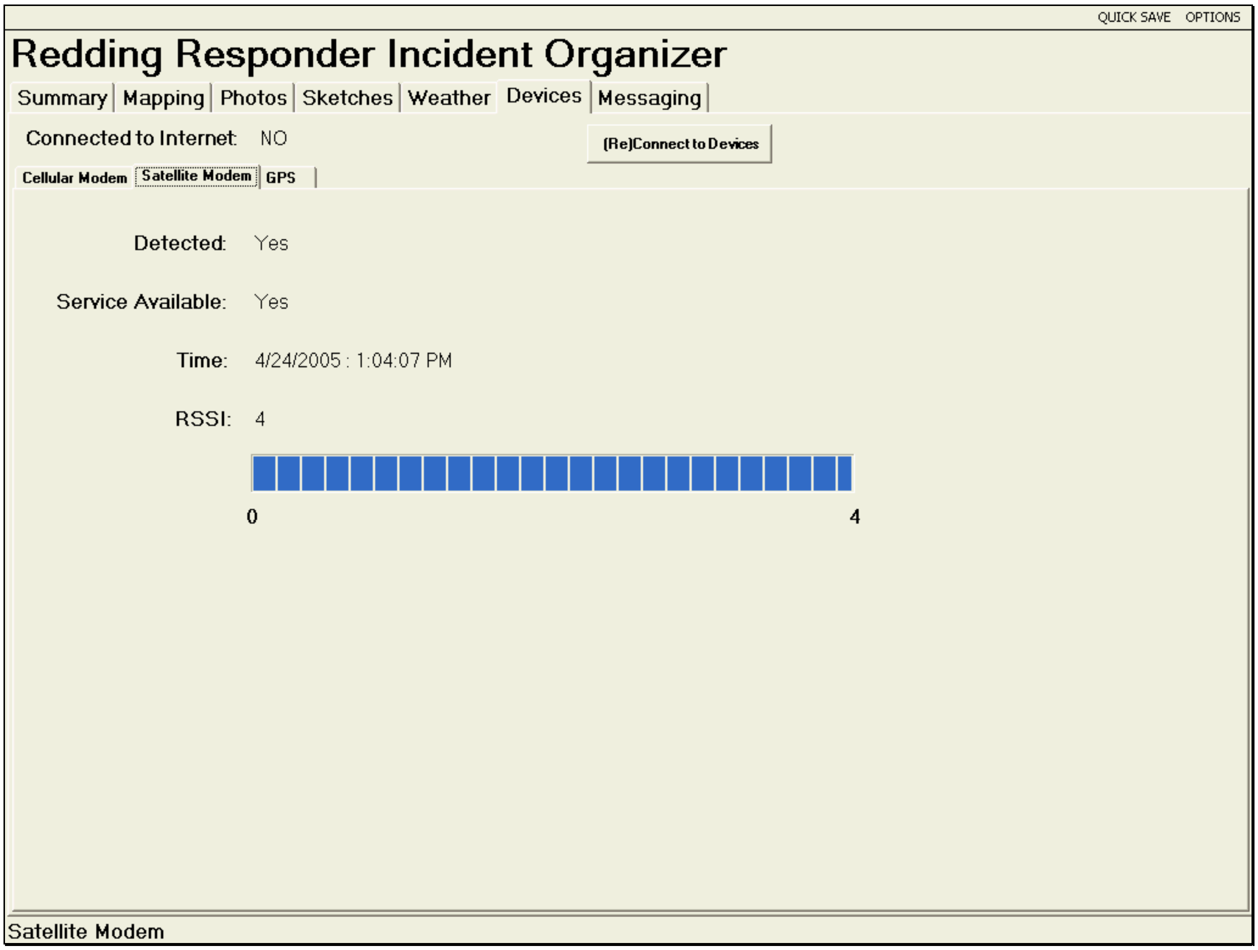

Figure 59: Prototype 2 – Devices Tab

Messaging Tab

Email functionality has been integrated entirely into the new Messaging tab (Figure 60). Users are given a choice regarding what they would like to send in the email and a "Send Email" button to initiate the process. Users may choose to send all photos and sketches, only the photos and sketches that were marked for email, or just a text message. In all cases, a small text message will be sent as a "beacon," providing a brief overview of the situation.

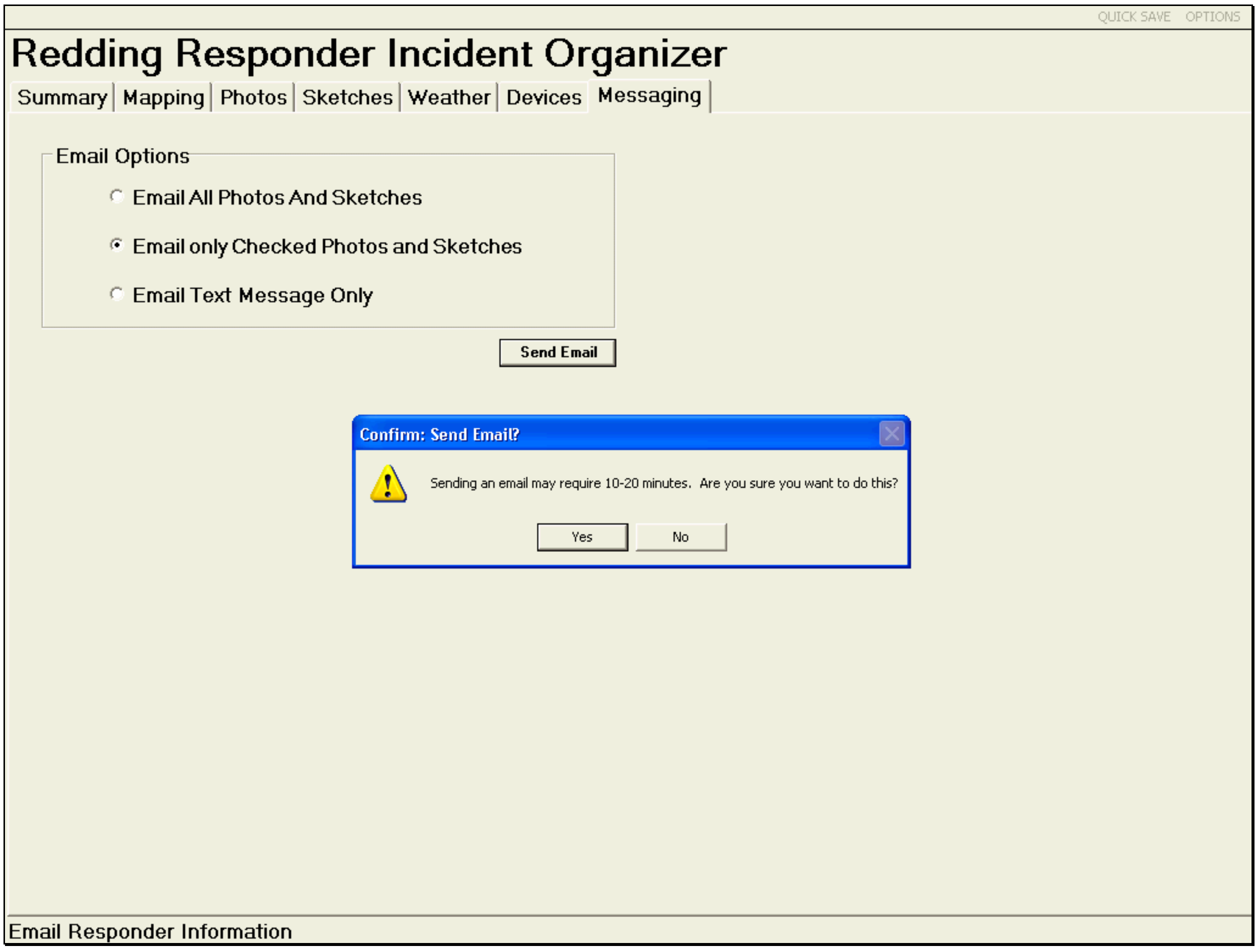

Figure 60: Prototype 2 – Messaging Tab, Send Email

As with the "Get Weather" functionality, pressing the "Send Email" button results in a warning and prompt notifying the users that the process may take 10-20 minutes and requires making an Internet connect, and asking the users if they would like to proceed. If they choose to do so, then a Microsoft Word document containing incident information is created, including optimized copies of images and sketches; an email message is created with a subject line and body indicating the incident location and the time of transmission; the message is flagged as urgent; and the email is automatically sent. Note that Microsoft Outlook is not used to send email messages, as was done in Prototype 1. Instead, the message is composed and sent in an entirely automated process. For the sake of simplicity, the preview screen for the email message was omitted from Prototype 2.

The email message is sent to the address specified in the initialization file. The user is not required to select or enter an address.

The email message is sent via a standard email, and should be readable using a number of applications. For instance, Caltrans uses Lotus Notes, and the message should be viewable via that application. Figure 61 shows a sample email in Microsoft Outlook. The body of the message includes text information, as provided in the Summary tab. The Microsoft Word document (Figure 62) contains this same information along with compressed photos, sketches (Figure 63), and their associated description. In this example, the Microsoft Word document contains 5 photos and 6 sketches and is 156KB in size.

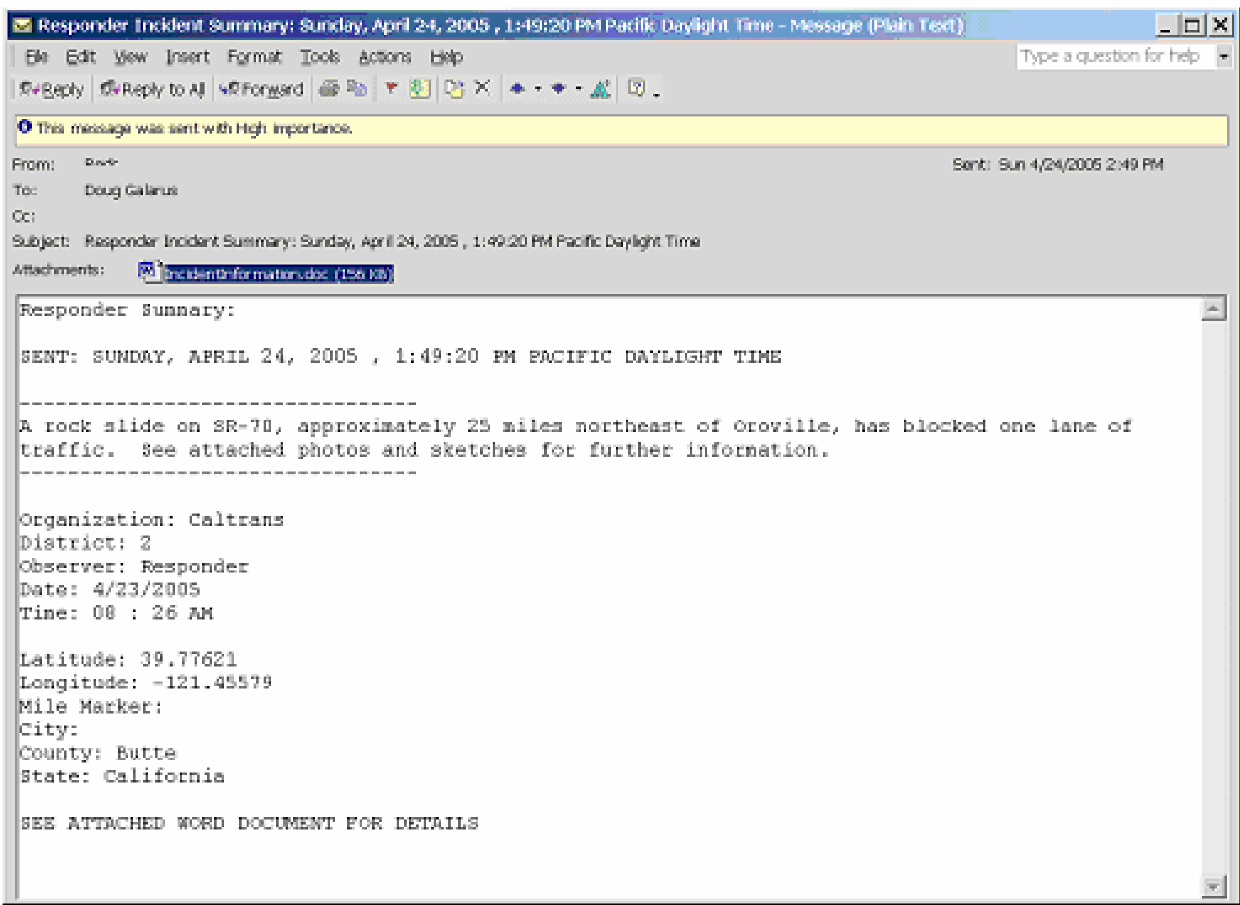

Figure 61: Prototype 2 – Resulting Email as Viewed by Recipient

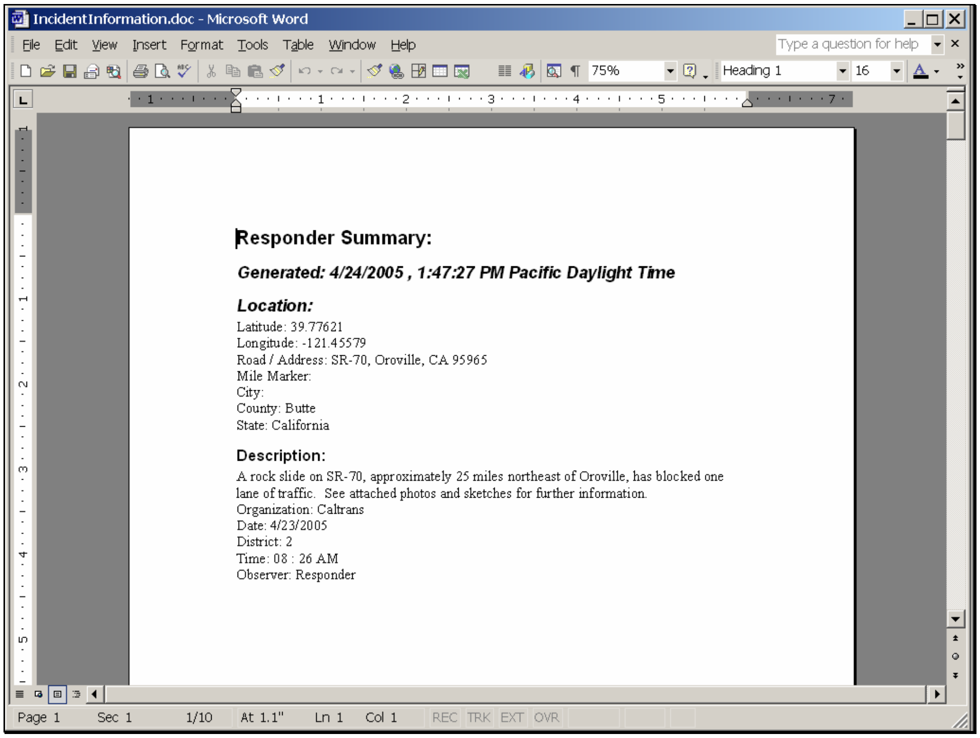

Figure 62: Prototype 2 – MS Word Attachment Containing Incident Information

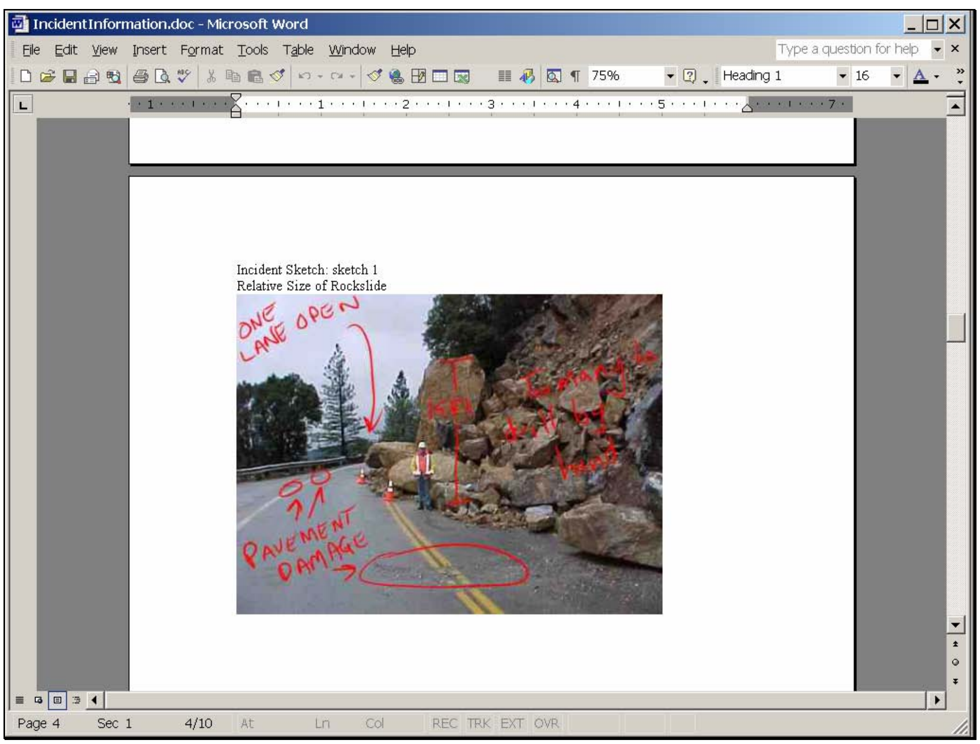

Figure 63: Prototype 2 – Sketch, Optimized and Included in Attachment

Hardware

Prototype 2 introduced several important hardware features:

- A Rugged Tablet PC
- A Portable "Box" Packaging the Remaining Components
- Wireless Communication between the PC and Devices
- Better Devices

Prototype 2 must be viewed as a prototype, and further work (the primary focus of Phase 2 of the project) will need to be done to make the unit field ready. However, Prototype 2 goes a long way to further prove the concept and viability of the project.

Prototype 2 components include:

1. Panasonic ToughBook Convertible Tablet PC
2. Garmin GPS 18 GPS Unit (Magnetic Mount)
3. Land Cellular CDM-819s Serial Data Modem
4. Globalstar (Qualcomm) GSP 1600 Satellite Phone
5. OrbitOne Porta-kit for GlobalStar Satellite Phone
6. Globalstar External Antenna (Magnetic Mount)
7. Cellular External Antenna (Magnetic Mount)
8. Digi AnywhereUSB USB Over IP Hub
9. Belkin Serial to USB Converter Cables
10. Radio Shack 300 Watt Dual Outlet Inverter
11. Surge Arrest Professional Surge Protector
12. USB Cable
13. Ethernet Cables
14. Power Cables, Power Strips and Power Supplies
15. D-Link DI-514 Wireless Router
16. Fans
17. PVC Shelves ("Poor Man's Rack Mount System")
18. Pelican Case

These components are shown in Figure 64, Figure 65, Figure 66, Figure 67, and Figure 68.

Figure 64: Prototype 2 - Hardware, Outside the Box

Design decisions for Prototype 2 hardware were made for the sake of practicality. While not all of the components would be used in a production system, they do provide a portable test unit that can be used for testing and evaluation of hardware, software, and general system functionality and performance. The system, when completely assembled, is relatively easy to transport (minus its bulk) and set up in a vehicle.

The PVC shelves ("Poor Man's Rack Mount System") provide an inexpensive means to efficiently integrate the components into a portable and relatively stable framework. Wired connections may come undone if the box is handled in a rough manner; that problem will be addressed in Phase 2.

The rugged Tablet PC is a candidate for use in the production system. As standard Commercial Off The Shelf (COTS) equipment, it worked well, as it should, with all of the devices. Wireless communication between the Tablet and the other devices certainly was a key obstacle that needed to be overcome in making the system work, and these components show that this is possible.

While moving toward equipment more suitable for field deployment, a conscious effort was made to use standard, COTS equipment. With the exception of the OrbitOne Porta-kit for the satellite phone, this was largely achieved. It was desirable to replace that unit with a smaller, more modular modem for the Globalstar system. Unfortunately, problems were encountered with an alternate device, so the Porta-kit remained a system component for this phase.

Aside from the Porta-kit, there is certainly room for consolidation and down-sizing of the system. The bottom shelf holds several power strips, power supplies for the various devices, and a number of power cables. In subsequent development, these power accessories should be combined to eliminate most of the cables and associated power supplies, and this will eliminate the need for the power strips.

The top shelf holds the Porta-kit and Satellite Phone/Modem; and the middle shelf (Figure 65) holds the bulk of the components: the AnywhereUSB unit, the D-Link Wireless Router, the Cellular Modem, and various cables, including Serial to USB converters, which connect the devices. These components could likely be as well, particularly if USB connectivity is eliminated and only Ethernet, included wireless, and Serial over Ethernet are used. Digi offers a device that shows promise in replacing both of the AnyWhereUSB and D-Link wireless router. This device was investigated during development of Prototype 2. However, the device could not operate as an access point or in a peer-to-peer environment. Thus, the wireless router would still have been necessary.

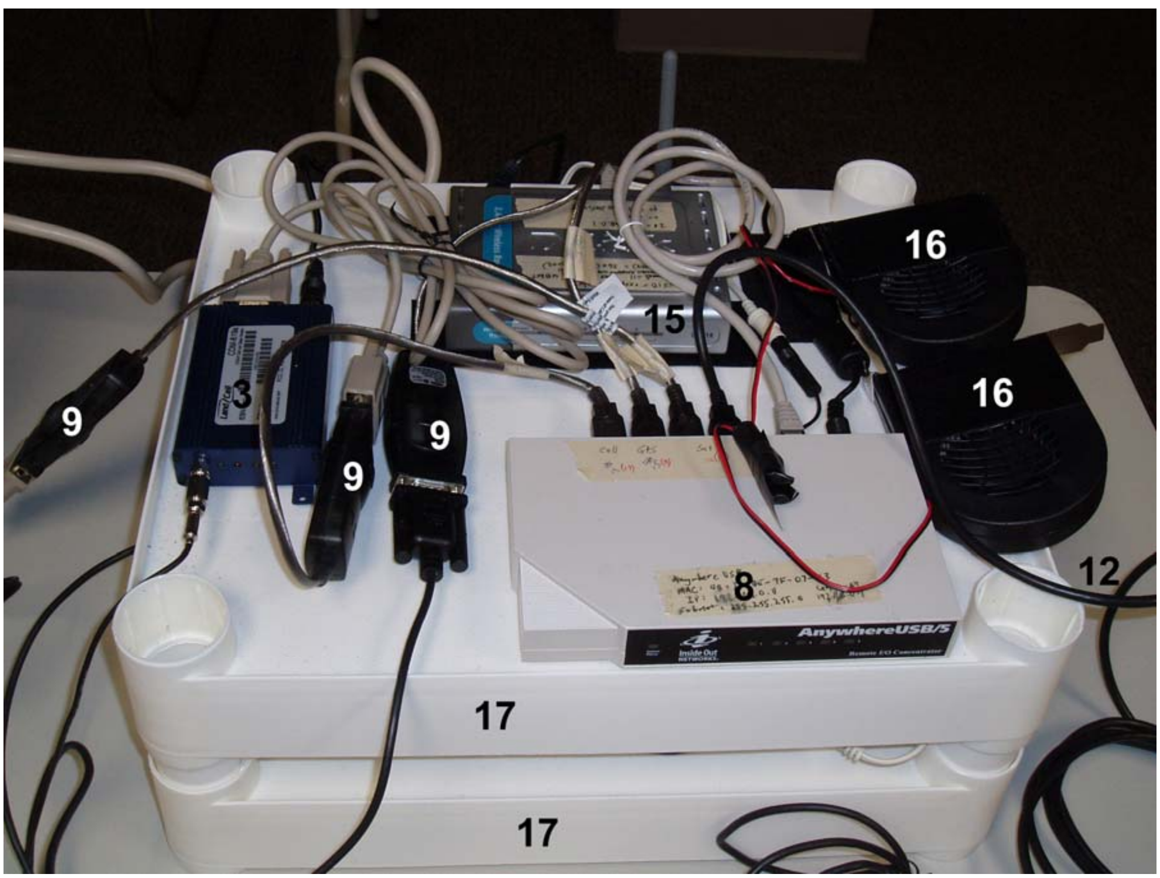

Figure 65: Prototype 2 - Hardware, Middle Shelf / "Rack" Devices

Figure 66 shows the components together on the shelves/rack system. Notice that the antennas (cellular, GPS and satellite), power, and the USB cable set aside for external mounting and connectivity.

Figure 66: Prototype 2 - Hardware, Outside the Box 2

Figure 67 shows the components enclosed in the case. For demonstration and testing, cables were run outside the case by leaving the lid slightly open. This configuration was not ideal, but served the purposes of this phase, allowing for easy storage and setup. Caution was taken to ensure that the cables were not pinched by the lid. Airflow was increased by leaving the lid partially open.

Figure 67: Prototype 2 - Hardware, External Antennas and Power

Figure 68 shows the cables enclosed within the case. A tray was used for front storage of the antennas. There is foam in the lid, the base and along the sides of the case to keep the components in place and to absorb shock.

With the cables carefully packed inside, the case can be closed and locked for storage and transport.

Figure 68: Prototype 2 - Hardware, the Responder "Briefcase"

7.5.7. Testing

The prototype unit was tested both by WTI and by Caltrans. It performed well, with a few minor glitches. With the exception of design changes that would be conducted for the sake of hardening or simplification, relatively few design changes were anticipated to result from functionality. In general, the system was considered to be solid. Note that further testing regarding communication, particularly satellite, would be necessary within this phase of the project. In particular, it is desirable to determine how to best handle intermittent signals characteristic of satellite service, as observed during the study.

7.5.8. Evaluation / Analysis

A formal survey was administered in conjunction with a demonstration of the system. This survey was open-ended, and elicited a great deal of useful information. In-depth discussions were also conducted in conjunction with the demonstration, and these yielded useful information regarding subsequent requirements and recommendations for implementation.

7.5.8.1. Survey – May 2005

Incident Organizer

All agreed that the Incident Organizer was user-friendly. The auto-population functions were considered very beneficial and no negative comments were noted. Following are summaries of comments regarding the sections of the Incident Organizer. In general, it was noted that the simple but highly functional interface was good, and that with the exception of a few noted suggestions below, few changes would be necessary.

<u>Summary Section</u>

This section was identified as good. The only suggested change was the inclusion of County, Route and Post Mile drop lists with a separate free-form Landmark field.

<u>Mapping Section</u>

The three map types (road, aerial and topographic) were identified as good. The inclusion of DHIPP aerials was mentioned again along with the ability to view maps created in ArcView. It was mentioned that dates should be associated with topographic maps and aerial photos since they could be quite dated.

Photos

The usefulness of this section was already established in evaluation of the previous prototype, so respondents were asked to identify scenarios in which they would use this functionality. Answers included:

- Vehicle accidents to indicate the size and requirements for cleanup.
- Hazmat Spills to indicate the size and location.
- Storm and earthquake damage to indicate the degree of damage and needs for repair.

It was noted that the system could be used generally in every incident because of the value of pictures. It was further noted that without pictures, the system would be of no point.

Sketches

The usefulness of this section was already established in evaluation of the previous prototype, so respondents were asked which to identify scenarios in which they would use this functionality. Answers included:

- To describe what is being viewed.
- To indicate damage and size.
- To outline proposed solutions.

Road and Weather Information

The usefulness of this section was already established, so respondents were asked what further information would be useful. Responses included:

- NOAA Forecast Discussions
- RWIS data
- Chain Control, if applicable
- Projected stream flows during flooding.
- RWIS, CDEC, MESOWEST, etc. within a user-selectable radius

Devices

Responses were mixed regarding the usefulness of this section. Some felt it was needed but should be kept simple. Others felt the information was too much. One response noted that this tab could be ignored by users who do not find it necessary.

Messaging

In regard to email, it was noted that email would be sent to a pre-configured address, freeing the user from selection and entry. User responses were mixed as to whether this was sufficient. Comments included:

- For most users this would be fine, but advanced users might require the option to enter further addresses.
- A preview of the message should be generated before it is sent to show users what is being sent.
- A server-side distribution list could be created making it possible for a single email to be sent to multiple recipients.

Help

It was agreed that on-screen help was not necessary, provided that the program remained intuitive. A separate reference guide and user manual for field use would be desirable, though.

Forms

Assuming the technical issues could be resolved regarding forms, respondents were asked what forms they would include. Answers included:

- Hazmat forms
- General information including type of traffic control, estimated duration of incident, type of incident.
- Caltrans E-Forms – FormFlow Software
- Damage Assessment Forms

Manuals

Assuming the technical issues could be resolved regarding manuals, respondents were asked what manuals they would include. Answers included:

- Hazmat manuals
- Maintenance manuals
- First Responder ICS manuals
- Phone listings
- Basic operation and user guide
- Detailed troubleshooting

Incident Email

Incident email functionality was examined and the following observations were made.

- Information in the email was useful. It was noted though that certain information was redundant with what the TMC would already know through voice communication.
- The quality of photos in the demonstration was on the borderline of what would be acceptable. A slightly better quality would be desired and worth the added transmission time.
- Microsoft Word is an acceptable format for organizing and presenting incident information. It is standard on all Caltrans PCs.
- Email can be an effective means for communication between responders and the TMC. It is already installed on everyone's desktop computer and is monitored. However, if things are busy, TMC staff doesn't monitor their email as carefully.
- In the event that communication is restricted because of terrain, it may be acceptable to send separate, smaller messages in order to increase the odds of successful transfer. However, this is less desirable than sending a single large message.

Communications

In light of the system, general communications issues were examined and the following observations were made:

- The system provides good real-time data from the scene.
- Information will already be available to the TMC via radio communication, but the system can provide a clearer "picture."
- In the event that radio communication is not available, the system might be considered as an alternative communications method, but only in extreme circumstances. A chat feature might facilitate this.
- The system could be considered for use in addition to voice communications.
- The information from the system should reach the TMC in 15 minutes or less where possible. 30 minutes to an hour might be acceptable, depending on the incident.
- There are locations in District 2 that have no communication capabilities (RF or cellular).
- To cover these gaps, there has been expressed interest in further developing cellular networks as well as using an 800 MHz system that is data-capable. The latter has been an on-going project that may not be completed for a number of years.
- Cellular and satellite are considered viable alternatives in the absence of RF communications.
- Very few service areas could be considered cellular only. Thus, units would have to carry both cellular and satellite equipment to have coverage everywhere. It was noted that cellular coverage is constantly improving.

General Use

General users of the system would include:

- First Responders
- Field Maintenance
- Maintenance Supervisors
- Traffic Management Team (TMT) Staff

Uses in rural areas would be similar to uses in urban areas and would include those previously mentioned.

There are other potential uses for this system including incident documentation for future analysis. This would ideally be implemented in conjunction with a searchable database. Use of this information might include defense in lawsuits or determining accident patterns.

Other non-DOT applications might include public information, fire, law enforcement, and EMS.

The system was viewed as a useful tool in collecting and sharing information between agencies, so long as the process is coordinated by the TMC.

Hardware Deployment in Vehicles

In regard to hardware deployment in vehicles, the following observations were made:

- The system should be mobile both within and outside a vehicle.
- Users may need to use both the pen and keyboard as input devices, but the possibility of using just the pen should be explored.
- The Tablet is not too big for such use. A PDA may be too small, but could be explored.
- A variety of options could be considered for vehicle deployment including a brief case, partially fixed in a vehicle, or permanently fixed in a vehicle with just the Tablet removable.

Cost

The prospective unit cost of the system was presented and respondents were asked if they felt it was viable and how many units they might anticipate deploying.

The cost was thought to be within reason, although a further cost benefit analysis should be conducted.

It was noted that the funding situation varies from year to year.

If the system works well, as many as 30-50 units could be deployed in District 2.

7.5.8.2. Discussions – May 2005 – General Discussion

Informal discussions were held with Caltrans staff in conjunction with the May 2005 site visit. These discussions are summarized as follows:

Weather Information

It was noted that the Point Forecasts used within the system are an experimental service, offered by the National Weather Service. While it is a concern that such an experimental service may change in the future, the immediate concern is that the data structures provided by the service may change, necessitating code changes. Caltrans understood this. Further evaluation will be necessary, including discussions with NWS regarding this service.

When asked if Zone Forecasts should be included, Caltrans indicated yes and gave the following example:

> *"If I'm in a HAZMAT situation, I want to know if it's raining upstream, and we're going to have a big flow, so certainly those things are of use for us."*

Thus, there is an interest and need for including weather information, both current and predicted, for areas surrounding an incident.

Sketches

As implemented in the second prototype, the only way part of a sketch can be erased is by erasing the entire sketch. The reason for this design choice is that it greatly simplifies the process. The obvious drawback is that if a user has made an elaborate sketch and makes a mistake towards the end, he or she must either keep the error or erase the sketch and start again. Caltrans expressed concerns that this would result in lost time and work, but recognized the trade-off for simplicity. A confirmation dialog indicating that the entire sketch will be deleted is necessary. Further investigation should be conducted to determine if "Undo" functionality or some better alternative is available for deleting a mistake while not sacrificing ease of use.

Email

The mechanism for sending email was discussed in light of the known communications challenges. In particular, it was noted that for a large email, there is a significant chance that the system will not be able to finish sending the message in one try when located in difficult terrain. In the event that the email fails, the system will automatically try again up to a fixed number of tries. If it fails in each of the retries, it will notify the user that it failed and that they should move to another location. In order to improve the odds of messages successfully transmitting, messages could be split into smaller chunks, perhaps one for each photograph or sketch. Doing so could result in an inconvenience for TMC staff, but they certainly could put the pieces back together if they were made aware of what all was being sent. This option, while not preferred, deserves further investigation.

In conjunction with this discussion, Caltrans asked whether the user could work on other things while the message is being transmitted. At present, this functionality is not implemented, but it certainly would be possible to transmit messages in a "background process" and allow users to continue working within the program during transmission. This should be implemented and tested in subsequent development.

The design decision to specify an email address in the initialization file was discussed in detail. This frees the users from selecting or manually entering an email address, freeing their time and simplifying use. The obvious drawback is that the user may need to send the email to multiple or different people. Certainly there are mechanisms that could be implemented (drop lists) to allow for the selection of different or multiple recipients. But, this would increase the amount of time required for use and would increase the complexity of the system. However, these changes may not be significant. Of greater concern was the technical constraint that for each recipient, a separate copy of the email must be generated and sent from the system. Thus, it would take the system twice as long to send the message to two recipients as it would to send to a single recipient. Further discussions about Lotus Notes groups, distribution lists and other server-side mechanisms revealed that they are viable alternatives that should be considered. The process could even be handled by a TMC operator, who would route information to all other appropriate parties. The latter may be desirable not only technically, but also from a policy standpoint. Further approaches would require server-side development, which is possible, but not desirable.

In regard to the content of the email messages, Caltrans said that there should be an associated preview pane showing users the contents of the message and quality of the compressed images. It was noted that quality of sketches degrades with higher compression ratios, potentially to the point where the sketches are not legible. Thus, users should be able to preview the message and adjust the compression level if necessary. While this adds complexity and further necessary interaction, it does seem to be necessary. In conjunction with this discussion, it was mentioned that different pen colors might provide better contrast, making the sketches more readable. This should be investigated further in conjunction with varying stroke widths and alternate means for display that could also improve contrast. (Note that the Tablet PC SDK includes several options that should be explored in regard to this.)

7.5.8.3. Discussions – May 2005 – Demonstration to Maintenance Staff

Maintenance Staff was shown the system and given a brief opportunity to try it out.

When asked about apparent ease of use and user friendliness, the following comment was made by a crew member:

> *It looks like it's really user friendly. I think with a minimal amount of training I could walk outside and do it right now.*

When asked further whether they felt they could use the system after several months of not using it and without re-training, the crew response was:

> *(It) looks almost fool-proof, there's only one way to go. And that's all it does. It's dedicated to that.*

In regard to use of the digital camera, it was noted that crews already use them and are comfortable with their use.

When asked if there was anything missing, any further information that would be useful during an incident, they responded that radar would be of value, particularly in the winter. RWIS was also discussed, although it was not always used in incident response. The inclusion of CCTV camera feeds was also suggested.

One crew member asked if it was possible to "multi-task" on the Tablet – i.e., use other applications on it while using the Responder application. It was noted that this was technically possible, but that it might not be desirable. Further investigation should be done in regard to this, because the units should be considered for multiple purposes. At present, the chance of "messing something up" is too high to allow full open use of the system for other purposes. All agreed that at this time, doing so was not worth this risk.

Crew members said that during storm damage incidents, the system could be used for reconnaissance, and information could then be forwarded immediately to appropriate authorities within the District and at the State level to mobilize resources and to expedite necessary paperwork. In conjunction with this prospective use, a supervisor said, "I think I can see a lot of these."

In conjunction with the earlier suggestion that incident information collected via the system be incorporated into a database, crews affirmed that they would then have not only a valuable training tool, but also a decision making tool:

> *If you have the database, we can look at all the incidents we've had confined to this ten mile stretch.*

While some similar information is currently archived, this isn't done for all incidents. Generally it is done for damage claim processes. In conjunction, the comment was made that:

> *This Responder (system) makes a better report than anything we're doing now. You've got your photos, and it's all in one nice e-mail package. We just write a report, download as many pictures as you want, take it home and plug it into your computer.*

A crew member then asked if you could take numerous pictures of an incident but only upload several for email while saving the rest. The answer was yes.

7.5.8.4. Discussions – May 2005 – Technical De-Briefing

Cellular and Satellite Technologies

Cellular and satellite capability was built into the system in order to facilitate the choice of the least cost communication method for a given area. The system chooses cellular if it's available and switches to satellite if cellular is not available. Cellular plans offer unlimited "minutes" while satellite minutes are relatively expensive – around $1 per minute with the plan used for testing. Another benefit of this approach is that cellular offers greater bandwidth.

A drawback of this approach is that the system must be bigger and more complex to accommodate both options. And, costs should be investigated further to determine whether it would be less expensive to go with a single means for communication. While cellular could suffice in some areas, it was indicated earlier that it would not provide complete coverage for many areas within District 2. Thus, satellite alone might be a preferred option. Caltrans staff elaborated further:

> *Is the cost difference really worth possibly having people not use it because of that kind of issues? I'm not sure that it is. We don't know what the cost difference is admittedly, but it's not just a cost issue.*
>
> …
>
> *I would say given the situation as it is now unless it was just an outrageous additional cost I would lean towards the simplicity and reliability of sticking with all satellite. With that said, if you can find a modem that you can integrate really totally seamlessly and comes up reliably so that the system operates in an idiot proof mode every time then I would revise that opinion.*

In contrast, the maintenance supervisor stated:

> *I just worry about getting rid of any redundancy we have; you're putting all your eggs in one basket and saying satellite's it. We're going to completely remove the cell portion, and if you're in a canyon, if you're near a wall or whatever, and you don't have it, you didn't even have the chance you could have gotten cell! I think your key was I totally agree you can't have the user making the decision; it's got to be all behind the scenes, seamless to them. I thought you were pretty much there.*

It was noted that there is some concern about the stability of satellite providers, particularly considering an earlier comment from staff that a past provider had gone out of business. In order to address this issue, stability of providers needs to be taken into account. Furthermore, modularity is desirable such that a cellular modem module could be replaced with a satellite modem module with minimal effort.

In regard to satellite service, participants discussed options for improving throughput. There are a limited number of providers for mobile satellite data service and most offer data rates comparable if not lower than that of the Globalstar system used for development and testing. It was noted that the only way to increase bandwidth using this provider would be to multiplex several units. This would be a very expensive option and would only yield linear improvement, so it likely isn't worth the effort.

In addition, Caltrans staff felt that the option of connecting the unit to a telephone line or a wired Ethernet connection, both of which may be available at maintenance yards, should be included. Technically both of these options are viable, although these connections might require connection setup, which may be beyond what would be expected of typical users. Thus, such configurations should be pre-configured.

USB

In general, it was suggested that the system not rely on any USB devices. Instead, it should rely on Ethernet and Serial over Ethernet. This certainly is possible and should be investigated further.

General Use, Usability and Proof of Concept

In regard to general usability and proof of concept, the maintenance supervisor commented:

> *Did you prove the concept? You bet! I think that goes hands down. I think it's exciting to see where it's at. I sent (DRI) a little note last night that it's nice to see that we were able to have an original concept and we're actually making it work. Just from where you were last time to where you are now it's nice to see. It really is. (The field test crew) sent me three or four different response (messages) and it was kind of fun to follow. I wish we'd had a real incident here close.*

Echoing similar sentiments, the ITS Engineer commented:

> *You can see it work. You really can. I think the proof of concept you're looking for is not only can you see it work, but all of the sudden everybody's throwing out all these ideas, you can also do this, this and this, and I think that speaks volumes to the success of the project. The key for the next phase is just as hard as this, if not harder. That's coming up with a slick, clean, reliable design that will work in the field that's easy enough to use that field guys will use it and that will be a benefit to them. That's every bit as hard, if not harder than this.*
>
> …
>
> *I think it's very intuitive, and I think we need to keep that intuitiveness to it. We roll out a lot of computer things here that if they have to have instructions on how to operate it, we're in trouble. He's right. User friendliness is the key to making them use it. And it's got to be rock solid. Reliable.*
>
> …
>
> *The key thing is coming up with a slick, clean, tight design that's robust reliable. Rock solid reliable. I think you're definitely on the right track with the user friendliness. That's why I keep leaning towards make it just satellite. Is it worth ten bucks to get that information to you? Probably is.*

The maintenance supervisor added:

> *He's right. Especially with my folks. Reliability is everything. You fail once, especially in the beginning, it'll sit and collect dust.*
>
> *…*
>
> *I think (the system) is pretty close, I wouldn't call it seamless, but it's definitely in the right direction, where you have both technologies and the possibility that it's even got the intelligence built into it where it's trying to decide which one to use. On the other side of that the problem I see is that there will be some cases where a user … might want to have an easy way to manually pick which one you want to use.*

The crew member responded:

> *But right now the way it is, that's pretty close to seamless. The problem you're going to run into is if you can't get either source. But (as demonstrated), whether you use cell or satellite, … you do not see that when you run the program.*

District 2 staff was unanimous in recommending that a second phase should be pursued. Tying the idea back to the RIME program and the original project concept, staff was asked if they see this as something that organizations could use.

> *I could see CHP, CDF using this. CDF more so on HAZMAT response, where, yeah, we would kind of use it, but they'd have their own system and that's consistent with what the whole RIME thing was about.*

Consistent with the discussion of involvement of further agencies is the implicit requirement that the system should minimize dependencies on Caltrans server resources. Thus, it could be configured and used by outside entities and could be used virtually "off-the-shelf" by all.

In regard to use of the system as an alternative to standard voice communications, it was agreed that the system would supplement such communication, but likely would not replace it:

> *Most of the time the field is going to be in contact with the TMC or dispatch anyway, and our TMC currently does not monitor e-mail especially when it's busy, that radio or cell phone or whatever communication is A. I'm going to send you a responder file on this incident, it's going to be long enough, or whatever our protocol is when it's going to be used, and then they'll look for it. I think you have to have that, because they're just not used to it, it's not part of their culture, and even if it wasn't, they can't be left guessing at every incident. Is this the one they're going to send me something that didn't work, and be wondering? There's going to have to be that upfront communication. Once that happens and that's normal, it's not a big deal at all I think.*
>
> *It huge for them to be able to see detail. Huge. (sic) got a camera phone and when he's out he sent them some photos and the feedback I got from them just on that is huge. "Oh man, I didn't know it was lying this way, or on this part of the road." They're just hearing verbal stuff, and they really responded positively just to that thing, let alone what we're talking about.*

Another potential use was discussed. A "press photograph" could be taken for the purpose of distribution to the press. This photograph would be transmitted at a higher resolution, suitable for publication. It could be forwarded to the public information officer. In order to implement this, the photograph would be identified as the press photograph and would likely be sent last, with a lesser priority than the primary incident photos and sketches. The possibility of even automating a process for sharing this information with other agencies and automatically publishing this information, where appropriate, to the web were mentioned as possibilities.

Storing incidents in a searchable database was further discussed. There appears to be great interest and promise in this. It was mentioned that all incident information is stored locally on the Responder system in structured XML format, which is conducive to such storage, even if translation is required.

It was further discussed that county, route, direction and post mile should all be recorded. While county and route could be selected from drop lists and automatically identified, as demonstrated in the prototype, mile posts would likely need to be manually entered using three digits or less.

Following field testing, a Caltrans crew member made the following observations regarding use of the system:

> *I had couple moments when it was flaky but the way I look at it (is that) in a couple places I was standing in the middle of nowhere (with) no other form of communication. ... Even though the communication took a couple times, it was still pretty neat to actually get out and pass on some information from the middle of nowhere. If you look at from better than nothing, then it's great. Is it perfect? No. Are you going to be able to get out every time? No. Obviously you're not. But its way better than what we have now. Once you (have someone) in the middle of nowhere sending data then you kind of start thinking about all these little things that can be done to provide service. I think it's going to open the door once we get to the point where this is solid….*

It was noted that at one point, the Tablet was turned on, but the communications box was not. The program handled this situation, as designed, by noting that connections were not present and by proceeding to the primary input screen. All agreed that this was appropriate behavior, but that the error message should have given further information about the situation and its potential resolution.

A suggestion was made that events may occur when incident information is transmitted and then subsequent information is gathered for transmission. This process should be made easy to use for the operator and easy to interpret by those receiving transmitted messages.

Incident Identification

Incidents are identified and stored by date and organization. This design decision was implemented to provide a consistent naming convention that does not require input or selection of a name by the end user. While the intent of this approach appears to have merit, the selection of date and organization alone was questioned. Perhaps location (county and/or road) as well as the name of the responder could become part of the identification of the incident. It was also mentioned that most incidents, at least major incidents, are given an incident name. Further investigation should be given to methods for identifying incidents within the program.

Maintenance and Support

Maintenance and support of the system were discussed in general terms and certainly will need to be investigated further before a production deployment. It was mentioned that the system, as is, would be easy to replicate and restore using products such as Symantec Ghost.

7.5.8.5. Discussions – May 2005 – Technical De-Briefing 2

The importance of using "hardened" equipment, particularly with a wide range of temperature ratings, was stressed. Temperatures in District 2 can range from well below zero to well above one-hundred degrees. In vehicles, temperatures would be even higher. Specific devices such as Digi's PortServer were discussed.

Of further importance is finding a way to eliminate the need to physically connect the camera via a cable to either the Tablet or the communication box. It was noted that several companies have come out with Ethernet (Wi-Fi) and Bluetooth cameras, which would allow for wireless connections between the cameras and the Tablet. These should be investigated further. It was noted that the short communication distance may be a problem with Bluetooth. It was further mentioned that it may be desirable to have a camera with integrated GPS capability. With this, photograph locations could be pinpointed automatically. Ricoh recently released a camera that does this in Japan. Caltrans staff noted that this would be nice, but not necessary because the Tablet and GPS already pinpoint the incident location.

The conditions in which the system would be used were discussed, confirming a requirement that the system be rugged. Rain, bright sun, wind and other conditions should all be expected.

In terms of mobility at the incident scene, Caltrans staff was very receptive to the idea of using an external Wi-Fi antenna, and extending the range of the system. Users could then use the Tablet several hundred feet from the vehicle. In conjunction, security was discussed. Encryption, MAC address filtering and other methods should all be used to protect the system, but it is considered unlikely that hacking would be a problem in places where the system would be used. A greater concern is that power lines, power tools and other equipment might cause interference. Further investigation is necessary. The system should, as it already does, make automated efforts to re-establish dropped connections, and this process should be transparent to the user unless user intervention is necessary.

It was noted that the Globalstar GSP-1620 was investigated for integration into the system. The advantage of this unit is that it is much smaller than the car kits and porta-kits used for the GSP-1600 handset. Unfortunately, the development team was unsuccessful in getting a test GSP-1620 unit to work. Caltrans agreed that further investigation should be devoted to getting this unit to work, because it would significantly reduce the size of the system.

A form factor for placing the system within a vehicle is discussed. One suggestion was that there would be a "box" behind the driver's seat in a vehicle that would hold the communication subsystem. As such, it would not be in direct sunlight and the temperature should only reach that of the cab. The unit itself would generate heat, and this should also be taken into consideration. There should be an ergonomic charging and docking station for the tablet, making its retrieval and replacement easy. Keeping the batteries charged is a major concern, and having a usable charging station appears to be vital to keeping the batteries charged. One problem that will need to be addressed regarding docking stations is that there is always the potential for liquid or other things to get in there that shouldn't be in there. Something needs to be done to prevent this.

Furthermore, there will be incidents in which the unit should operate directly off vehicle power so its batteries don't run out. It should be convenient to dock the unit, or connect it to power for this use within the vehicle. Antennas could be permanently mounted in the event that the system is permanently fixed within a vehicle.

Modularity, both in terms of software and hardware was discussed and agreed to be crucial to success.

It was discussed that the system needs to be conveniently located for easy access, but not in the way when is not in use. Thus, the pros and cons of possible configurations need to be weighed.

It was mentioned that keyboards can be difficult to use in the field.

A discussion of signal strength readings and associated functionality was conducted. Caltrans noted that:

> *"The added complexity is worth simplifying it for the user."*

If user frustration is reduced by better facilitating automation, then the added complexity may be worthwhile. Further investigation is necessary.

7.5.8.6. Discussions – May 2005 – NORCAL EMS, CDFP

Discussions regarding the system were held with NORCAL EMS and CDFP. Both groups expressed interest in the Responder system and saw potential application within their organizations.

7.6. Preliminary to Phase 2 Pilot 1 [First Application (Contract) Field Pilot Stage]

7.6.1. Time Frame

May 2005 – December 2005

7.6.2. Overview

This iteration is presented as a placeholder for subsequent development of a pilot system in Phase 2. It contains a summary of the requirements and certain design aspects as gathered in Phase 1 of the project. Work conducted during this iteration consisted of finalizing research and summarizing it in this final report.

7.6.3. Concept

The concept remains unchanged from the previous iteration:

> A system integrating hardware, software and communications shall be developed to give responders the ability to download and use pertinent and available electronic data including maps and aerial photographs as well as weather conditions. The system will also allow for the collection and transmission of at-scene information that is difficult to convey via voice communications. Photos can be taken at the scene, associated with data such as time and GPS location, and organized to provide a more complete picture of the scene. Photos can be enhanced with hand-drawn diagrams outlining the situation and plans in much the same way a football coach might outline a formation or play on a chalkboard. Forms can be included and tailored to a situation or by responsibility, facilitating more accurate and timely recording of information as well as future evaluation and analysis.

The objectives remain as:

- Create and provide the information elements, framework and pilot deployment of an information collection system centered on the information needs of District 2 field units and Redding TMC for transportation management and incident response/clearance, and of relevance to other emergency response organizations. The incident information collection system will include capabilities for collection of incident images, facilities for annotating images and maps to describe incident scope and severity, incident GPS location, as well as form-based information as deemed appropriate by District 2.
- Create and provide the information elements, framework, and pilot deployment of an incident support information system based on the needs of District 2 field units and Redding TMC, and of relevance to other emergency response organizations. The incident support information system will include capabilities for downloading maps and aerial photos, weather conditions, and other support materials related to the incident and its location.
- Provide the necessary hardware and communications infrastructure for the exchange of at-scene information collected via the information collection system and the distribution of incident support information to responders as described for the incident support

system. The communications system will provide the means to exchange information between District 2 field personnel at the scene and Redding TMC, and will be capable of incorporating other emergency response organizations. In Responder vehicles this will consist of a mobile data terminal (ruggedized Tablet PC), a satellite or satellite/cellular combo phone, Internet data connectivity kit including cabling and software and providing, GPS hardware with computer connectivity, and a digital camera with computer connectivity. The incident information collection system and the incident support information system software will reside on and interface with this equipment to facilitate the collection of information and transmission of data to and from the incident scene.

7.6.4. Requirements

Requirements were further refined to incorporate items resulting from the May 2005 demonstration, discussions and survey. These requirements will be revisited at the start of Phase 2 of the project, but can be considered as a requirements summary for Phase 1. New requirements are listed in italics:

1. A system shall be implemented to collect incident information.
    a. The system shall collect and store incident metadata.
    b. The system shall collect the incident location.
        i. The system shall record the precise location of the incident using latitude and longitude.
        ii. The system shall record post mile location of the incident.
    c. The system shall collect the incident occurrence time.
    d. The system shall collect a description of the incident.
        i. The system shall record the type of incident.
            1. The system shall record analysis of spill impacts for Hazmat incidents.
            2. The system shall record severity of incidents.
        ii. The system shall record traffic control, closures and directions of traffic in a form.
        iii. The system shall record equipment needed for incident clearance.
        iv. The system shall record incident measurements.
    e. The system shall collect incident photographs.
    f. The system shall collect incident sketches.
    g. The system shall facilitate sketches.
        i. The system shall facilitate sketches to annotate incident photographs.
        ii. The system shall facilitate sketches to annotate maps.
        iii. The system shall facilitate sketches to annotate aerial photos.
        iv. The system shall facilitate free-form sketches.
    h. The system shall facilitate forms.
        i. The system shall display forms.
        ii. The system shall facilitate entry of information into forms.
        iii. The system shall facilitate permit forms.
        iv. *The system shall include Hazmat forms.*

v. *The system shall include Traffic Control Forms: type of traffic control, estimated delay, type of incident.*

vi. *The system shall include standard Caltrans forms.*

vii. *The system shall include damage assessment forms.*

i. The system shall facilitate manuals.

i. The system shall organize manuals for browsing and searching.

ii. The system shall allow bookmarks in manuals.

iii. The system shall include Hazmat manuals.

iv. The system shall include maintenance manuals.

v. The system shall include the First Responder ICS manual.

vi. The system shall include phone listings for Caltrans staff and other public safety officials.

j. The system shall store incident information as a collection, not disparate pieces.

k. *The system shall allow incident information to be edited.*

l. *The system shall allow incident information to be deleted.*

m. *The system shall store incident information in a format compatible with database import utilities.*

n. *The system shall automatically identify incidents.*

i. *The system shall identify incidents by date, organization, name of responder, county, and/or road.*

ii. *The system shall facilitate searching and organizing incidents by date, organization, name of responder, county, and/or road.*

o. *The system shall allow for the entry of a free-form incident name.*

2. The system shall be used by Caltrans' staff, but shall be of potential for use by EMS, fire and other agencies.

a. The system shall be usable by one primary field contact person for communication with dispatch.

b. The system shall transmit incident information to a single contact.

c. *The system shall be usable by other agencies.*

i. *The system shall be configurable for use by other agencies.*

3. The system shall be deployed within Caltrans' vehicles in the field.

a. *The system shall be flexible in deployment to include the possibility of a briefcase, partially fixed within a vehicle, or entirely fixed within a vehicle.*

i. *The system shall be portable.*

b. *The system shall be storable in a "box" behind the driver's seat.*

   c. *The system shall be storable in a "box" in the bed of a truck.*
   d. *The system shall use hardened equipment.*
      i. *The system shall be usable in temperatures between -20°F to 120°F.*
      ii. *The system shall be storable in temperatures between -20°F to 150°F.*
      iii. *The system shall release heat generated during operation.*
      iv. *The system shall be usable in all weather conditions including rain, snow, bright sun, and wind.*
   e. *The system shall have a charging/docking station.*
      i. *The system shall have an ergonomic charging/docking station.*
      ii. *The system shall facilitate easy retrieval and replacement of equipment.*
      iii. *The system shall facilitate easily recharging batteries.*
      iv. The system shall have a charging/docking station that is resistant to liquid spills, dirt, and other debris.
   f. The system shall be operable directly off vehicle power.
   g. The system shall be stored within the vehicle in a manner such that it doesn't interfere with other work.
   h. The system shall allow for antennas to be permanently fixed.
   i. The system shall allow for antennas to be removable.
   j. The system shall have a modular hardware design.
4. The system shall be operational within and in the vicinity of Caltrans' vehicles in the field.
   a. *The system shall be usable up to 200 hundred feet from the vehicle.*
5. The system shall be easy to use.
   a. The system shall include a checklist for use and procedure at the scene.
   b. *The system shall include a reference guide for basic operation.*
   c. *The system shall include a user manual including detailed trouble-shooting.*
   d. The system shall automatically recognize when connected to a camera.
   e. The system shall automatically present a preview of photographs.
   f. The system shall facilitate management of photos on the camera.
      i. The system shall facilitate archival of photos from the camera.
      ii. The system shall facilitate deletion of photos from the camera.
   g. The system shall require minimal navigation to complete operations.
   h. The system shall use functional names for interface elements.

i. The system shall facilitate pre-stored configuration information and default values.

    i. The system shall store default contact information (email address) for incident information transmission.

        1. The system shall allow the user to override default contact information by selection or entry.

j. The system shall be designed for ease of use so as not to require embedded help.

k. *The system shall be reliable.*

6. The system shall automate the collection of incident information.

    a. The system shall automatically geo-locate the responder.

7. The system shall minimize the amount of time required for use.

    a. The system shall facilitate the collection and entry of incident information in less than 20 minutes.

    b. The system shall facilitate automated transmission of incident information.

    c. *The system shall allow users to multitask while communication tasks are in process.*

8. The system shall transmit information to the TMC and other outside agencies.

    a. The system shall transmit incident information to a single contact.

    b. The system shall preview messages prior to transmission.

    c. The system shall automatically scale and compress photos and sketches for transmission.

        i. The system shall default to minimal suitable quality for transmission.

        ii. The system shall allow the user to override image quality.

    d. The system shall facilitate breaking messages into "chunks" in the event of transmission problems.

    e. The system shall transmit incident records in less than 15 minutes.

    f. The system shall allow the transmission of all incident information including all sketches and photographs.

    g. The system shall allow the selection and transmission of incident information including selected sketches and photographs.

    h. The system shall allow the transmission of text-only incident information.

    i. The system shall allow the selection and transmission of press photographs.

        i. The system shall give press photos a lesser priority than overall incident information.

        ii. The system shall default to suitable quality for transmission of press photographs.

iii. *The system shall transmit press photographs in sufficient quality for print and Internet publication.*

j. *The system shall mark information that has been successfully transmitted.*

i. *The system shall use mark information to facilitate interpretation of multiple transmissions to a recipient.*

9. The system shall receive information from the TMC and other outside sources.

a. The system shall display weather information based on the responder's location.

i. The system shall display weather forecasts based on the responder's position.

ii. The system shall display wind directions.

iii. The system shall display storm information.

iv. The system shall display wild land fire information.

v. *The system shall display RWIS data*

vi. *The system shall display Chain Control.*

vii. *The system shall display projected stream flows.*

viii. *The system shall display weather information from CDEC, MESOWEST, & MADIS.*

ix. *The system shall display zone forecasts.*

x. *The system shall display road camera (CCTV) displays.*

b. The system shall display road maps based on the responder's location.

i. The system shall include pre-loaded road maps.

c. The system shall display aerial photos based on the responder's location.

i. The system shall include pre-loaded aerial photos.

ii. The system shall include pre-loaded Caltrans' DHIPP aerials photos.

iii. *The system shall indicate creation dates for aerial photos.*

d. The system shall display topographic maps based on the responder's location.

i. The system shall include pre-loaded topographic maps.

ii. *The system shall indicate creation dates for topographic maps.*

e. The system shall display Caltrans' maps.

i. *The system shall indicate creation dates for Caltrans' maps.*

f. The system shall display the location of the command post, crews and equipment at the incident.

g. The system shall display locations of other responders, contract personnel and equipment at the incident scene.

h. The system shall display locations and estimated times of arrival of responders, contract personnel and equipment en-route to the incident scene.
i. The system shall display staff availability.
j. The system shall display expected traffic volumes.
k. The system shall display chemical information for Hazmat spills.
l. The system shall display affected facilities.
m. The system shall download data to responders while en-route to and at the scene of an incident.
n. The system shall not download unnecessary information such as graphics and links.
o. The system shall use incident location information to identify and expedite downloads.
p. *The system shall display information within a user-selectable radius.*
q. *The system shall minimize dependencies on Caltrans' server resources.*

10. The system shall have data communications capability in all areas of District 2.
    a. The system shall be operable in rural areas including mountainous areas.
    b. The system shall be operable in urban areas.
    c. *The system shall attempt to automatically mitigate communication failures.*
        i. *The system shall retry sends or downloads in the case of failure.*
        ii. *The system shall switch over to another communication device, if available, in the event of a failure.*
    d. *The system shall notify the user if communication fails.*
    e. *The system shall be compatible with existing wired networks including POTS and LAN.*
11. The system shall display diagnostic information for system devices.
    a. The system shall display diagnostic information in clearly separate location from other information.

7.6.5. Design / Specification (Phase 2)

A number of design specifications were listed as a consequence of the May 2005 demonstration, survey and discussions. This listing was not intended to be comprehensive, but rather to document certain items that were explicitly requested or discussed. A more formal design specification will be developed at the beginning of Phase 2, with a documented traceability to the requirements.

- The system shall use a Tablet PC as a mobile data terminal to collect and record incident information.
    - The system shall use a custom-developed application for data collection and recording.
        - The system shall auto-populate Organization and District fields.
        - The system shall use a location description field to indicate post-mile and direction.
        - The system shall automatically navigate to photograph locations.
        - The system shall minimize interaction required to select and copy photos and maps for annotation (sketches).
        - The system shall copy descriptions along with photos to sketches.
        - Forms shall auto-populate.
        - Entry shall be made using pen or keyboard.
            - *Entry shall be possible using pen alone.*
        - The application shall be self-contained, with no requirement for exit or transfer to other applications for use.
        - *The system shall use drop lists for the entry of County, Route and Milepost.*
        - *The system shall allow free-form text entry of Mile Posts with a maximum of three digits.*
        - *The system shall use free form text field for Landmark.*
        - *The system shall use a photograph quality of 640x480.*
        - *The system shall use JPEG quality level 5 or greater for transmitted photographs.*
        - *The system shall use GIF for free-form sketches.*
        - *Microsoft Word shall be used as the email attachment format.*
        - *The system shall prompt the user for confirmation prior to deletion of incident information.*
        - *The system shall use stroke widths, color, and blending to maximize contract of sketches on photos and maps.*

- The system shall use email as the transport for incident information.
- *The system shall use XML to store incident information.*
- *The system shall use encryption, MAC address filtering and other means for security*.

7.6.6. Implementation (Phase 2)

To be conducted during Phase 2.

7.6.7. Testing (Phase 2)

To be conducted during Phase 2.

7.6.8. Evaluation / Analysis

To be conducted during Phase 2.

8. LITERATURE REVIEW AND RESEARCH SUMMARY

Literature review was conducted within the context of research and throughout the duration of the study. The summary of literature findings and research is presented together, with references cited and quoted where appropriate.

8.1. Related Projects, Efforts and Standards

Following are summaries of several projects, efforts and standards that have been encountered in conducting research for this study. In one way or another, they involve goals and technologies similar to those of the Responder study.

8.1.1. Integrated Incident Management System (IIMS)

The Integrated Incident Management System (IIMS) project was created with the following goal:

> *To improve incident management and emergency response by enhancing communication of incident data among incident management and emergency response personnel; both on-scene and at multi-modal communications and operations centers.*[19]

This multi-agency project was funded by the New York State Department of Transportation in partnership with the New York City Department of Transportation, the New York City Police Department and the Department of Emergency Management. Additional support was provided by the USDOT.[20]

IIMS is capable of transmitting scene data in real-time to incident operations centers and other mobile units. Mobile data terminals are used to collect and transmit incident information including data reports, location from GPS, and digital incident photographs. This data is primarily collected and transmitted to assist in choosing appropriate resources to clear the incident.

Stated benefits include[21]:

- Identifies locations more accurately
- Verifies incident at interconnected Operations Centers
- Facilitates coordinated response
- Improves equipment and personnel dispatch
- Reduces time to detect, verify and clear
- Will improve incident data analysis (future)

Key vehicle components include a dash mounted terminal with keyboard and touch screen monitor, a rugged laptop computer, a portable camera, and a mobile vision camera.[22]

[19] http://www.dot.state.ny.us/reg/r11/iims/
[20] http://www.dot.state.ny.us/reg/r11/iims/proj_desc.html
[21] http://www.dot.state.ny.us/reg/r11/iims/proj_desc.html
[22] http://www.dot.state.ny.us/reg/r11/iims/vehicle_install.pdf

Capabilities include the ability to draw areas and make measurements on maps, indicate critical task alerts, distinguish emergencies from non-emergencies, filter and sort incidents, and send text-based messaging.[23,24]

The IIMS Incident Data Management Console application uses large buttons and tabs that are easy to interact with using the touch screen. Figure 69 shows the IIMS Map Tab. Interesting features include mile marker indications and user-drawn areas on the map. Figure 70 shows the Pictures tab. Note the capability to "Grab Video."

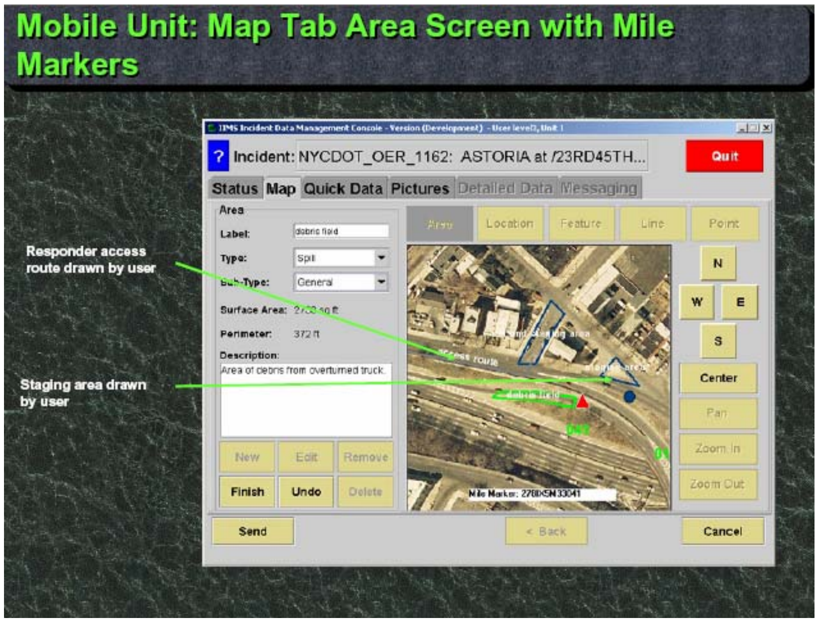

Figure 69: IIMS Map Tab[25]

[23] http://www.dot.state.ny.us/reg/r11/iims/whats_new.html
[24] http://www.dot.state.ny.us/reg/r11/iims/features_benefits.html
[25] http://www.dot.state.ny.us/reg/r11/iims/mu_views.pdf

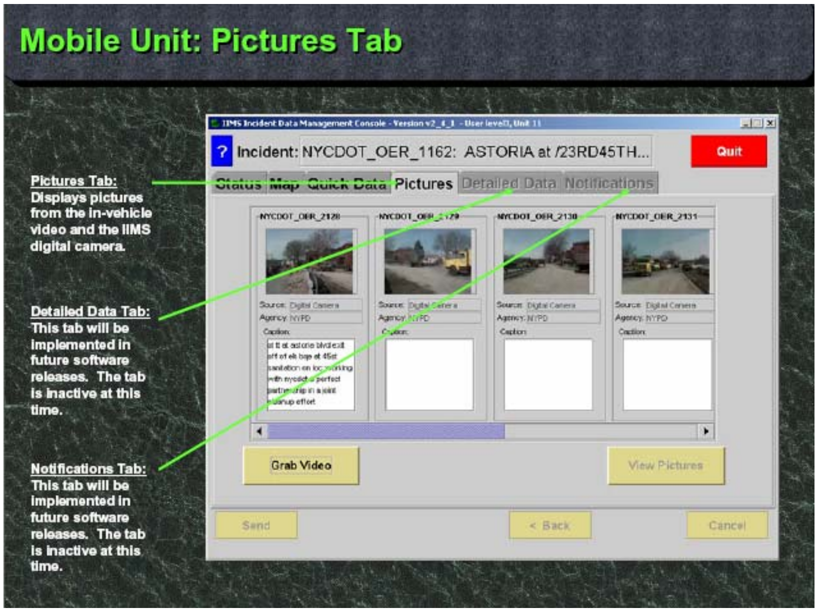

Figure 70: IIMS Pictures Tab[26]

The Incident Data Management Console (Figure 71) on the Operations Center slide shows[27] a listing of incidents that have been reported. Incident data, maps and photos can then be displayed for selected incidents.

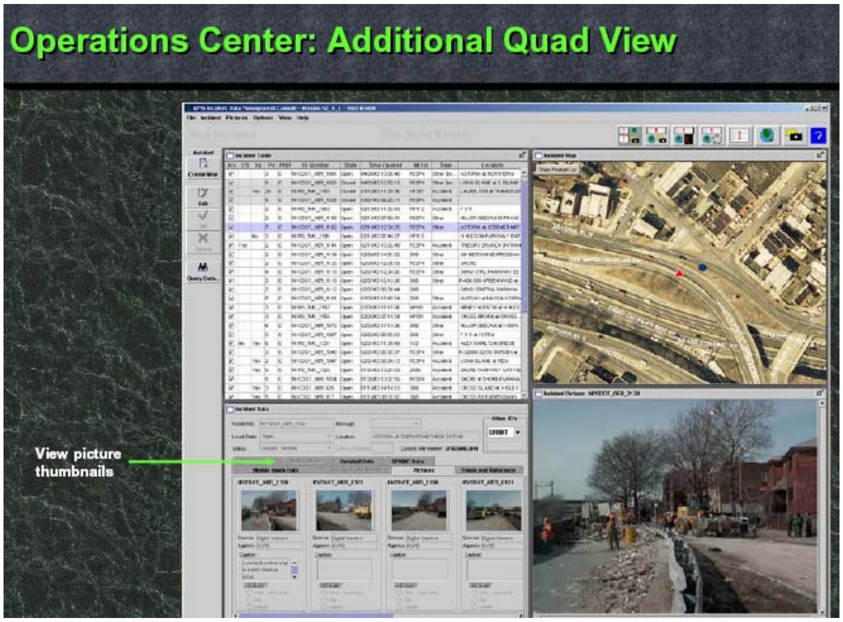

Figure 71: Operations Center Application[28]

[26] http://www.dot.state.ny.us/reg/r11/iims/mu_views.pdf
[27] http://www.dot.state.ny.us/reg/r11/iims/lu_views.pdf
[28] http://www.dot.state.ny.us/reg/r11/iims/lu_views.pdf

A sample incident summary involving an over-turned tractor trailer and debris spill stated that IIMS reduced the incident clearance time by 1.5 hours from 4 hours to 2.5 hours. The following reasons were given[29]:

1. *Access route to the incident scene was displayed to all responding agencies through the GPS /GIS feature.*
2. *Both the map feature and the images identified where the debris and truck were.*
3. *Images of the debris field and the overturned truck at the incident scene were transmitted by DOT OER responder # 4 in real time through the IIMS network to Kew Loop Yard and to Sanitation Operations Center, which identified the equipment and crews that needed to be dispatched.*
4. *Dispatch of unnecessary equipment and crews to the incident was avoided, thus enhancing the effective management of the incident scene.*

The test area for the system was New York City, and 28 vehicles were equipped with the system.[30] Data exchange used both wireless and wire line communications.[31]

8.1.2. Bay Area Incident Response System (BAIRS)

The Bay Area Incident Response System (BAIRS) uses GIS and wireless technology to automatically identify, locate and dispatch resources to accident sites in the San Francisco Bay Area. This Caltrans District 4 system is estimated to have reduced incident clearance time to an average of 90 minutes or less for 75% of all incidents. Cameras in laptop computers send real-time video to the BAIRS system which can be relayed to a Caltrans TMC, law enforcement, or medical personnel. BAIRS was implemented in approximately one year using off-the-shelf technology. The BAIRS team included Caltrans IT, Caltrans GIS, CHP, Metropolitan Transportation Commission (MTC), the International Union of Operating Engineers, and Deloitte Consulting.[32]

TMC dispatchers and District 4 maintenance supervisors use the BAIRS application, which enables them to locate open incidents in real-time. They can then use spatial query tools to locate the nearest staff and resources to the incident.[33]

BAIRS was a 2004 winner in the Computerworld Honors Program, "Honoring Those Who Use Information Technology to Benefit Society,"[34] and a 2004 award winner for Caltrans' Excellence in Transportation Awards for System Operations.[35]

[29] http://www.dot.state.ny.us/reg/r11/iims/anatomy_of_incident.html
[30] http://www.dot.state.ny.us/reg/r11/iims/test_area.html
[31] http://www.dot.state.ny.us/reg/r11/iims/features_benefits.html
[32] http://www.dot.ca.gov/ctnews/archive/CTNews_7-04.pdf
[33] http://www.gis-t.org/yr2004/gist2004sessions/4.3.3.pdf
[34] http://www.cwheroes.org/archives/past_recipients/
[35] http://www.dot.ca.gov/awards/winners/04winners.htm

8.1.3. (CAPWIN)

The Capital Wireless Integrated Network (CAPWIN) is a partnership between the states of Maryland and Virginia and the District of Columbia, formed to develop an "interoperable first responder data communication and information sharing network." The vision of CAPWIN is to "enable data interoperability for first responders wherever they are."[36]

Current capabilities of CAPWIN include:

- Group and individual messaging with archiving.
- Contact lists.
- Secure communication access via commercial wireless providers and state wired networks.
- PC and PDA operation.
- 24/7 help desk, dedicated operations center and data backup systems.

CAPWIN uses 'open' development standards in a secure environment, and uses web service components for compatibility with existing agency infrastructure and to ensure future compatibility with evolving technologies. Standards such as TCP/IP, XML, HTML and IEEE 1512, as well as commercial-off-the-shelf software are used in a modular system that supports 10,000 concurrent users.[37] Commercial communication providers used with CAPWIN include Sprint, Cingular, Nextel, and Verizon.[38] CAPWIN establishes connections to agencies' preferred wireless carriers.[39]

CAPWIN is leveraged on existing private sector infrastructure, which allows users to benefit from new technologies without bearing the sole burden of paying entirely for this infrastructure. Similarly, the use of commercial-off-the shelf equipment reduces development risk and cost. CAPWIN also makes efficient use of limited bandwidth by using data compression and TCP/IP header reduction techniques.[40]

Identified prospective future capabilities include[41]:

- Multi-state sharing of local criminal data not available through the National Crime Information Center (NCIC)
- Transportation system integration, including remote video, incident logs, road sensors, etc.
- Computer Aided Dispatch (CAD) data exchange across jurisdictions and public safety disciplines

[36] http://www.capwin.org/index.cfm?fuseaction=t1&ID=2
[37] http://www.capwin.org/index.cfm?fuseaction=t1&ID=5
[38] http://www.capwin.org/index.cfm?fuseaction=t2&ID=30
[39] http://www.capwin.org/docs/Vol%203%20Issue%208%20August%202005.pdf
[40] Capital Wireless Integrated Network (CapWIN): Building a Bridge in Transportation and Public Safety Communications, George. S. Ake, Jr., MPA, University of Maryland
[41] http://www.capwin.org/index.cfm?fuseaction=t2&ID=31

- Advanced GIS capabilities including incident/user GPS identification, aerial photo overlays, etc.
- Voice over IP
- Secure email

Other anticipated enhancements include improved performance for users over “slower wireless connections.”

8.1.4. COMCARE Alliance

COMCARE is a national alliance of over 100 member organizations with the goal of creating an environment for “borderless, geographically targeted” information sharing for emergency response.[42]

One initiative of the COMCARE Alliance was the development of the Vehicular Emergency Data Set (VEDS), and XML standard for the transmission of telematics data to emergency response agencies.[43]

Other COMCARE initiatives include advocacy of the “Wireless Communications and Public Safety Act (WiCAPS) of 1999, which directed the Federal Communications Commission to encourage states to develop plans to upgrade wireless emergency communications systems; and the development of the Emergency Provider Access Directory, which facilitates routing of geographically targeted emergency messaging.[44]

8.1.5. Organization for the Advancement of Structured Information Standards (OASIS) Emergency Management Technical Committee

This technical committee is responsible for several standards for incident and emergency-related data interoperability: the Common Alerting Protocol (CAP) and the Emergency Data Exchange Language (EDXL).[45]

CAP is a standard for alerting and event notification applications. CAP has been implemented by a number of agencies including the Department of Homeland Security, the National Weather Service, the United States Geological Survey, the California Office of Emergency Services and the Virginia Department of Transportation.[46,47] EDXL is a framework for emergency data exchange standards supporting operations, logistics, planning and finance. EDCL addresses the problem of incompatible systems by providing a common exchange format.[48]

8.1.6. IEEE Incident Management Working Group (1512)

The IEEE Incident Management Working Group (1512) publishes a set of standards including:

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42 http://www.comcare.org/About%20COMCARE.html
43 http://www.comcare.org/telematics.html
44 http://www.comcare.org/WICAPS.html
45 http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency
46 http://www.oasis-open.org/committees/download.php/5830/CAP_Factsheet.doc
47 http://www.incident.com/cookbook/index.php/Public_CAP_Feeds
48 First responder XML by Diane Frank, Federal Computer Week (http://www.fcw.com), October 28, 2004.

- IEEE 1512® - 2000 (Common Incident Management Message Sets for Use by Emergency Management Centers)
- IEEE 1512.1® - 2003 (Traffic Management)
- IEEE 1512.2® - 2004 (Public Safety)
- IEEE 1512.3® - 2002 (Hazardous Materials)
- IEEE P1512.4 - (Entities External to Centers)

These standards provide message sets for traffic management, public safety and hazardous materials incident response activities.[49]

The 1512 working group states benefits of:[50]

- Reduced traffic incident clearance times.
  - Reduced congestion
  - Reduced secondary collisions
  - Improved air quality
  - Improved safety for travelers and emergency personnel at incident scenes

By:

- Enabling improved interagency coordination among public safety and transportation management agencies
- Enabling more rapid dispatching
- Enabling more effective coordination of response vehicles and personnel

8.1.7. Project54

Project54 is a research and development effort between the University of New Hampshire and the New Hampshire Department of Safety with the purpose of integrating electronic devices in police cruisers and multi-agency radio systems.[51] Supported devices include emergency signal systems, radar units, video systems, GPS systems, VHF radios, bar code readers, and CAD/RMS/AVL/Field Reporting Software.[52]

The result is an "Organized Vehicle System," an embedded computer positioned in a center console within the vehicle (Figure 72). User interfaces are also positioned in the center console and within arms reach of officers. Simple voice commands can be used to perform every function within the vehicle. Data queries can also be conducted by voice and without the help of a dispatcher. Remote control is also possible via handheld computers using 802.11b connections from outside the vehicle.[53]

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[49] http://grouper.ieee.org/groups/scc32/imwg/
[50] http://grouper.ieee.org/groups/scc32/imwg/brochure.pdf
[51] http://www.project54.unh.edu/overview/about.html
[52] http://www.project54.unh.edu/implementation/devices.html
[53] http://www.project54.unh.edu/Reference/Download.pm/1993/Document.PDF

Figure 72: Project54 In-Car LCD Touch-screen and Application in a Police Cruiser[54]

The goal of Project54 is to create integration standards for in-car electronic devices, providing a safe "hands- and eyes-free" interface for officers and a modular, scalable system facilitating easier installation, modification, expansion, inspection and repair by departments.[55] By using a single user interface, Project 54 strives to minimize user distraction. Further functionality can be added within this interface so long as it conforms to the "inter-application communication

[54] http://www.project54.unh.edu/Gallery/ImageDetail?IMAGE_ID=221

[55] Project 54: Standardizing Electronic Device Integration in Police Cruisers, by Andrew L. Kun, W. Thomas Miller III, and William H. Lenhart, University of New Hampshire. IEEE Intelligent Systems, September/October 2003.

standard." Hardware components can also be added, provided that they comply with standards such as RS-232.[56]

Project54 research indicates that a balance must be struck between "overwhelming the officers with too much information and empowering them." They further report that simple commands that triggered automated retrieval of data could ultimately save time and increase user satisfaction when compared to requesting the information from dispatch.[57]

8.1.8. Montana Highway Patrol Mobile Data System

Through a grant from the U.S. Department of Transportations, the Montana Highway Patrol team worked with five counties and three cities in Montana to create an extensive microwave backhaul network as a foundation for mobile data communication. The system provides secure field communications, accurate dispatch and instant access to nationwide law-enforcement databases. Prior to system implementation, officers had to depend on dispatchers to run checks. With the system, officers are able to do their own checks. Other services such as cellular digital packet data (CDPD) were not viable at the time the system was implemented.

Due to rugged terrain, neither laying fiber nor leasing lines were options, and microware proved to be the best and possibly only option. Initial capacity was 4 x DS-1 (4x1.5 Mbps). Plans for a second phase will increase coverage by adding new sites and increasing network capacity to DS-3 (45 Mbps). [58]

8.1.9. San Antonio LifeLink

This system was implemented to link San Antonio Fire Department ambulances in proximity to the San Antonio freeway system with hospitals. Roadside fiber and a mobile LAN communication network were used to conduct real-time videoconferencing between ambulances and physicians in hospitals. Patients' vital statistics could also be transmitted.

Web radios using unlicensed, spread-spectrum communication technologies were selected for ambulance to roadside communication. Computers were configured to automatically load and start the LifeLink software application when powered on.[59]

8.1.10. WTI Blackfoot Tribal Incident Reporting

The goal of this project was to "improve accident reporting through the application of advanced technology to increase the accuracy and completeness of accident reporting and to reduce the time necessary." Research and development was conducted to evaluate hardware and software for prospective deployment as an incident information collection mechanism. An integrated GPS system was used to identify and record incident locations with greater precision. It was

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[56] Project 54: Standardizing Electronic Device Integration in Police Cruisers, by Andrew L. Kun, W. Thomas Miller III, and William H. Lenhart, University of New Hampshire. IEEE Intelligent Systems, September/October 2003.
[57] Evaluating the User Interfaces of an Integrated System of In-Car Electronic Devices, by Andrew L. Kun, W. Thomas Miller III, and William H. Lenharth. Proceedings of the 8th International IEEE Conference on Intelligent Transportation Systems, Vienna, Austria, September 13-16 2005.
[58] Wireless network links counties: Law enforcement agencies build statewide microwave backhaul communications network. Communications News, December 2004.
[59] http://www.transguide.dot.state.tx.us/mdi/LifeLink.html

determined that Personal Digital Assistant's (PDAs) did not have the necessary display space to facilitate the entry of incident information. A Tablet PC was subsequently used to develop a proof-of-concept application, implementing the envisioned functionality.

8.2. Use of Mobile Data and Data Communications for Incident Response

The utility and effectiveness of technology as applied to incident response depends directly on end users. If end users do not perceive a system as reliable or useful, they will not use it. This is a natural conclusion. Other conclusions are drawn from research and experience.

In a study of mobile data access conducted by Penn State University Researchers[60], the authors noted that connection reliability is more important to users than download speed. In other words, the system must be available and usable when needed; otherwise it won't be used, regardless of other features such as high-bandwidth. This is true even if the system will only be used once or twice a year. They further found that PDAs were too small and their battery life was too limited to make them useful. Laptop computers were too big and tethering them to vehicles puts an unnecessary limitation on users who often need to work outside, but in proximity of their vehicles. The researchers suggest that ruggedized pen-based tablets should be tested as an alternative to meet first responders' needs. Furthermore, they observe that the number of information systems and sources are so wide and disparate that it is difficult to imagine their integration into a single larger system. And, perhaps most importantly, they observe that technology is not a replacement for current dispatch and local controls models, it simply enhances them.

In regard to communication, rugged terrain introduces challenges that are not addressed by conventional means. A recent public communications article regarding public safety radio in the Rocky Mountains west of Denver Colorado reports[61]:

> *"The terrain presents a collection of radio-coverage challenges. Each mountain is a new problem. Each valley is a new problem. Connecting all of them is a problem. The terrain and economics defy a simple radio solution, so each mountain and each valley required a unique solution to provide reliable communications just to those specific areas."*

This article points out that the most ideal locations for radio towers present the greatest challenges: providing power for running and access for maintaining equipmentit. As a result, public safety officials often have to rely on multiple means of communication including cellular to compensate for gaps in their existing systems. In these cases, expensive system enhancements are necessary for the provision of better service.[62]

Despite these challenges, technology is recommended to enhance incident clearance efforts including the use of cameras to document accident information; to clear people, vehicles and debris from incident sites; and to facilitate reconstruction following clearance. Furthermore, it is recommended that databases be developed to document response and clearance times.[63]

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[60] Mobility and the First Responder by Steve Sawyer, Andrea Tapia, Leanard Pesheck and John Davenport, Communications of the ACM, March 2004.
[61] Communications in Difficult Terrain by Ralph H. Gould, Public Safety Communications, APCO, November 2005.
[62] Perseverance Earns Remote California County 800-MHz System by Harold Carter, Public Safety Communications, APCO, November 2005.
[63] http://www.metroplan.org/consultants/IMS-final.pdf

Another study from the University of Virginia notes the drawbacks of voice communications in that it limits the flow of information. Alternative media such as maps, images, text messages, video feeds, conferencing, statistical data, and location tracking are all suggested for providing a "more comprehensive understanding of a disaster with minimal time and effort." The authors propose real-time GPS-based location information as well as wireless communications for onsite connectivity, allowing for freedom of movement for emergency responders. [64] In conjunction with mobile data, GIS, GPS and sketching tools have been demonstrated to improve the efficiency of responders while being perceived as easy to use.[65]

An innovative prototype system was publicly demonstrated in May 1994 in Bellevue Washington to implement a mobile data collection system for first responders with wireless communication capability. This system allowed responders to transmit and receive maps and even hand-drawn sketches of incident scenes. This was all carried out over a 4800 Kbps data connection and was viewed as successful. In regard to development of this and several similar systems, it was stated that[66]:

> *In each case a major lesson learned was that the customer needs to drive the effort, because frequently the ideas we have going into the design cycle are influenced by the excitement of the technology rather than the functional requirements. In the case of each prototype, major gains were possible with essentially simple but well-thought out technology.*

The uses of GIS and imagery in regard to rock slides, landslides and other related areas of impact to transportation are gaining attention beyond the context of incident management. The New Hampshire DOT has implemented a GIS system to document and analyze rock cuts throughout the state. This application demonstrates the utility of data collection and analysis by saving the DOT an estimated 2000 annual man hours.[67] Similarly, Montana has developed a Rockfall Hazard Classification and Mitigation System. This system incorporates image displays of 10,800 miles of roadway taken every 10 meters.[68]

In an article that explores the potential of Ground Based Imaging (GBI) history, Roger Chappell of the Washington State DOT poses the question "If a picture is worth a thousand words, what is a 'smart image' worth?" He suggests the utility of images that "know" where they are taken, when they were taken, and how they relate to other images that were taken.[69] Surely these and similar applications and ideas are complemented by data collection efforts conducted in conjunction with incident management.

[64] Integrated Peer-to-Peer Applications for Advanced Emergency Responder Systems Part I: Concept of Operations, by A. Bahora, T. Collins, S. Davis, S. Goknur, J. Kearns, T. Lieu, T. Nguyen, J. Zeng, B. Horowitz, S. Patek of the University of Virginia, Proceedings of the 2003 Systems and Information Engineering Design Symposium.

[65] Visual Decision-Support Tools for First Responders by J. Ballard, J. Choi, T. Oakes, M. Pizzuto, J. Ramirez, d. Brown and J. Dalton, University of Virginia, Proceedings of the 2004 Systems and Information Engineering Design Symposium.

[66] Applications of Mobile Computing and Communication , Bernd Bruegge and Ben Bennington, IEEE Personal Communications, February 1996.

[67] http://trb.org/publications/trnews/rpo/rpo.trn220.pdf

[68] http://www.mdt.mt.gov/research/docs/research_proj/rockfall/project_summary.pdf

[69] http://www.wsdot.wa.gov/TA/T2Center/T2Bulletin-archives/2003-04winter.pdf

8.3. Software

8.3.1. Usefulness

From a point early in this study, participants agreed that the system had to be easy to use. Thus, there was a focus on usefulness, which is made up of both utility and usability. [70] The iterative spiral process model and systems engineering methodology were combined to elicit feedback and requirements to address both utility and usability.

"User friendliness" is defined as "any program or computer system designed so that individuals who lack extensive computer experience or training can use the system without becoming confused or frustrated." [71] Holzinger[72] lists the essential usability characteristics of software projects as:

- learnability, so the user can rapidly begin working with the system;
- efficiency, enabling a user who has learned the system to attain a high level of productivity;
- memorability, allowing the casual user to return to the system after a period of non-use without having to relearn everything;
- low error rate, so users make few and easily rectifiable errors while using the system, and no catastrophic errors occur;
- satisfaction, making the system pleasant to use.

The benefits of quality in use are: [73]

- <u>Increased efficiency.</u> *A system incorporating good ergonomic design and tailored to the preferred way of working, will allow the user to operate effectively and efficiently rather than lose vital time struggling with a poorly design user interface and badly thought-out functionality.*
- <u>Improved productivity.</u> *A good interface to a well designed product will allow the user to concentrate on the task rather than the tool which, if designed inappropriately, can extend rather than reduce the time to do a task, as well as directly affecting other aspects of performance or quality.*
- <u>Reduced errors.</u> *A significant proportion of so-called "human error" can be attributed to a product with a poorly designed interface to functionality which is not closely matched to the user's task needs. Avoiding inconsistencies, ambiguities or other interface design faults reduces user error.*

[70] Usability in Quality of Use. Proceedings of the 6th International Conference on Human Computer Interaction, Yokohama, July 1995. Anzai & Ogawa (eds), Elsevier.
[71] Usability in Quality of Use. Proceedings of the 6th International Conference on Human Computer Interaction, Yokohama, July 1995. Anzai & Ogawa (eds), Elsevier.
[72] Usability Engineering Methods for Software Developers. Hlzinger, A. 2005. Communications of the ACM, Volume 48, Number 1.
[73] Quality in Use: Meeting User Needs for Quality. Bevan, N. 1999. Journal of Systems and Software.

- *<u>Reduced training.</u> A poorly designed user interface and dialogue can prove a barrier to an otherwise technically sound system. A well designed system designed with a focus on the end-user can reinforce learning, thus reducing training time and effort.*
- *<u>Improved acceptance.</u> This is particularly important where usage is discretionary. Users would rather use and would be more likely to trust a well designed system which gives access to functionalities which make information easy to find and provides the information in a format which is easy to assimilate and use.*

These characteristics were and will continue to be used to make sure the application exhibits both usability and utility.

8.3.2. Mapping – Evaluation of Alternatives

Early research was conducted to evaluate various mapping packages and services for use in the Responder application including:

- Microsoft MapPoint 2004
- Microsoft MapPoint.NET
- ESRI ArcWeb Services
- Microsoft TerraServer

Microsoft MapPoint 2004[74] runs as a stand-alone application with all mapping information stored on the local computer. MapPoint 2004 was ultimately integrated within the Responder application to provide road maps. MapPoint 2004 proved effective because of well documented programming interfaces, an ActiveX control that could be readily integrated into applications such as the Responder application, and very good performance. The limitations of MapPoint include difficulty in integrating map information not already stored in MapPoint such as ESRI Shape files.

Microsoft's MapPoint.NET[75] was evaluated as a possible alternative to MapPoint 2004. A primary benefit of using MapPoint.NET would be that maps would not have to be stored on the local computer, freeing already limited space for other purposes. This benefit was also a drawback because MapPoint.NET can only be used with a live Internet connection, and all maps must be downloaded. Maps are requested and downloaded using Web Services, an XML-based data exchange framework. The MapPoint Web Service framework is quite flexible, providing some capabilities not available in MapPoint 2004. A further difference that was considered was the pricing structure. There is a transaction cost associated with each MapPoint.NET request, whereas MapPoint 2004 requires a license for use of the application for each PC on which it is installed. Due to the low-bandwidth data connections of cellular and satellite, it was determined that MapPoint 2004 was preferable to MapPoint.NET, regardless of pricing.

ESRI's ArcWeb Services[76] were evaluated and were found promising due to the diversity of available map and imagery types. Available data types include "street maps, live weather maps,

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[74] http://www.microsoft.com/mappoint/products/2004/
[75] http://mappoint.msn.com/
[76] http://www.esri.com/software/arcwebservices/

digital orthophoto quarter quadrangles (DOQQs), topographic maps, live traffic information, census data, shaded relief imagery, flood data, …”[77] ArcWeb Services are accessible using Web Services, providing comparable ease in programming to MapPoint.NET. Similarly, ArcWeb Services suffer the drawback of requiring a live Internet connection. And, ArcWeb Services also require a per-transaction fee. ArcWeb services were not used in the Responder application because of the requirement of a live Internet connection and also because of the transaction cost. If a higher-bandwidth connection were available, then their use might be more desirable.

Microsoft’s TerraServer[78] was evaluated and found promising for several reasons. First of all, TerraServer offers a rich web services interface to maps and aerial photos. Second, this data is offered free of charge, with no associated licensing or use fees. However, it was determined that it was not viable to download maps and aerial photos from TerraServer on the fly. In certain instances, it took more than 5 minutes to download maps and aerial photos, and evaluators stated that this was too long to wait for this data. Subsequently, research was conducted to determine an effective means for caching data from TerraServer. A description of this methodology is given in a subsequent section of this document. Because TerraServer included aerial photos and topographic maps that could be used free of charge, it was desirable at least for demonstration and development purposes to use these items.

ESRI’s ArcGIS was not evaluated but is considered to be a viable and desirable tool for integration with the Responder system. The primary concern regarding ArcGIS is the associated licensing fee. Further research would be necessary to determine licensing fees associated with deploying the ArcGIS runtime within the Responder application. Using ArcGIS would facilitate the display and use of a wide variety of maps, including Caltrans’ maps, which are already in ArcGIS formats. ArcGIS will be investigated further in Phase 2 of the Responder study.

Several other mapping services and utilities worthy of note have come online since this initial evaluation: Google Maps, Google Earth, and Microsoft Virtual Earth. These services offer richer interfaces than their predecessors, but also require greater bandwidth. Thus, they are not viable for the Responder application.

8.3.3. Mapping – USGS/TerraServer Tiles

The U.S. Geological Survey (USGS) provides public domain images and maps to TerraServer and these images and maps are in the public domain.[79] All that is requested is a reference to the USGS. Thus, this imagery could be used free of charge in the Responder application, making it appealing for demonstration and development.

TerraServer uses “tiles” measuring 200 pixels by 200 pixels as building blocks for larger maps and aerial photos. It was determined that a structure and naming convention similar to that used by TerraServer could be used to store and organize “tiles” on the local computer. Tiles could then be loaded on demand and “stitched” together (Figure 73) to create full-sized maps for display in the Responder application. In order for this to work, tiles would need to be downloaded and stored prior to use. TerraServer contains approximately 4.5 Terabytes of

[77] Source: http://www.esri.com/software/arcwebservices/about/overview.html
[78] http://terraserver.microsoft.com/
[79] http://terraserver.microsoft.com/about.aspx?n=AboutAboutImages

imagery[80], so it certainly wouldn't be possible to store all tiles locally. However, it could be viable to store a relevant subset of tiles locally on the Responder Tablet PC.

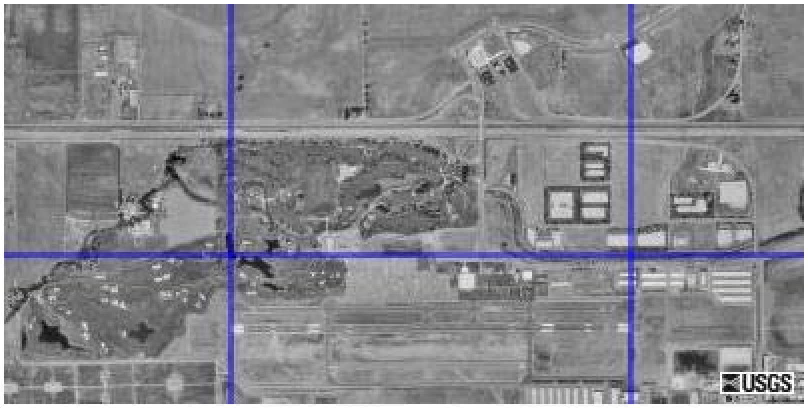


Figure 73: TerraServer Tiles Stitched to Form Larger Image[81]

Tiles were downloaded for the RIME region from TerraServer using Web Services[82] and stored on a development computer for analysis. The tiles fell in UTM Zone 10.

Aerial photos are available from TerraServer at resolutions of 1m, 2m, 4m, 8m, 16m, 32m, 64m, 128m, 256m and 512m. Topographic maps are available from TerraServer at resolutions of 2m, 4m, 8m, 16m, 32m, 64m, 128m, 256m and 512m.

Estimated storage required for TerraServer tiles covering the RIME Region and the entire state of California is shown in Table 2. All total, nearly 40 GB of storage would be required for all aerial and topographic tiles for the RIME region. Since the Responder Tablet PC has a 30 GB hard drive, it is not feasible to store all tiles locally. Space could be saved by excluding certain resolutions. However, approximately 20 GB is necessary for storage of 1m aerial tiles and 34 GB is necessary for the storage of 1m aerial tiles and 2m aerial and topographic tiles. These tiles, which show the most detail, are most useful and cannot be eliminated. Excluding resolutions lower than 2m would only help minimally. Thus, another means must be found for filtering tiles.

[80] http://terraserver.microsoft.com/About.aspx?N=AboutSponsors
[81] http://terraserver.microsoft.com/About/AboutTerraServiceExampleMap.htm
[82] http://terraserver.microsoft.com/about.aspx?n=AboutTerraServiceOverview

Table 2: Estimated Storage - TerraServer Tiles for RIME Region and All of California

	RIME		California	
	44867 sq. mi.		155959 sq. mi.	
	Aerial	Topo	Aerial	Topo
Resolution (m)	**GB**	**GB**	**GB**	**GB**
1	19.7982	0.0000	68.8192	0.0000
2	5.9364	8.3304	20.6351	28.9567
4	1.5965	2.2776	5.5495	7.9170
8	0.3943	0.6753	1.3706	2.3473
16	0.0966	0.2266	0.3358	0.7875
32	0.0237	0.0800	0.0824	0.2780
64	0.0061	0.0176	0.0213	0.0613
128	0.0015	0.0037	0.0053	0.0127
256	0.0004	0.0007	0.0013	0.0025
512	0.0001	0.0001	0.0003	0.0005
Total	27.8539	11.6120	96.8210	40.3635

Since only tiles in proximity of roadways serviced by Caltrans would be used in the Responder application, it was determined that only those tiles should be stored, if space allowed. Certainly this would reduce required storage space. Table 3 shows total storage requirements for tiles corresponding to roadways in the RIME region. Note that the total of 6.75 GB is expressed in disk space used rather than file size, so it is greater than what would be shown if totaling individual files sizes. Furthermore, there is some overlap of tiles, so this figure is an overestimate of actual requirements. And, several portions of roadways outside the RIME region were included, resulting in total road miles greater than those presented earlier. Since topographic maps are not stored at 1m resolution, the requirements for corresponding topographic tiles would be less than 6.75 GB and the total for aerial tiles and topographic tiles would be less than 13.5 GB. This figure is within reason for local storage on the local Tablet computer.

Table 3: Storage Requirements (Size on Disk) - Aerial Tiles Covering RIME Region Roads

Road	Miles	Tiles	MB	Road	Miles	Tiles	MB
US 101	285	52,213	461	SR 139	143	27,788	256
I 5	280	52,117	437	SR 147	12	2,772	29
I 80	125	24,190	233	SR 149	5	1,683	15
I 505	22	4,005	27	SR 151	3	927	9
SR 1	98	17,705	148	SR 160	16	3,577	31
SR 3	153	26,973	240	SR 161	19	4,080	44
SR 16	51	9,850	75	SR 162	170	28,239	259
SR 20	228	42,171	374	SR 169	24	4,969	43
SR 28	11	2,642	24	SR 172	9	2,008	25
SR 29	52	10,245	87	SR 174	14	2,719	31
SR 32	74	15,409	155	SR 175	20	4,029	40
SR 36	251	44,450	432	SR 191	12	2,571	26
SR 44	106	20,679	236	SR 193	13	3,061	30
SR 45	82	14,047	125	SR 211	75	12,326	111
SR 49	129	22,789	239	SR 253	17	3,242	31
SR 53	7	1,766	17	SR 255	9	1,923	15
SR 65	30	6,665	58	SR 267	12	2,762	31
SR 70	194	33,991	337	SR 273	16	3,410	40
SR 84	24	4,484	38	SR 281	17	3,463	32
SR 89	289	51,691	516	SR 284	10	2,346	23
SR 96	146	25,797	210	SR 299	313	57,810	506
SR 99	154	25,208	251	US 97	10	11,256	88
SR 113	40	7,491	63	US 199	36	7,057	62
SR 128	51	8,076	73	US 395	204	38,926	279

	Miles	Tiles	MB	GB
Totals	**4061**	**757,598**	**6912**	**6.75**

Table 4 shows tile totals and space used for tiles that were stored on the Responder Tablet PC. Note that additional tiles were stored to provide partial coverage for the Sacramento and Redding metropolitan areas. These were stored for the sake of demonstration. All total, less than 10GB of storage was required for these tiles. This total was within reason, even with the 30 GB total hard disk size. Thus, storing only the tiles in proximity of Caltrans' roadways in the RIME region proved to make local storage of tiles viable. However, for larger regions such as the entire state of California, a larger hard drive would likely be needed.

Table 4: Storage Figures for Actual Tiles Stored for RIME Region. (Includes Sacramento and Redding Metro Areas)

	Aerial			Topo		
Resolution	**Tiles**	**Size (bytes)**	**Average per file**	**Tiles**	**Size (bytes)**	**Average per file**
1	427,895	3,131,111,256	7,317	0	0	0
2	161,329	1,415,897,059	8,776	158,976	1,957,905,005	12,316
4	72,010	679,859,032	9,441	71,082	957,397,388	13,469
8	30,839	287,633,813	9,327	30,505	487,266,170	15,973
16	11,856	108,373,248	9,141	11,856	254,147,790	21,436
32	3,941	35,371,343	8,975	3,941	119,305,321	30,273
64	1,324	12,307,515	9,296	1,324	35,373,102	26,717
128	525	4,879,752	9,295	524	11,605,381	22,148
256	254	2,308,925	9,090	253	4,351,464	17,199
512	174	1,595,546	9,170	164	2,383,038	14,531
Total	**710,147**	**5,679,337,489**	**7,997**	**278,625**	**3,829,734,659**	**13,745**
File Size=5.28 GB **Size on Disk=5.96 GB**				**File Size=3.56 GB** **Size on Disk=3.83 GB**		
Total File Size=8.84 GB, Total Size on Disk=9.79 GB						

Maps and aerial photos are updated relatively infrequently, so their local storage should not cause problems in presenting timely information. However, it was noted during development and evaluation that some of the aerial photos and USGS topographic maps were dated. It would be desirable to use more recent imagery, if available, and this imagery should be updated on at least an annual basis on the Responder Tablet PCs. This update process could be a time-intensive process, and consideration should be given to methods to make the update process as simple and accurate as possible.

This same tiling process could be used with other maps. However, if further map types are to be integrated, an analysis should be conducted to determine the most effective means for integrating them. For instance, it may be more efficient to store certain maps in vector format rather than raster format. It may also be more efficient to use the ArcGIS runtime or an equivalent utility and associated formats for display and storage.

For maps and other data types that are time-sensitive such as weather maps, maps of fleet and crew locations, road condition maps, etc., it is not possible to pre-store the maps. In these cases, information would have to be time-stamped and downloaded such that the information is still relevant and accurate. It may be possible in these cases to superimpose downloaded time-sensitive data atop cached layers or backgrounds such as aerial, topographic, elevation or street maps. This approach has been considered for RWIS and other weather station data that is aggregated and stored in the WeatherShare system. For the low-bandwidth connections provided by cellular and satellite, it may only be feasible to download the data and then display the data on cached maps.

8.3.4. Weather Data

Unlike streets maps, aerial photos and topographic maps, weather data is time-sensitive to periods of hours if not minutes. Conditions may change dramatically over a short period of time and predictions may change in similar time frames. Thus, weather information must be downloaded on the fly for it to be of use to Responders. Determining an efficient means for identifying, locating and downloading weather data was the primary research topic in regard to weather.

For the purpose of this study, three types of weather information were considered: alerts, current conditions, and (point) forecasts. While this information is available from a variety of public and private sources, only weather data made available to the public through the National Weather Service was used for demonstration and development within this study. These sources appear to be viable, but further sources and service agreements should be considered for production use.

8.3.4.1. Alerts

Alerts are readily available from the National Weather Service (NWS) in several public formats including web pages via weather.gov and in XML via several experimental services.

Public NWS Web Pages: Weather.gov

Given an Internet connection and a web browser such as Microsoft Internet Explorer, computer users can access alerts via the National Weather Service's gateway page: http://www.weather.gov/. It is necessary to manually drill down to specific locations and information via this web page by following links or entering information in forms. This process is demonstrated in subsequent figures and tables for weather occurring on November 25th, 2005.

Figure 74 shows the NWS Gateway Page to National Weather Information. Table 5 summarizes the HTML components that comprise this page. All total, 45 separate files and over 170 KB of data are downloaded to display this page, which is used to select more specific regional locations for further weather information. Various alerts are color-coded on a national map.

Figure 75 shows the NWS Sacramento Gateway Page for Northern California weather information. Table 6 summarizes the HTML components that comprise this page. All total, 31 files and nearly 250 KB of data are downloaded to display this page, which is used to select more specific regional locations for further weather information. Also included are links to and thumbnails of graphical and regional forecasts as well as radar and satellite images.

Figure 76 shows current conditions and a forecast for Chester in Plumas County. Note that although Chester is a considerable distance from Quincy, it is displayed when the image map is clicked over Quincy and other locations in Plumas County. Table 7 summarizes the HTML components that comprise this page. All total, 30 files and over 140 KB of data are downloaded to display this page, which includes a graphical and text forecast for Chester as well as current conditions and links to a special weather statement.

Figure 77 shows the NWS Special Weather Statement for Plumas County, which applies to Chester and all of Plumas County, as well as other counties and regions in Northern California. Table 8 summarizes the HTML components that comprise this page. All total, 16 files and over 66 KB of data are downloaded to display this page, which includes primarily the text of the special weather statement. The NWS Sacramento Banner, several logos and numerous links occupy other space on the page, inflating its download size.

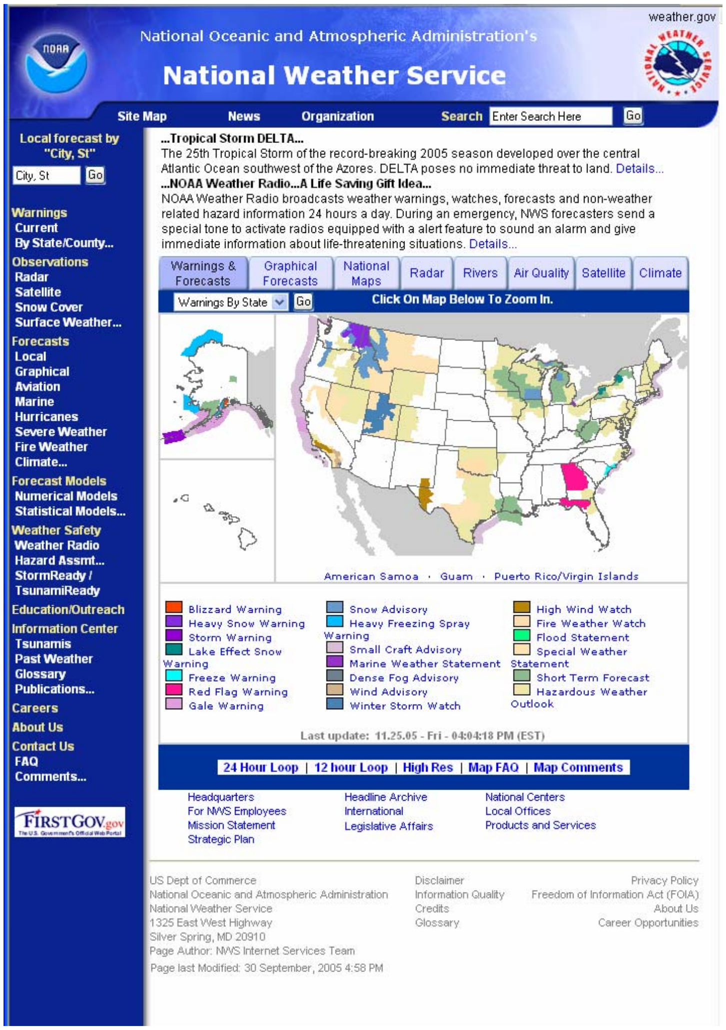


Figure 74: NWS Gateway Page to National Weather Information - 11/25/2005

Table 5: Breakdown of NWS Gateway Page HTML - 11/25/2005

National Map:	http://www.weather.gov/
45 Files:	1.css, 25 .gif, 14 .jpg, 1 .js, 3 .png, 1 .htm
Total Size:	174,208 bytes
Alaska Map:	1,583 bytes
Hawaii Map:	356 bytes
US Map:	10,811 bytes
Html:	91,331 bytes

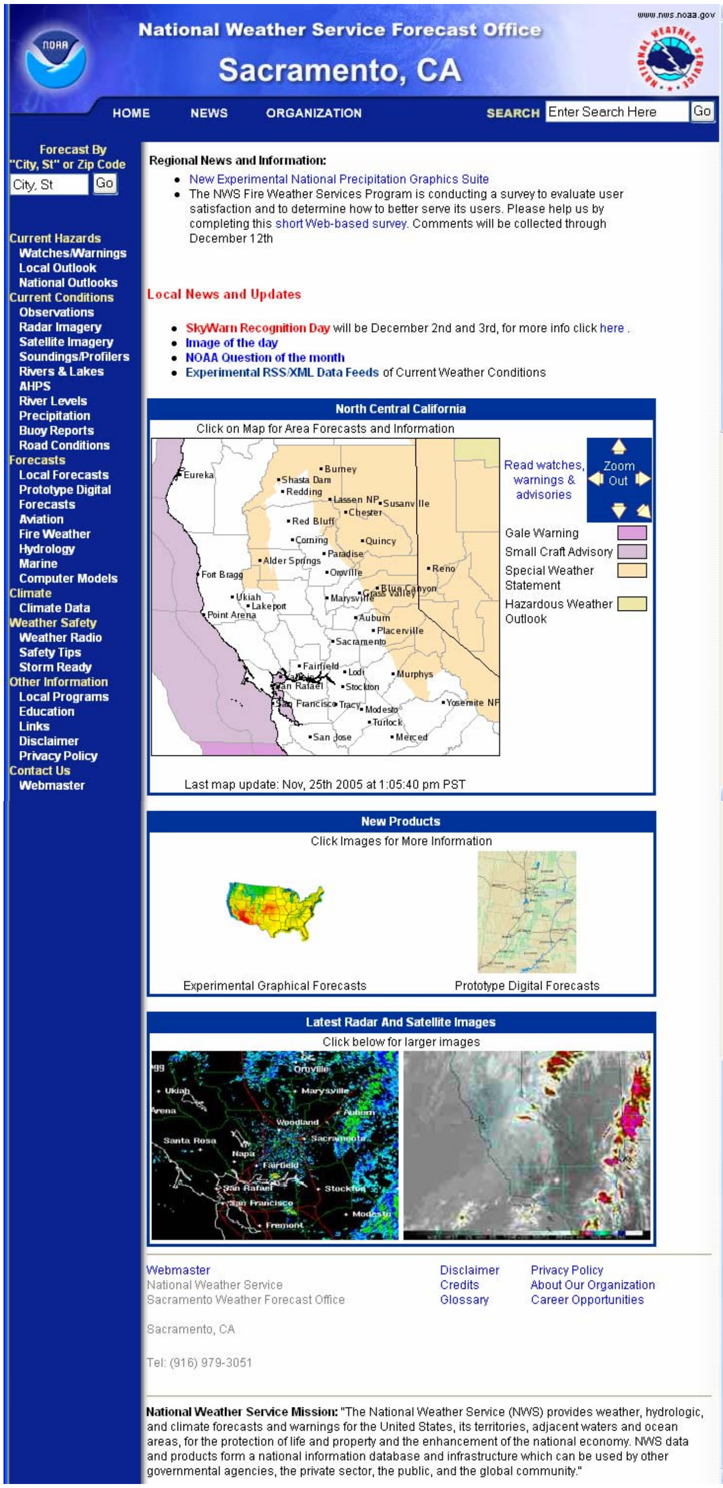


Figure 75: NWS Sacramento Gateway Page for Northern California - 11/25/2005

Table 6: Breakdown of NWS Sacramento Northern California Gateway Page HTML - 11/25/2005

NWS Sacramento, Northern California:	http://www.wrh.noaa.gov/sto/
31 Files:	1.css, 12 .gif, 9 .jpg, 1 .js, 7 .png, 1 .htm
Total Size:	255,719 bytes
Satellite Thumbnail:	4,155 bytes
Radar Thumbnail:	20,480 bytes
Digital Forecasts Map/Link:	91,610 bytes
Graphical Forecasts Map/Link:	44,988 bytes
North Central California Map:	10,030 bytes
Html:	37,477 bytes

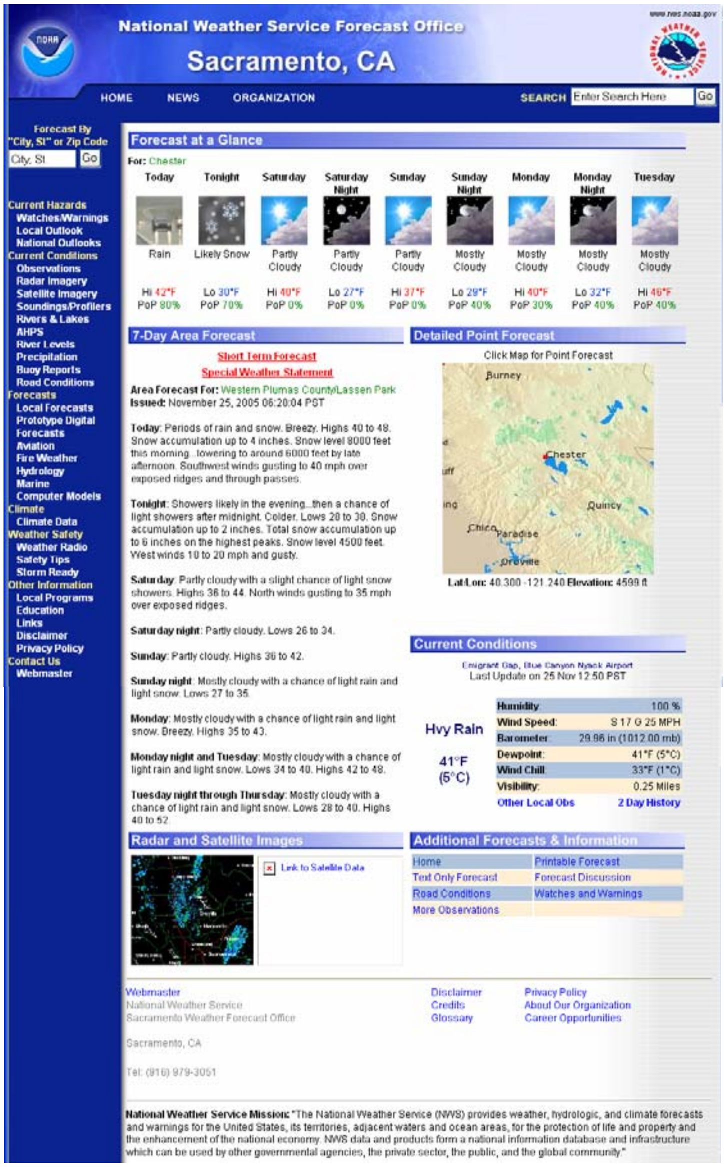
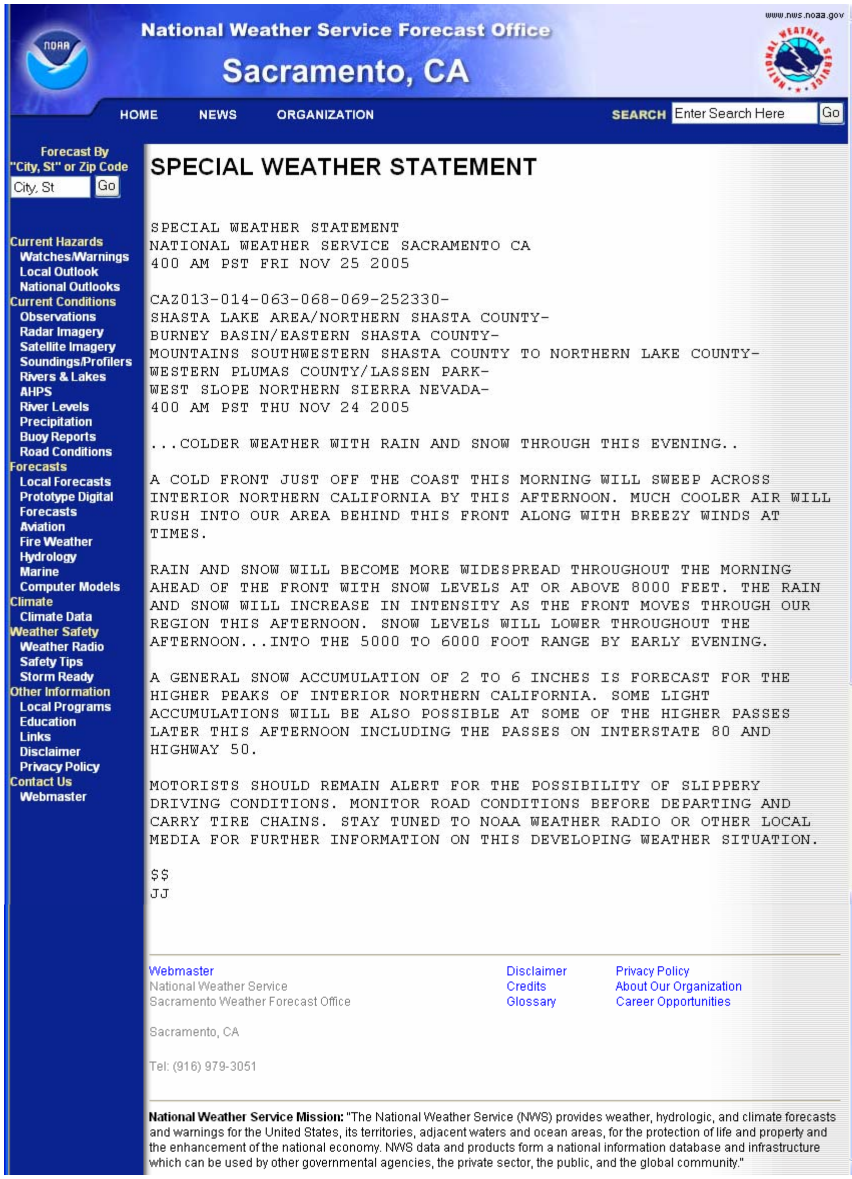


Figure 76: Current Conditions and Forecast for Chester (Plumas County) - 11/25/2005

Table 7: Breakdown of NWS Chester/Plumas County Forecast Page HTML - 11/25/2005

Chester Forecast at a Glance:	http://www.wrh.noaa.gov/total_forecast/index.php?wfo=sto&zone=caz068&fire=caz268&county=cac063
30 Files:	1.css, 8 .gif, 18 .jpg, 1 .js, 1 .png, 1 .htm
Total Size:	143,532 bytes
Mostly Cloudy Icon:	1,847 bytes
Mostly Cloudy Night Icon:	2,346 bytes
Night Snow Icon:	1,275 bytes
Partly Cloudy Icon:	1,982 bytes
Partly Cloudy Night Icon:	2,867 bytes
Rain Icon:	1,650 bytes
Radar Icon:	15,562 bytes
Detailed Point Forecast Map:	14,864 bytes
Html:	38,776 bytes



www.nws.noaa.gov

National Weather Service Forecast Office

Sacramento, CA

HOME NEWS ORGANIZATION SEARCH Enter Search Here Go

Forecast By "City, St" or Zip Code

City, St Go

Current Hazards
Watches/Warnings
Local Outlook
National Outlooks
Current Conditions
Observations
Radar Imagery
Satellite Imagery
Soundings/Profilers
Rivers & Lakes
AHPS
River Levels
Precipitation
Buoy Reports
Road Conditions
Forecasts
Local Forecasts
Prototype Digital Forecasts
Aviation
Fire Weather
Hydrology
Marine
Computer Models
Climate
Climate Data
Weather Safety
Weather Radio
Safety Tips
Storm Ready
Other Information
Local Programs
Education
Links
Disclaimer
Privacy Policy
Contact Us
Webmaster

SPECIAL WEATHER STATEMENT

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE SACRAMENTO CA
400 AM PST FRI NOV 25 2005

CAZ013-014-063-068-069-252330-
SHASTA LAKE AREA/NORTHERN SHASTA COUNTY-
BURNEY BASIN/EASTERN SHASTA COUNTY-
MOUNTAINS SOUTHWESTERN SHASTA COUNTY TO NORTHERN LAKE COUNTY-
WESTERN PLUMAS COUNTY/LASSEN PARK-
WEST SLOPE NORTHERN SIERRA NEVADA-
400 AM PST THU NOV 24 2005

...COLDER WEATHER WITH RAIN AND SNOW THROUGH THIS EVENING..

A COLD FRONT JUST OFF THE COAST THIS MORNING WILL SWEEP ACROSS INTERIOR NORTHERN CALIFORNIA BY THIS AFTERNOON. MUCH COOLER AIR WILL RUSH INTO OUR AREA BEHIND THIS FRONT ALONG WITH BREEZY WINDS AT TIMES.

RAIN AND SNOW WILL BECOME MORE WIDESPREAD THROUGHOUT THE MORNING AHEAD OF THE FRONT WITH SNOW LEVELS AT OR ABOVE 8000 FEET. THE RAIN AND SNOW WILL INCREASE IN INTENSITY AS THE FRONT MOVES THROUGH OUR REGION THIS AFTERNOON. SNOW LEVELS WILL LOWER THROUGHOUT THE AFTERNOON...INTO THE 5000 TO 6000 FOOT RANGE BY EARLY EVENING.

A GENERAL SNOW ACCUMULATION OF 2 TO 6 INCHES IS FORECAST FOR THE HIGHER PEAKS OF INTERIOR NORTHERN CALIFORNIA. SOME LIGHT ACCUMULATIONS WILL BE ALSO POSSIBLE AT SOME OF THE HIGHER PASSES LATER THIS AFTERNOON INCLUDING THE PASSES ON INTERSTATE 80 AND HIGHWAY 50.

MOTORISTS SHOULD REMAIN ALERT FOR THE POSSIBILITY OF SLIPPERY DRIVING CONDITIONS. MONITOR ROAD CONDITIONS BEFORE DEPARTING AND CARRY TIRE CHAINS. STAY TUNED TO NOAA WEATHER RADIO OR OTHER LOCAL MEDIA FOR FURTHER INFORMATION ON THIS DEVELOPING WEATHER SITUATION.

$$
JJ

Webmaster
National Weather Service
Sacramento Weather Forecast Office

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Tel: (916) 979-3051

National Weather Service Mission: "The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community."

Figure 77: NWS Special Weather Statement for Plumas County - 11/25/2005

Table 8: Breakdown of NWS Plumas County Weather Alert Page HTML - 11/25/2005

Special Weather Statement:	http://www.wrh.noaa.gov/warnings.php?wfo=sto&zone=CAZ068&pil=SFOSPSSTO&productType=SPECIAL%20WEATHER%20STATEMENT
16 Files:	1.css, 6 .gif, 7 .jpg, 1 .js, 1 .htm
Total Size:	67,944 bytes
Html:	22,955 bytes

In order to reach the special weather statement that applies to this area, an initial address had to be entered in the browser, and three subsequent "clicks" were required. These manual processes are somewhat time-consuming and tedious on a fast Internet connection, but when coupled with the total size of the files that make up these four pages, accessing this information via a slow data connection would be frustrating, time-consuming and perhaps not even worth the effort. All total, 122 files will have been requested and downloaded, comprising over 626 KB. At best, with a 9600 Kbps connection such as that provided at a maximum over the GlobalStar network, it would take nearly 9 minutes to download this much data. With the overhead of requesting the individual files that comprise these pages, it would take far more time.

Several methods could be used to expedite the process. For instance, bookmarks could be created to provide direct access to specific pages such as the Chester report page or the special weather statement. However, this would introduce the necessity for the end-user to select the correct page(s) from bookmarks and would still carry a great deal of excess information.

Alternate approaches need to be considered for accessing and downloading alert information as well as other weather information. It is neither feasible nor desirable for end-users to manually request and download alerts in this manner. They would certainly become frustrated and would lose valuable time in which they could be doing other things.

NWS XML CAP Alerts

The National Weather Service makes weather alerts available in several text-only XML formats at http://www.weather.gov/alerts/. Alerts may be selected and downloaded for the entire state in RSS[83] (Really Simple Syndication) or CAP[84] (Common Alerting Protocol) format, or in RSS format for individual counties and/or zones. The statewide RSS feed includes general descriptions of current alerts, coupled with links to more detailed information that is contained within a web page that includes all current alerts for the entire state. So, using the statewide RSS feed to get a detailed alert for a specific region requires two requests and the download of alerts

[83] See: http://blogs.law.harvard.edu/tech/rss for the RSS specification.

[84] See: http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=emergency for further information about the CAP standard.

for areas that are not of interest. RSS feeds for individual counties/zones were not available during early development on this project and thus, were not used. These feeds do include the full text of alerts and only include alerts for the specific counties/zones. As such, they should be investigated further for prospective use. In the absence of individual RSS feeds, CAP alerts were chosen for evaluation and prospective use. The NWS CAP alerts are made available in a single XML file that contains all current alerts for the state. California's CAP alerts are available at http://www.weather.gov/alerts/ca.cap. While this file does become quite large during severe weather events, its use is possible even on low-bandwidth connections. Furthermore, because of the XML structure, it is easy to parse the file to extract specific alerts.

Table 9 shows the CAP alert for Western Plumas County/Lassen Park on November 7th, 2005. This section was extracted from the ca.cap file on that date. Note that the CAP format includes tags for a headline, a full description, a web link, and the area for which the alert applies. These tags add overhead to the text, but make it easy to identify and parse using code.

At the time the ca.cap file was downloaded on November 7th, 2005, there were 56 alerts in place for California and the file was occupied 129,680 bytes. This is rather large and would require a download of approximately 2 minutes with a 9600 Kbps connection. However, when compressed using the .zip format, the ca.cap file occupies only 7976 bytes, with a compression ratio of over 16:1. The compressed file could be downloaded in a matter of seconds, even with a slow connection.

Unfortunately, the National Weather Service does not provide this file in compressed form, so a process was implemented on the WeatherShare server to download and compress the ca.cap file every 30 minutes. Rather than download the uncompressed CAP file from NWS, the Responder application downloads the compressed file from WeatherShare upon demand. Then, the application un-compresses the file, parses it, extracts the CAP alert(s) that apply to the Responder's location, and displays them within the Incident Organizer. The use of WeatherShare for this is consistent with its purpose. In fact, these alerts will likely be integrated into the WeatherShare system in the future.

This method has proved reliable and efficient in system testing.

Table 9: CAP Alert for Western Plumas County, Lassen Park 11/7/2005


```
<cap:info>
      <cap:category>Met</cap:category>
      <cap:event>Winter Storm Watch</cap:event>
      <cap:urgency>Unknown</cap:urgency>
      <cap:severity>Unknown</cap:severity>
      <cap:certainty>Unknown</cap:certainty>
      <cap:effective>2005-11-07T13:07:00</cap:effective>
      <cap:expires>2005-11-08T00:30:00</cap:expires>
      <cap:headline>
            ...WINTER STORM WATCH NOW IN EFFECT FROM EARLY THIS EVENING
            THROUGH TUESDAY MORNING...
      </cap:headline>
      <cap:description>
            URGENT - WINTER WEATHER MESSAGE
            NATIONAL WEATHER SERVICE SACRAMENTO CA
            500 AM PST MON NOV 7 2005
            CAZ068-080030-
            /O.EXT.KSTO.WS.A.0002.051108T0000Z-051108T2000Z/
            WESTERN PLUMAS COUNTY/LASSEN PARK-
            500 AM PST MON NOV 7 2005
            ...WINTER STORM WATCH NOW IN EFFECT FROM EARLY THIS EVENING
            THROUGH
            TUESDAY MORNING...
            PRECIPITATION IS EXPECTED TO INCREASE LATE THIS AFTERNOON THROUGH
            THIS EVENING OVER THE WESTERN PLUMAS COUNTY AREA AND LASSEN PARK.
            SNOW LEVELS WILL START OUT HIGH...BUT EXPECTED TO FALL TO 5000 TO
            5500 FEET AFTER MIDNIGHT. TOTAL SNOW ACCUMULATIONS OF 12 TO 20
            INCHES ARE POSSIBLE FROM THIS EVENING THROUGH NOON ON MONDAY.
            LOCALLY STRONG GUSTY WINDS ARE ALSO POSSIBLE NEAR THE MOUNTAIN
            PASSES.
            A WINTER STORM WATCH MEANS THERE IS A POTENTIAL FOR SIGNIFICANT
            SNOW ACCUMULATIONS THAT MAY IMPACT TRAVEL. CONTINUE TO MONITOR
            THE
            LATEST FORECASTS. MOTORISTS TRAVELING OVER THE HIGH ELEVATIONS
            SHOULD CARRY CHAINS.
            $$
      </cap:description>
      <cap:web>
            http://www.weather.gov/alerts/ca.html#CAZ068.STOWSWSTO.130700
      </cap:web>
      <cap:area>
            <cap:areaDesc>Western Plumas County, Lassen Park
            (California)</cap:areaDesc>
            <cap:geocode>006007</cap:geocode>
      </cap:area>
</cap:info>
```

8.3.4.2. Current Observations

Current observations are also available in several formats via the National Weather Service. Because direct web page access is a manual, time-consuming process (as discussed in previous section on alerts), it is not used for current observations. See Figure 76 for an example of current conditions within a web page. Observations are also available in XML format for 114 observation stations in California. The link to current conditions for Chico is http://www.nws.noaa.gov/data/current_obs/KCIC.xml, and link to current conditions for Redding is http://www.nws.noaa.gov/data/current_obs/KRDD.xml. (See Table 10 for an example observation from Chico.)

There are several challenges in making use of these current conditions. First, incidents, particularly in rural areas, are likely to occur some distance from reporting stations. While it is feasible, it is not desirable to display conditions from all 114 observation stations at once. Instead, it is better to determine which stations are nearest to the incident. In order to determine the nearest stations, station locations (latitude and longitude) are stored in the Responder application and compared against the latitude and longitude of the responder. An approximation of straight-line distance and direction are calculated for each, and only those within a fixed radius (75 miles) are chosen for display.

Since observations for stations are stored in individual files, it would be possible to request and download each of the closest stations' reports. However, with the added overhead of making individual web requests, this approach was not considered optimal. Instead, it was determined that the individual reports could be downloaded to the WeatherShare server on a periodic basis (every 30 minutes), concatenated into a single file, and compressed. The result is an even better compression ratio than was observed for alerts: over 21 to 1. On November 7th, 2005, the 114 observations occupied 286,682 bytes when concatenated together. When this file was compressed, it occupied only 13,369 bytes, which could be downloaded in between 10 and 20 seconds on a 9600 Kbps connection. This was likely as good as, if not better than the amount of time that would be required to request individual files, and the overall file exhibited a far greater compression ratio than that for individual files. For instance, on that same date, Chico's file, KCIC.xml, occupied 2,237 bytes. When compressed, it required 986 bytes. While this savings is significant, it corresponds to a compression ratio of approximately 2.25, far less than the 21 to 1 ratio for the concatenated file.

Note that as with the CAP files for alerts, the XML format for observations is well-structured, allowing for easy parsing of individual readings for temperature, wind speed, barometric pressure, etc.

As with alerts, the use of WeatherShare for this purpose was consistent with its purpose, and the information was already being downloaded to WeatherShare.

Table 10: KCIC.xml Current Observation File for Chico Municipal Airport - 11/7/2005


```
<?xml version="1.0" encoding="UTF-8"?>
<current_observation version="1.0"
         xmlns:xsd="http://www.w3.org/2001/XMLSchema"
         xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

xsi:noNamespaceSchemaLocation="http://www.weather.gov/data/current_obs/current_observation.xsd">
        <credit>NOAA's National Weather Service</credit>
        <credit_URL>http://weather.gov/</credit_URL>
        <image>
                <url>http://weather.gov/images/xml_logo.gif</url>
                <title>NOAA's National Weather Service</title>
                <link>http://weather.gov</link>
        </image>
        <suggested_pickup>15 minutes after the hour</suggested_pickup>
        <suggested_pickup_period>60</suggested_pickup_period>
        <location>Chico Municipal, CA</location>
        <station_id>KCIC</station_id>
         <latitude>NA</latitude>
         <longitude>NA</longitude>
        <observation_time>Last Updated on Nov 7, 11:58 am PST</observation_time>
        <observation_time_rfc822>Mon,  7 Nov 2005 11:58:00 -0800 PST</observation_time_rfc822>
         <weather>Light Rain and Breezy</weather>
         <temperature_string>82 F (28 C)</temperature_string>
         <temp_f>82</temp_f>
         <temp_c>28</temp_c>
         <relative_humidity>NA</relative_humidity>
         <wind_string>From the Southeast at 25 Gusting to 32 MPH</wind_string>
         <wind_dir>Southeast</wind_dir>
         <wind_degrees>130</wind_degrees>
         <wind_mph>25.3</wind_mph>
         <wind_gust_mph>32</wind_gust_mph>
         <pressure_string>29.81&quot;</pressure_string>
         <pressure_mb>NA</pressure_mb>
         <pressure_in>29.81</pressure_in>
         <dewpoint_string>NA</dewpoint_string>
         <dewpoint_f>58</dewpoint_f>
         <dewpoint_c>14</dewpoint_c>
        <visibility_mi>10.00</visibility_mi>
        <icon_url_base>http://weather.gov/weather/images/fcicons/</icon_url_base>
        <icon_url_name>na.jpg</icon_url_name>
        <two_day_history_url>http://www.weather.gov/data/obhistory/KCIC.html</two_day_history_ur
l>
        <ob_url>http://www.nws.noaa.gov/data/METAR/KCIC.1.txt</ob_url>
        <disclaimer_url>http://weather.gov/disclaimer.html</disclaimer_url>
        <copyright_url>http://weather.gov/disclaimer.html</copyright_url>
        <privacy_policy_url>http://weather.gov/notice.html</privacy_policy_url>
</current_observation>
```

8.3.4.3. Point Forecasts

While current condition reports and alerts may be of help to responders, they may not always pertain to a specific incident location. Also, weather events of interest may be predicted that are not classified as alerts, warnings or special weather statements. For instance, even light wind or rain could have an impact on the clearance of an incident. Zone forecasts are available from the National Weather Service, providing forecasts for moderate-sized areas that generally have similar weather conditions. These zone forecasts will be considered for future inclusion in the Responder application, but were not included during this phase of research and development. Instead, the National Weather Service's experimental point forecasts from the National Digital Forecast Database[85] were used.

NWS lists, among others, the following benefits[86] for use of the National Digital Forecast Database:

- More Timely and Consistent Weather Information - Information that is up-to-date, available on demand, and provided with spatial and temporal consistency to help users make more informed decisions.
- Information Delivered in a Variety of Formats - Product formats (e.g., grids, graphics, and text) meet the needs of a diverse customer base.
- Higher Temporal and Spatial Resolution - More detailed forecast information taking into consideration rapidly changing weather scenarios and geographic features that influence the weather.
- Support for Weather Enterprise - Furnish commercial weather providers with digital data in standard formats to allow creation of a wide range of products to meet their customers' needs.
- Easier Access - To reach as many businesses and households as possible, digital data will be made available over the Internet and traditional dissemination systems in standard formats accessible to a variety of devices.

All of the listed benefits are applicable to the Responder application and its use. Grid resolution for the NDFD data is 5 km[87]. Point forecasts for a given location, as specified by latitude and longitude, correspond to the nearest grid point in the NDFD. Thus, the point forecast, particularly for rural locations, may provide a better and more specific forecast than a general zone forecast or a forecast for a site that is 50-100 miles away.

Point forecasts from the NDFD are experimental, so some qualification should be placed on their use and stability. However, it does appear that the National Weather Service intends to continue to enhance this service, which NWS has given prominent visibility on its weather pages. As of November 8th, 2005, Maximum Temperature, Minimum Temperature, 12-hour Probability of Precipitation, Temperature, Dewpoint and Weather elements were considered operational[88]. Quantitative Precipitation Forecast (QPF), Snow Amount, Wind Direction and Speed, and

85 http://www.weather.gov/ndfd/
86 http://www.nws.noaa.gov/ndfd/resources/dsconops0604-3.pdf
87 http://www.weather.gov/ndfd/technical.htm
88 http://www.weather.gov/ndfd/resources/oper_status_table.pdf

Apparent Temperature were still considered experimental at that time, but comment periods for these measures had either expired or were to expire soon, indicating that they should become operational in the near future.

Point forecasts are requested using a specially formed URL such as the following:

> http://ifps.wrh.noaa.gov/cgi-bin/dwf?outFormat=xml&duration=48hr&interval=1&latlon=Go&siteID=STO&latitude=39.77616&longitude=-121.45572

This URL specifies a request for a point forecast over a 48 hour period at one hour intervals for the point at latitude 39.776, longitude -121.45572, which corresponds to the SR-70 Butte County Incident Location. Table 11 shows an abbreviated example of the XML returned by such a request made on November 25th, 2005. Note that the time indicated in the forecast is expressed in Greenwich Mean Time (GMT), and requires conversion. Further note that subsequent periods that correspond to subsequent 1 hour intervals are omitted from the example, but are included in the response XML. XML formatting makes for easy parsing and flexible use of this information.

The size of the corresponding response to this request was 20,764 bytes. This is uncompressed, and compression was not used with point forecast data. The reason that compression via WeatherShare was not used for point forecasts was that it would require either that a massive amount of NDFD data corresponding to grid points in the RIME region be downloaded at regular intervals; or that WeatherShare would receive a request, make the related request from the National Weather Service, compress the results, and then send results to the Responder client. While the latter was not attempted, it was anticipated to result in minimal if any reduction in download time. The possibility of downloading and integrating NDFD data into WeatherShare will be explored in subsequent WeatherShare development. This process would more readily facilitate the compression of this information for download. However, the size of this data is not a great concern at this time, since it can generally be downloaded in well less than a minute, even on a slow connection.

Point forecasts have been well-received by prospective users, and performance for downloads has proved adequate, so their use is likely to continue in the Responder application.

Table 11: Point Forecast for SR-70 Butte County Incident Location - 11/25/2005


```
<?xml version="1.0" ?>
- <griddedForecast duration="48 hours">
  <forecastCreationTime>Thu Nov 24 23:33:19 2005</forecastCreationTime>
  <latitude units="degrees">39.80</latitude>
  <longitude units="degrees">-121.45</longitude>
  <elevation units="feet above mean sea-level">1938</elevation>
  <duration>48</duration>
  <interval>1</interval>
- <forecastDay>
  <validDate>Nov 25</validDate>
- <period>
  <validTime>00</validTime>
  <maxTemp units="degrees F">66</maxTemp>
  <temperature units="degrees F">61</temperature>
  <dewpoint units="degrees F">46</dewpoint>
  <rh units="percent">58</rh>
  <skyCover units="percent">89</skyCover>
  <windSpeed units="mph">4</windSpeed>
  <windDirection units="angular degrees">168</windDirection>
  <pop units="percent">42</pop>
  <qpf units="inches">0.01</qpf>
  <wx>Chance Rain</wx>
  </period>

…
```


8.3.4.4. Conclusions Regarding Weather Data

It was not feasible to require manual interaction with web pages for the download and display of weather information. Too much interaction was required, and time for download was excessive. Text-only, XML-formatted versions of alerts, current conditions, and forecasts, made available by the National Weather Service, proved to be viable sources of weather information for the Responder application. These sources facilitated the use of automated, location-based processes for retrieval.

A further step was taken to minimize download time required for these data elements. Where possible, information was compressed and stored on the WeatherShare server for use by the Responder application. This use of the WeatherShare server was consistent with its purpose and with data that was already being aggregated on the server or planned for future aggregation and use. Additional weather data such as RWIS could be handled in a similar manner, using WeatherShare as a provider of this data in a compressed format. While this design decision makes the Responder system dependent on the WeatherShare system, the benefits appear to be worthwhile. In the event that WeatherShare could not be used for this purpose, the same information could still be downloaded from the National Weather Service, although there would be no compression and download times would be greater.

8.3.5. Transmission of Incident Information

8.3.5.1. Transmission Alternatives

There are a variety of means for communicating incident information via an Internet connection from the Responder application to an external entity, typically to someone at the TMC for Caltrans. These include chat/instant messaging, ftp or http upload, and email, among others, as well as custom-developed applications using TCP/IP.

Chat/instant messaging would be an interesting option. However, a special client would be necessary for use, and the client may not be allowed on agency computers. Furthermore, chat is susceptible to a number of attacks and could result in unnecessary use of bandwidth. Firewall issues further complicate this matter, because ports necessary for communication may be blocked by many agencies. It may be desirable to investigate chat/instant messaging as a means for two-way communication between responders and the TMC. However, this option is not preferred at this time.

Ftp or http upload could be used to allow the upload of incident information to a server, and ftp would certainly be an efficient means for this upload. The problem remains though of how to inform TMC operators that information has been uploaded. This could be accomplished in a variety of ways, but was not preferred at this time due to the apparent necessity for a server and custom coding on the server.

A custom application could be developed using TCP/IP to provide the greatest flexibility and efficiency. However, it would be necessary to implement a custom application on the TMC-side to receive data from the client-side custom application. This option was not preferred at this time due to the potential complications of implementing such a solution. However, it may be considered in future implementation.

Email was chosen as the preferred means for communication of incident information with the TMC. There were several factors in making this decision. First of all, there was no need for special or custom software on the TMC side. TMC operators already have email clients and monitor email regularly. Thus, email from a responder using the Responder application could be received and read with no additional required software. Furthermore, valid email is allowed to pass through corporate firewalls, so there is no need to open additional ports in a firewall. Finally, email could readily be composed “in code” within the Responder application and sent to the TMC. The one “hitch” in this process is that the email must be relayed through a valid email server. In order for this relay to occur, a server must allow relays. While in the past, SMTP relays have been a source of security problems, relays can be done in a relatively secure fashion by requiring authentication. Thus, with a valid account on a server that allows relays, the process can be accomplished. Note that this is the same mechanism used by Microsoft Outlook and various other email clients to communicate with servers using the STMP protocol and to send email through them. The prospect of sending an email message directly from the Responder application to a Caltrans email server was tested, but failed because the server would only accept email from valid email servers.

So, for the purpose of development and demonstration on this project, an email account was created using a third-party email provider. This email account proved reliable for this purpose, but it is recommended that an account on an agency server be used for production purposes in the future. It should be noted further that email is delivered in an asynchronous fashion, and nothing guarantees that email will be delivered within a certain time period. For the chosen third-party email provider, results were good in that email appear to be transmitted near-instantly. However, email could be delayed after transmission by the rely server in transit or even by the receiving server. This is perhaps the greatest drawback of using email as the means for transmission and receipt of incident information.

8.3.5.2. Email Contents

Basic incident information such as location and description could be transmitted in plain text using email. However, to transmit incident images, it was necessary to either use html-formatted email, or to transmit images as attachments. Rather than transmit images as separate attachments, it was decided that they should be "packaged" together into a single file. This was done for several reasons. First, it was consistent with the notion behind the Incident Organizer within the Responder application that incident information should be treated as a collection of related information rather than separate, disjoint chunks or files. Second, it would facilitate easy storage and exchange of information. A single file attachment can be stored more easily than multiple files and the pieces within the single file are kept together in storage.

The file format chosen for use was Microsoft Word. Microsoft Word is installed as a standard program on Caltrans computers, so opening a Microsoft Word attachment would not be a problem for TMC operators. And, it likely wouldn't be a problem for other prospective recipients. Other possibilities were explored for development and demonstration, but were dismissed for use in this version. A zip archive could have been used, but the recipient would have been required to use a utility to "unzip" the file attachment. MHTML (Mime-encoded HTML) was also explored as an option, but was dismissed because of no apparent advantage over Microsoft Word documents. Further options include a custom XML format, but this would require a special reader application for use by the recipient.

So, email messages would be composed with a plain text message to include the incident location and description, and an attached Microsoft Word document to contain photos and sketches as well as the same plain text information. Thus, the Microsoft Word document could serve as a self-contained document of the incident at a point in time and separate from the email with which it was attached.

While the Microsoft Word document could be compressed to reduce its size and associated transmission time, it was determined that the compression ratios would not be significant. Furthermore, the added requirement that the document be uncompressed by the recipient was undesirable. Instead, emphasis was placed on compressing the size of the images included in the document. This was accomplished in two ways: by reducing the actual dimensions of the image to 640 x 480 and by using JPEG compression to reduce the storage size of the image.

Appendix V – Sample Responder Email 291, shows example email composed and sent by the Responder application for the sample SR-70 Butte County incident. Note that a text-only "beacon" email is sent prior to transmission of the full email including the attachment. This is done to increase the likelihood of success of at least a single message getting out from the incident scene. As will be discussed later, rugged surrounding terrain may have an adverse impact on the transmission of large data sets, and an email with too large an attachment may fail under such circumstances. Alternative means for packaging and sending incident information will be discussed later in this document.

The figures in the example show that the reduction of images to 640 x 480 resolution does not appear to have a severe impact on usefulness of the images, even for the maps and sketches. However, there does appear to be degradation in quality sufficient to make sketch annotations difficult to read. Further research and development is planned to implement sketches that show greater contrast with the associated images. Capability may even be added to allow the responder to manually adjust compression settings to make sketches more readable. However, it would be desirable for the sake of ease-of-use to have this process conducted automatically, without intervention by the end-user. Determining a means for greater contrast, whether through display method or through the use of alternate colors may make this possible.

Regardless, this example shows images that are nearly adequate if not wholly adequate for the intended purpose. The total size of the Microsoft Word attachment for this example is 156KB, and it contains 1 un-annotated photo, 4 annotated photos, 1 annotated map, one freehand sketch, and corresponding text information. Transmission of this attachment would require somewhere between two to five minutes over a 9600 Kbps connection. For the amount of information conveyed in these amounts, this transmission time certainly seems reasonable. And, if a greater transmission time is allowed, there is room for improvement in terms of image quality.

Thus, the methodology chosen for composition and transmission of incident information via email appears to be viable. Again note though that the asynchronous behavior of email transmission could be detrimental to the timely delivery of incident information.

8.4. Hardware

The greatest research and development challenge regarding hardware was that of selecting and integrating components that are usable within and in the vicinity of a vehicle in the field. This challenge includes making the hardware field ready and able to withstand the rigors of weather and rough use. It also includes the challenge of reducing the size of the system.

The logical diagram of the Prototype 2 hardware and communication framework in Figure 78 shows how the system operates.

- The Tablet PC communicates with the wireless router via an 802.11b connection.
- The wireless router is connected to the USB hub via a wired Ethernet connection.
- The USB hub is connected to the cellular modem, the satellite modem and the GPS via a Serial to USB converter.
- A USB cable is connected to the USB hub for the purpose of connecting external devices such as a digital camera.
- The cellular modem communicates with a cellular tower, which in turn provides a gateway to the Internet.
- The satellite modem communicates with a satellite, which in turn provides a gateway to the Internet.
- The GPS receives signals from GPS satellites.

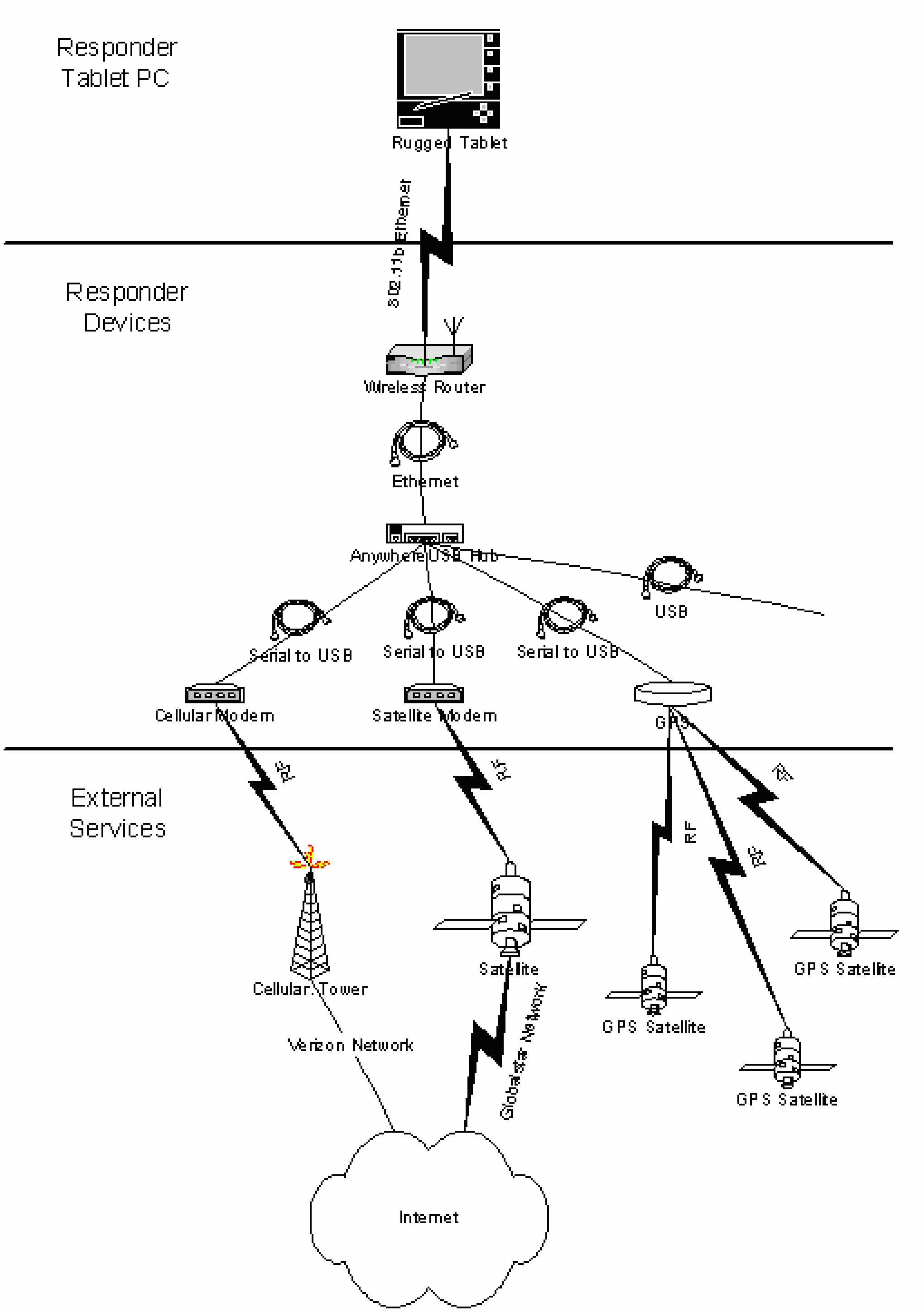

Figure 78: Prototype 2 - Logical Hardware and Communication Framework

The Responder application communicates with devices (satellite modem, cellular modem, and GPS) via a virtual COM (serial) port. In essence, the application does not need to "know" if the devices are physically connected or whether the connection is a virtual connection. It simply needs to know the COM ports assigned to the devices. Drivers convert between Ethernet, USB and Serial on the software side. Likewise, the router, hub and various cables and converters convert between the corresponding transports on the hardware side. Figure 79 depicts the various hardware and software layers.

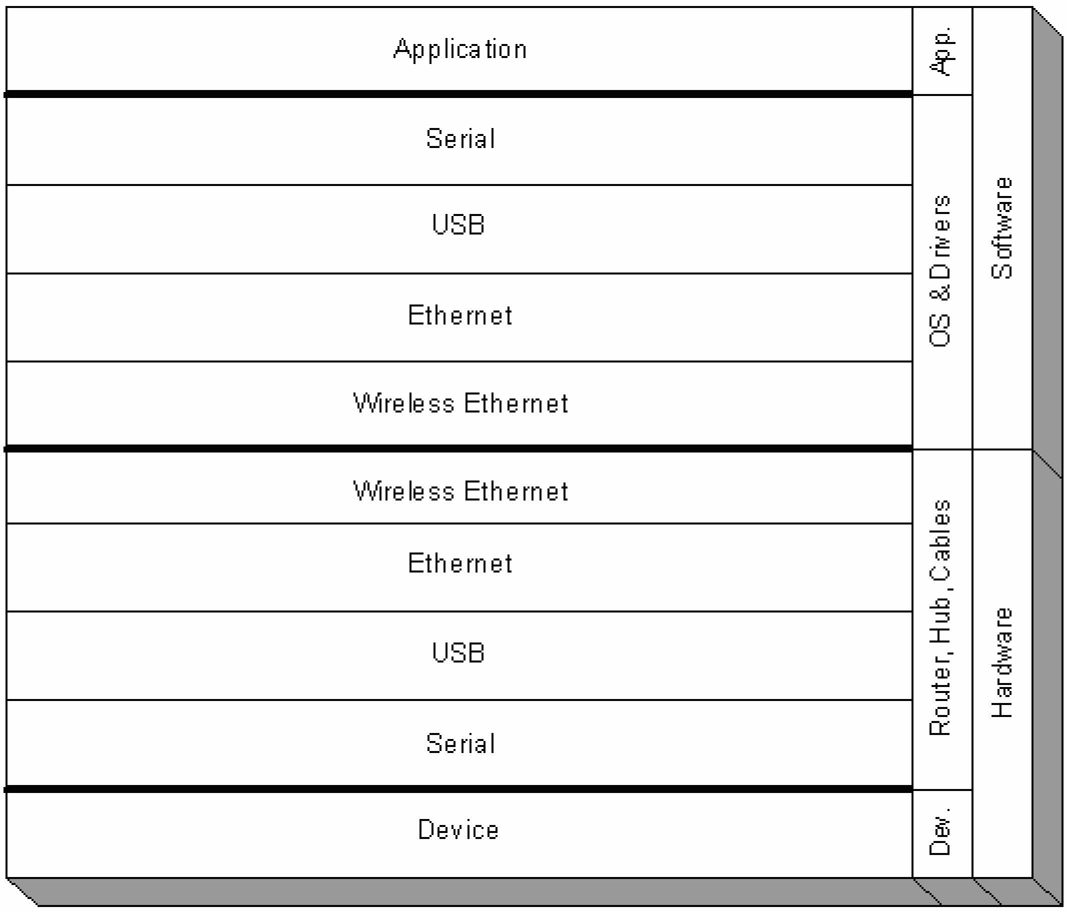

Figure 79: Prototype 2 - Hardware, Software Relationship

The USB hardware and software layers could be eliminated, given the appropriate device and software, reducing the complexity of the system. The only functionality that would be lost would be the external USB cable. That cable is not necessary if the camera is connected directly to the Tablet to upload images.

There are several immediate ways in which the system could be made far more compact. If the satellite communication unit was not necessary and the system could operate entirely using cellular communications, then current Tablet PC offerings with integrated GPS and CDMA modem, as well as integrated Wi-Fi, could, when coupled with a Wi-Fi camera such as those recently marketed by Nicon, offer all of the capabilities of the Responder system. This may in fact be viable in urban and certain rural settings. The benefits of the compact size and minimal complexity of this system should be examined further.

It is also interesting to note that vehicle manufacturers such as Ford are now offering "mobile office" options for vehicles. Ford recently demonstrated an example of the prospective mobile office at the Specialty Equipment Market Association show in Last Vegas. Included was a touch-screen computer, wireless cellular card, capability to connect to a digital camera, and GPS connectivity.[89] This accessory is anticipated to cost about $3000 and may be offered as a dealer installed accessory soon as 2006.[90]

[89] http://news.com.com/Ford+squeezes+an+office+into+a+truck/2100-11389_3-5925840.html
[90] http://www.freep.com/news/statewire/sw123441_20051031.htm

8.5. Communications

8.5.1. Introduction

Perhaps the most interesting and challenging aspect of this study was that of determining the potential and limitations of data communications in remote rural locations, particularly those within Northern California. These challenges apply to other similar areas and pertain to related applications. Extensive time was devoted to the study of several means for data communication in these areas.

Two primary means for communication were analyzed: mobile satellite and digital cellular. Other means exist and may be viable, including digital communication via a private radio network including those with frequencies over 800MHz. However, only limited analysis was conducted in this regard. The limiting factor for such technology is the lack of infrastructure, and it was determined best for proof-of-concept to use satellite and cellular networks for which infrastructure already exists. Although this study does not go as far as a cost-benefit analysis, it certainly could be the case that use of these commercial providers is not only adequate in terms of coverage, but also in terms of cost. Nevertheless, the Responder application was developed in a manner that would allow for the use of other types of IP-based networks.

Satellite communication was studied because it was most likely to provide coverage over all of District 2. As will be demonstrated in this section, there are certain limiting factors that reduce the effectiveness of mobile satellite communication – i.e., obstruction of the sky. However, satellite does for the most part provide complete coverage for the District.

Cellular communication was studied because, while it does not provide complete coverage, it does provide expansive coverage along major routes such as Interstate 5. Furthermore, cellular provides greater bandwidth at a lower cost than satellite. Thus, a combination of the two could potentially be more cost-effective and more efficient than satellite alone.

Satellite and cellular were studied side-by-side, for prospective use individually and in conjunction with each other, or even with other systems.

The data communication coverage analysis focused primarily on two regions in northern California. The Gibson area north of Redding houses a District 2 maintenance yard, and was identified by Caltrans as a prospective testing site for the Responder application due to communication challenges in that area. Several visits to this site were used to gather signal strength readings and test the application. The State Route 70 area, particularly that of SR-70 Butte County Landslide, referenced previously, was studied in great detail both through site visits and through analysis of communication models. This area, known as the Feather River Canyon, exhibits perhaps the most extreme communication challenges in District 2. As such, it was thought that if the system could be made to work in this area, it could be made to work virtually anywhere in District 2.

Globalstar was chosen as a satellite provider because it offered readily available and easy to use equipment for mobile data communications. Other mobile systems such as Iridium could be used similarly. Mobile satellite communication systems were determined to be preferable to fixed satellite systems because they require virtually no special configuration based on location. Fixed satellite systems require a directed antenna to be pointed at a corresponding satellite. For responders, such a system would require special set up for each location. In addition, while systems exist to automate this process, such systems may be prohibitively expensive and/or require excessive time for setup or unwieldy equipment for use. Mobile providers such as Globalstar and Iridium use Low Earth Orbit (LEO) satellite constellations, which introduce some dynamic behavior when used in rugged terrain.

Verizon was chosen as a cellular provider also because it offered readily available and easy to use equipment for mobile data communications. Furthermore, the Verizon network is widespread both in northern California and in Montana, where the majority of testing and development occurred. Verizon uses CDMA (Code-Division Multiple Access) technology, but nothing in the Responder application is dependent on CDMA. Other providers and cellular technologies could be readily used with the system. It is anticipated that similar results would be found for other providers and technologies, although coverage areas, data rates and costs would certainly vary.

Aside from obvious differences such as data rates, prices and associated hardware, there is a fundamental difference between the services provided by such satellite and cellular providers. In general, at a given location, either cellular service is available, or it is not. There are circumstances in which cellular signal strength may fluctuate and even drop to zero, but coverage can generally be considered fixed given existing infrastructure. The same can be said for most private radio solutions. The behavior of satellite systems such as Globalstar's, on the other hand, is much more stochastic. At a given location, it is possible that at one moment there is a strong signal and at the next there is no signal. This is particularly true in mountainous areas. Thus, the method of analyzing these systems varied to account for this fundamental difference in signal behavior.

8.5.2. Preliminary Testing and Observations in Montana

Appendix VI – Preliminary Satellite Phone Report includes a complete report of a preliminary communications report that was submitted in October 2004. This report includes early observations and analysis from testing conducted primarily with the GlobalStar satellite phone.

This testing began with a simple observation made while using the phone in the shadow of several of Montana's highest mountains: calls can be dropped when the terrain obstructs a significant portion of the sky. For voice calls, this is certainly a nuisance, but it isn't necessarily an insurmountable barrier. If a voice call is disrupted, the call can be reestablished and the conversation can pick up where it was left off. However, for data transmission, if a file is in the middle of transmission and the call is dropped, then transmission must restart at the beginning. Moreover, this process must be repeated until the data is transmitted entirely without disruption or until the process is stopped due to frustration or simply running out of time.

A single study[91] by Frost & Sullivan was identified to shed some light on the situation, but that report provided information of limited use under the circumstances:

> *"Overall, it can be said that signal blockage is signal blockage, no matter which system. If there was sufficient clear sky, both systems would be operable and the main differentiator was audio quality. Under all types of conditions, Globalstar showed time*

[91] Satellite Telephone Quality of Service Comparison: Iridium vs. Globalstar
http://common.globalstar.com/docs/fs_study.pdf

> *and time again a significant and measurable superiority over the Iridium system in this aspect."*

First of all, this observation is made in regard to voice calls. Second, in regard to signal blockage, no differentiation is made between degrees of signal blockage. For instance, while signal blockage was observed in our early testing, it still was possible to establish communication for a period of time. Finally, the observation distinguishes the Globalstar system from the Iridium system. While it may be true that Globalstar outperforms Iridium, it should be noted that this study was commissioned by Globalstar. Unfortunately, no other study was known at the time to address the impact of terrain/sky obstruction on service for Globalstar.

So, signal strength readings, as indicated by "bars" on the telephone display, much like signal strength bars on a cellular phone, were analyzed to reveal further patterns. Since calls are billed at approximately $1 per minute, it was not feasible or prudent to conduct extensive testing with live calls. So, a combination of limited testing with live calls and extensive testing with signal strength readings was conducted.

Following initial informal observations, a drive test and stationary test were conducted with visual signal strength monitoring and manual recording. During these tests, periods of excellent signal strength were observed, and periods of fluctuating and diminished signal strength were observed. Obstruction from surrounding mountains reached and exceeded a 25 degree angle of elevation and surrounding trees caused obstruction exceeding 25 degrees. To characterize sky obstruction, a panoramic photograph of the test site was taken, revealing obstruction of the sky characterized by angles of elevation and direction. This methodology was subsequently refined and automated. Something was causing fluctuation, and terrain/sky obstruction was the most likely culprit. Note that weather was calm during these tests, with clear skies and no precipitation.

Manually established data connections were also attempted at the test site using a portable computer, the satellite phone, and a mobile data kit (cable and software). Several attempts, including redials, were required to successfully send a 150 KB email message. Several attempts were made to open web sites, and redials were necessary to successfully download the full contents of these web pages. Furthermore, several bandwidth measurements succeeded and revealed 2.4 Kbps and 2.7 Kbps connections.

A controlled experiment was subsequently conducted at a location with relatively little surrounding obstruction, no more than 9-10 degrees. (Over 99.8% of observed signal strength readings were greater than zero at this location, and over 97.3% were the maximum, 4.) This location had been observed to exhibit consistent excellent signal strength. A device was constructed to completely obstruct the satellite antenna, blocking all signals. Then, signal strengths and actual calls were observed while obstructing the antenna for fixed periods of time. It was determined that calls were dropped when signal strength drops to zero for eight seconds or longer. However, if signal strength drops to zero for less than eight seconds, calls are generally not dropped.

Extended site tests were conducted at two additional sites. The first site had significant obstruction reaching and exceeding a 30 degree angle of elevation. In forty minutes of testing at this site, a number of signal outages were observed with the greatest lasting 6.5 minutes. There were four intervals over which signal strength was not broken measuring 11.5 minutes, 9 minutes, 8.5 minutes and 2.5 minutes. At the second site, obstruction was less with angles of elevation measuring up to approximately 20 degrees. In 30 minutes of testing, signal strength measured four 97.7 percent of the time, and zero 1.61% of the time. In no case did signal strength drop to zero for more than 5 seconds, so signal strength did not decrease sufficiently to drop a call at this location.

Another test was conducted over the 200 mile stretch of Interstate 90 between Bozeman and Missoula, in both directions. This mobile test resulted in maximum signal strength of 4 being registered 99.66% of the time. There are several areas along this route that exhibit moderate obstruction of the sky, but it appears that obstruction was not significant enough to severely reduce signal strength. During this test, weather ranged from partly cloudy to heavy rain, so weather did not appear to have an impact. (Later observations were noted during heavy snow and while the antenna was completely covered in snow. This appeared to have no impact on performance.)

The primary conclusion from this preliminary testing is that terrain does have an impact on satellite service. Furthermore, in the event that signal strength drops to zero for a period of time greater than seven seconds, a call will be dropped. To add a little buffer for certainty, it could be considered desirable to avoid signal drops to zero that last longer than five seconds.

Note that a propagation analysis for land-mobile radio and several drive tests of cellular were conducted in this preliminary analysis. See Appendix VI – Preliminary Satellite Phone Report for further details.

8.5.3. Communication Options and Pricing

It was neither a goal of this study to determine the best cellular or satellite service provider, nor was it a goal to conduct a cost-benefit analysis of the various options. These tasks are important and should be conducted subsequent to this Phase. It was a goal to determine if cellular and/or satellite was viable, and two major providers of each of these services were chosen for development purposes and evaluation: Verizon Wireless for cellular and Globalstar for satellite. A number of alternatives exist for each. Data via land-mobile radio is an option was well. So long as a service provides TCP/IP connectivity to the Internet or a corporate intranet, it should be possible to use the system with that service; therefore other providers could be considered in the future.

8.5.3.1. Pricing

At the time this report was being written, Globalstar was offering bundled voice and data service for prices ranging from $0.99 per minute down to $0.49 per minute with data time billed in 15-second burst intervals. Previous plans were offered on a monthly basis, but current plans are offered on an annual basis. This is an improvement because there will be no issues of losing minutes at the end of each month. Their site notes rates as low as $0.05 per 15-second data session, which would correspond to $0.20 per minute, although none of the listed plans have that rate. It may also be possible to purchase minutes for collective use by multiple devices within an organization, although it is not explicitly noted.[92]

Verizon Wireless offers an ever-changing number of data plans and options. “Quick2Net” offers low-end data service using voice minutes, so the price would correspond to that of a voice plan. NationalAccess offers 1xRTT service and was used for this project. This service was offered for $79.99 per month for unlimited access. (A government discount resulted in a lower rate.) Rates have subsequently dropped. The recent “BroadbandAccess” offers EV-DO service with higher data rates. BroadbandAccess is offered at $59.99 per month for unlimited minutes.[93]

8.5.3.2. Coverage

Globalstar service is available throughout the continental United States and they have plans to extend service to Alaska in 2006.[94] Service requires that the antenna have a “clear view of the sky,” so usage is generally limited to vehicles and outdoors, although fixed phone service is available. As discussed throughout this report, terrain and structures can cause obstruction of the sky that degrades service.

Verizon service is available throughout the continental United States, primarily along roadways and in urban areas. As of December 2005, BroadbandAccess was offered in 171 major metropolitan areas.[95] With the possible exception of the portion of the RIME region near Sacramento, BroadbandAccess was not available in the RIME region at this time. However, service is noted to be continually expanding.[96] Figure 80 shows Verizon data service in northern

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92 http://www.globalstarusa.com/en/airtime/datapricing/
93 http://www.verizonwireless.com/b2c/mobileoptions/broadband/serviceoverview.jsp
94 http://www.globalstarusa.com/en/content.php?cid=300
95 http://www.verizonwireless.com/b2c/mobileoptions/broadband/serviceoverview.jsp
96 http://www.verizonwireless.com/b2c/mobileoptions/broadband/coveragearea.jsp

California as of December 2005. Broadband access coverage is shown in purple and is limited to areas surrounding Sacramento and San Francisco. National access coverage is shown in yellow, and reasonable coverage is shown for the RIME region with several exceptions: service is not available along I-5 north of Shasta County and is generally unavailable in counties to the west of I-5. Service appears sporadic in mountain areas, which is consistent with observations noted later in this report.

Figure 80: Verizon Data Service in Northern California as of December 2005[97]

8.5.3.3. Data Rates

Globalstar offers data rates up to 9600Kbps.[98]

For Verizon cellular, Quick2Net offers data rates of 14.4Kbps. NationalAccess offers data rates averaging 60-80 Kbps with bursts of up to 144 Kbps[99]. BroadbandAccess offers data rates with average download speeds of 400-700 Kbps and theoretical capability of reaching 2Mbps.[100]

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[97] http://www.verizonwireless.com/b2c/CoverageLocatorController?requesttype=ZOOM%20OUT
[98] http://www.globalstarusa.com/en/content.php?cid=606
[99] http://www.verizonwireless.com/b2c/mobileoptions/broadband/serviceavailability.jsp
[100] http://www.verizonwireless.com/b2c/mobileoptions/broadband/serviceoverview.jsp

8.5.3.4. Technical Information about Globalstar

Statistics for the Globalstar network and constellation are provided in more detail later in this report. Following are several important observations, characteristics and distinctions gathered from literature:

The Globalstar system offers a feature called "path diversity," which allows a handset to communicate with multiple satellites and perform "soft handoffs" between satellites. The feature enhances service in difficult areas such as urban canyons surrounded by buildings and rugged mountains and canyons.[101] Assuming a 48 satellite configuration and no more than a 10 degree angle of elevation of obstruction, areas between 25 degrees and 50 degrees North latitude will be within range of 2 or more Globalstar satellites 100% of the time and 3 or more Globalstar satellites at least 80% of the time. Coverage is optimal between 35 and 40 degrees north latitude.[102] In areas with obstruction of the sky above 10 degree angles of elevation, performance is impacted significantly by what is called "shadowing." In the absence of shadowing, the theoretical performance of Globalstar versus Iridium, another satellite service provider, is comparable. However, when satellites are shadowed, path diversity provides Globalstar with better performance. [103]

In the absence of obstruction, one should expect the following distribution of visible satellites above a 20 degree angle of elevation at 40 degrees North latitude, approximately that of the SR-70 incident location:

# visible satellites	probability
0	0
1	10
2	70
3	20

Figure 81: Probability of Visible Satellites above a 20 Degree Angle of Elevation at 40 Degrees North Latitude[104]

Approximately 90% of the time there should be at least two visible satellites above 20 degrees and service should be uninterrupted, barring other unforeseen circumstances.

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[101] Introduction to Globalstar, by Peter Bacon – Director, Regional Maketing, Globalstar. Copyright 1998, The Institute of Electrical and Electronics Engineers.
[102] Signal design and system operation of Globalstar versus IS-95 CDMA – similarities and differences, by Learnard Schiff and A. Chockalingam. Wireless Networks 6 (2000).
[103] Satellite Systems Performance with TCP-IP Applications by P. Loreti, M. Luglio, R. Kapoor, J. Stepanek, M. Gerla, F. Vataloaro, and M.A. Vazquest-Castro, Copyright 2001 IEEE.
[104] Quick Position Determination Using 1 or 2 LEO Satellites by Nadav Levanon, Tel Aviv University, IEEE Transactions on Aerospace and Electronic Systems. Vol. 34, No. 3, July 1998.

8.5.4. Propagation Analyses for Land-Mobile Radio and Cellular Coverage in Northern California

Propagation analysis can be used to predict coverage for various radio systems by taking into account attributes of those systems as well as terrain and vegetation. Several propagation analyses were conducted by Dr. William Jameson over the study areas to determine the effect of terrain on these areas. For the sake of simplicity, cell tower locations, as listed by the FCC, were used as tower locations in these analyses. No attempt was made to distinguish providers, so the coverage depicted may be greater than actual at the corresponding point in time. Note too that it is believed that subsequent towers have been brought into operation since the time of this analysis, so coverage has likely improved. The results are however quite demonstrative of the impact of terrain on the coverage of such systems.

8.5.4.1. Radio Coverage from Redding to Mount Shasta, Including Gibson

The following maps show approximations (Figure 82 and Figure 83) to cellular and 800 MHz land mobile coverage between Redding and Mount Shasta. Nine tower locations (Table 12) were used for this analysis. The large blue + signs in the figures are tower locations. Figure 82 shows approximated cellular coverage. Note that this plot is based on performance information obtained from a cellular engineer, but is not precise. (A more detailed analysis could be conducted using cellular propagation analysis tools, but that was determined unnecessary for the purposes of this study.) Figure 83 shows prospective coverage for the same area by an 800MHz Land Mobile radio system, assuming the same tower locations. Note that it is not implied that these are actual towers for an 800MHz system. They were chosen for the sake of demonstration and for comparison with cellular.

While these plots may not be precise, they do indicate the impact of irregular terrain on this region, and that towers appear to have been chosen to cover most of I-5 north of Redding. Note too that the two systems exhibit similar coverage.

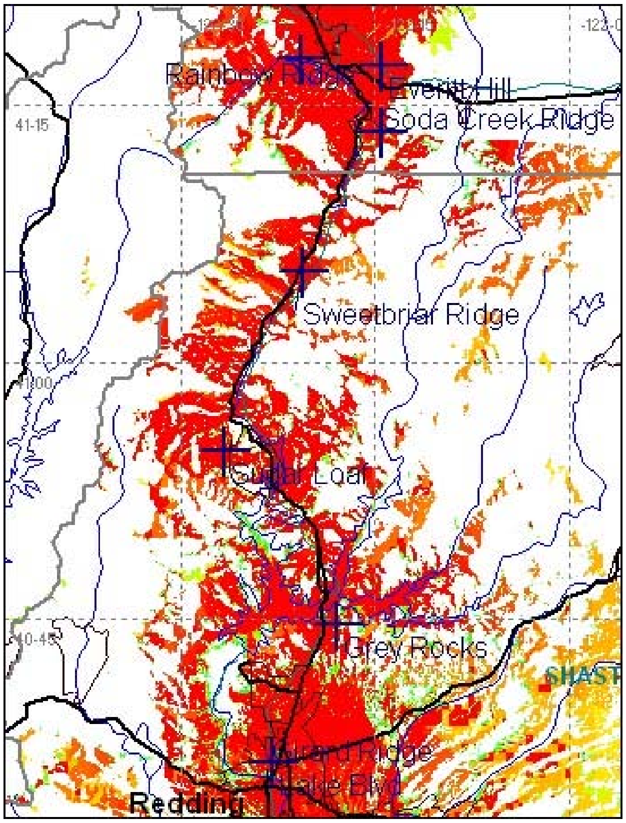

Figure 82: Redding I-5 Cellular Coverage Plot

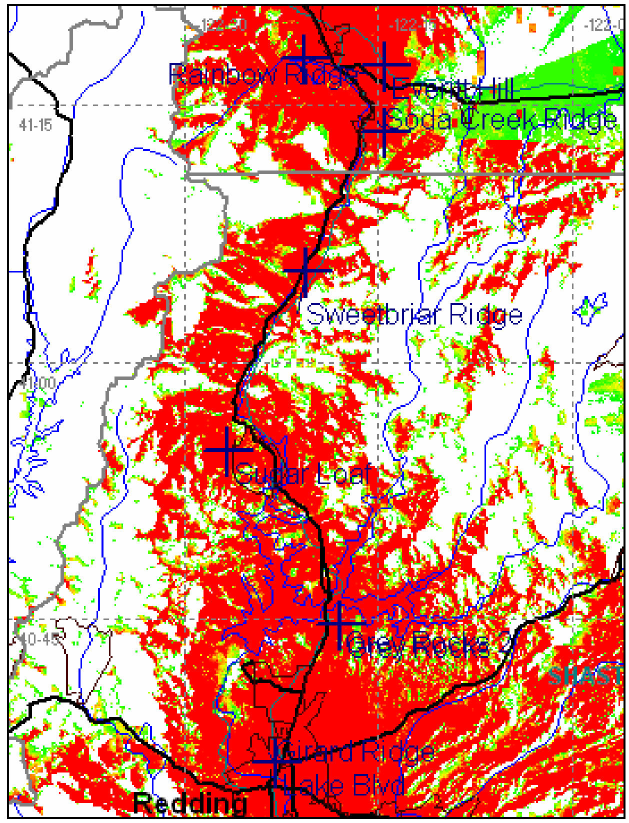

Figure 83: Redding I-5 800 MHz Land Mobile Coverage Plot

30 dBu – Excellent Coverage
20 dBu – Fair Coverage
10 dBu – Marginal Coverage

20 dBu - Excellent land mobile coverage
10 dBu -Good land mobile coverage
0 dBu -Acceptable land mobile coverage

Table 12: Tower Locations for Redding to Mount Shasta Propagation Analyses

Tower Site	Latitude	Longitude
310 Lake Blvd, Redding	40° 36' 39" N	122° 22' 55" W
Gray Rocks*	40° 44' 47" N	122° 18' 0" W
Gray Rocks*	40° 45' 2" N	122° 18' 8" W
Sugar Loaf	40° 54' 52" N	122° 26' 42" W
Sweetbriar Ridge	41° 5' 18" N	122° 20' 32" W
Girard Ridge	41° 7' 36" N	122° 17' 31" W
Soda Creek Ridge	41° 13' 29" N	122° 14' 33" W
Rainbow Ridge	41° 17' 43" N	122° 20' 41" W
Everitt Hill	41° 17' 19" N	122° 14' 29" W
		* Separate towers.

Figure 84 shows the tower locations, modeled coverage, and the Gibson maintenance yard location. Figure 85 shows a 3D view from Gibson north to Mount Shasta. Note that Gibson is on the fringe of modeled coverage. Notice further that coverage gaps exist along I-5. Figure 86 shows a 3D view south from Gibson toward Lake Shasta, Redding and the Central Valley. Similar coverage caps appear in this view.

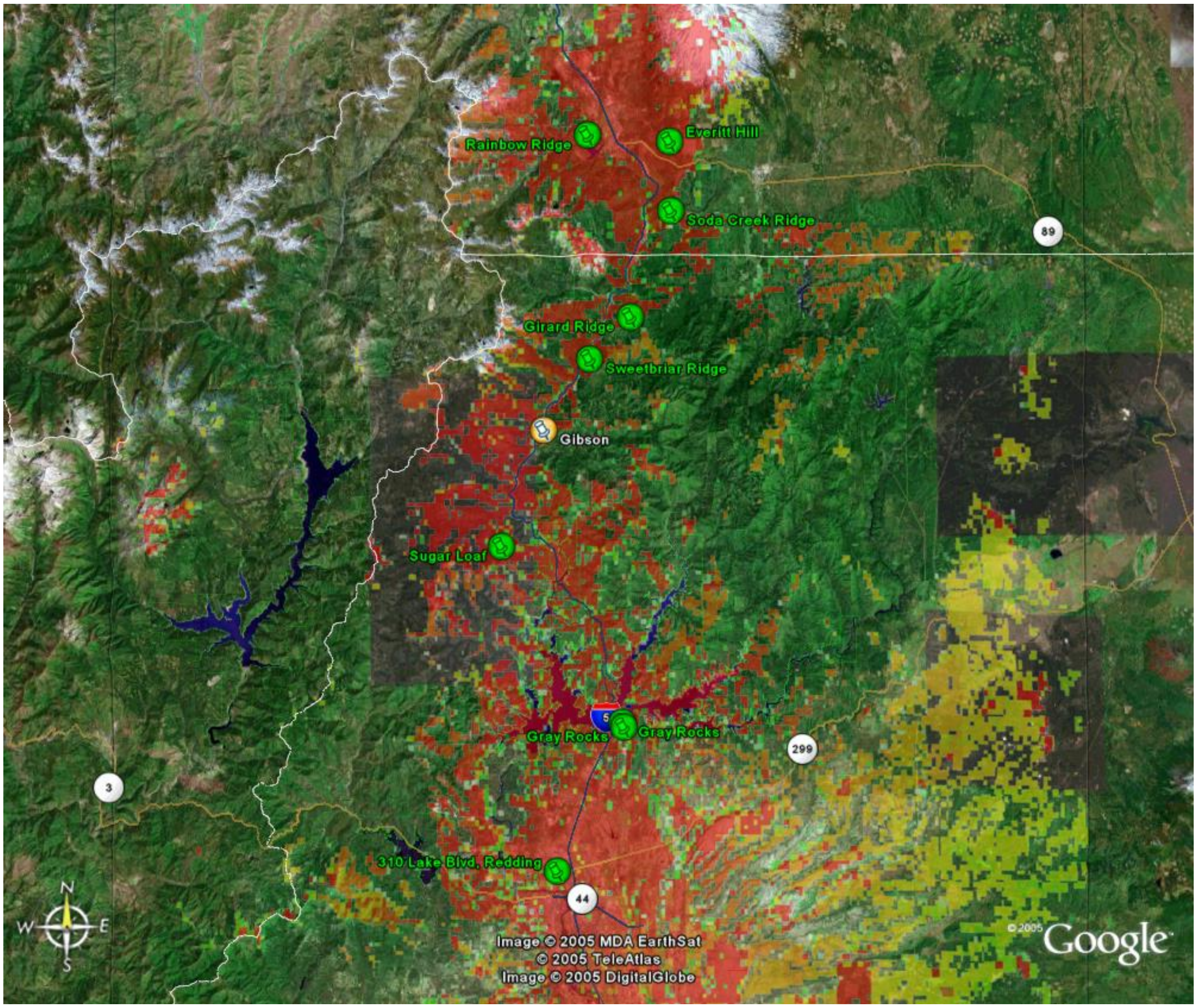

Figure 84: Gibson, Tower Locations and Modeled Cellular Coverage along I-5 North of Redding

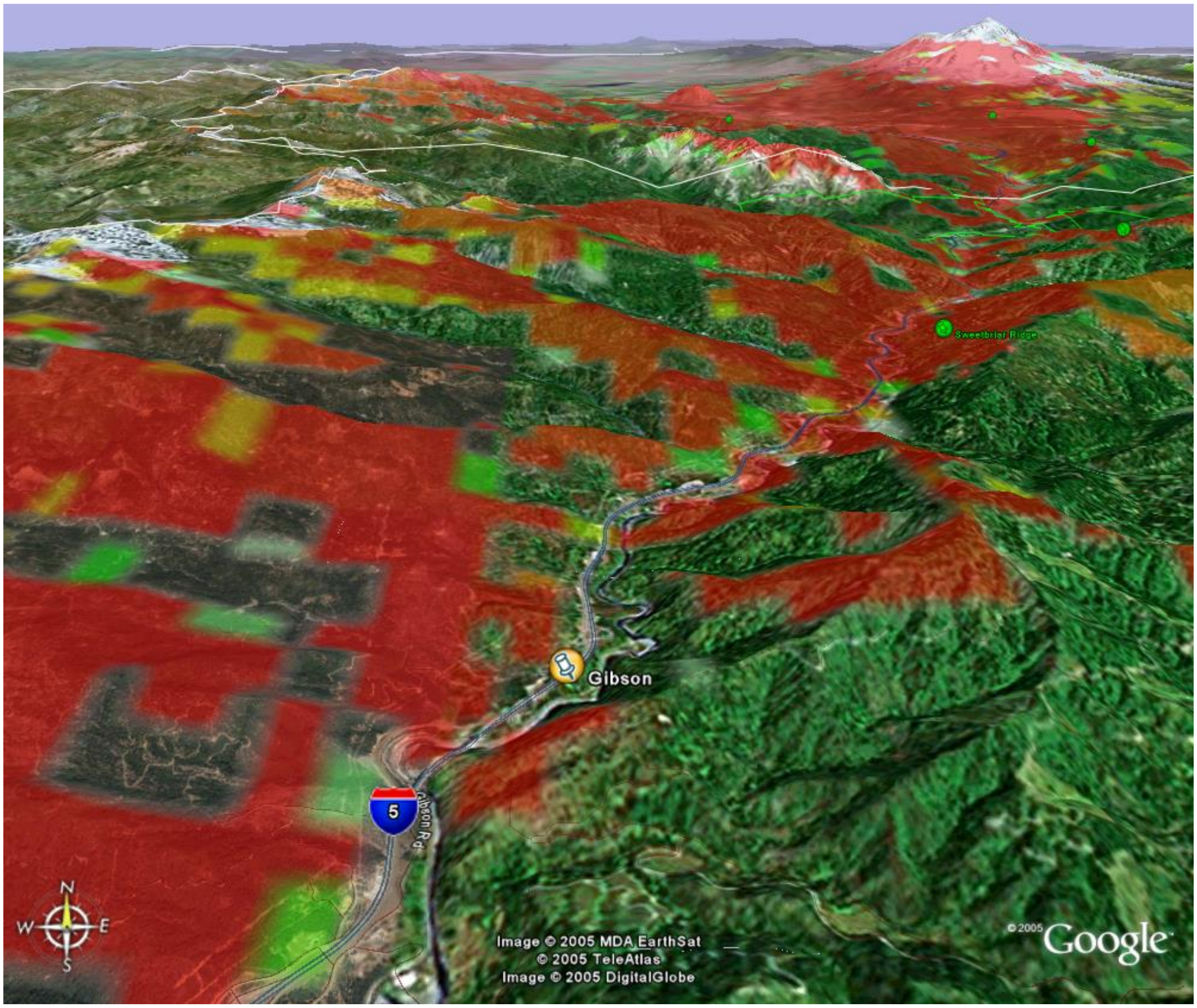

Figure 85: Modeled Cellular Coverage from Gibson North to Mount Shasta

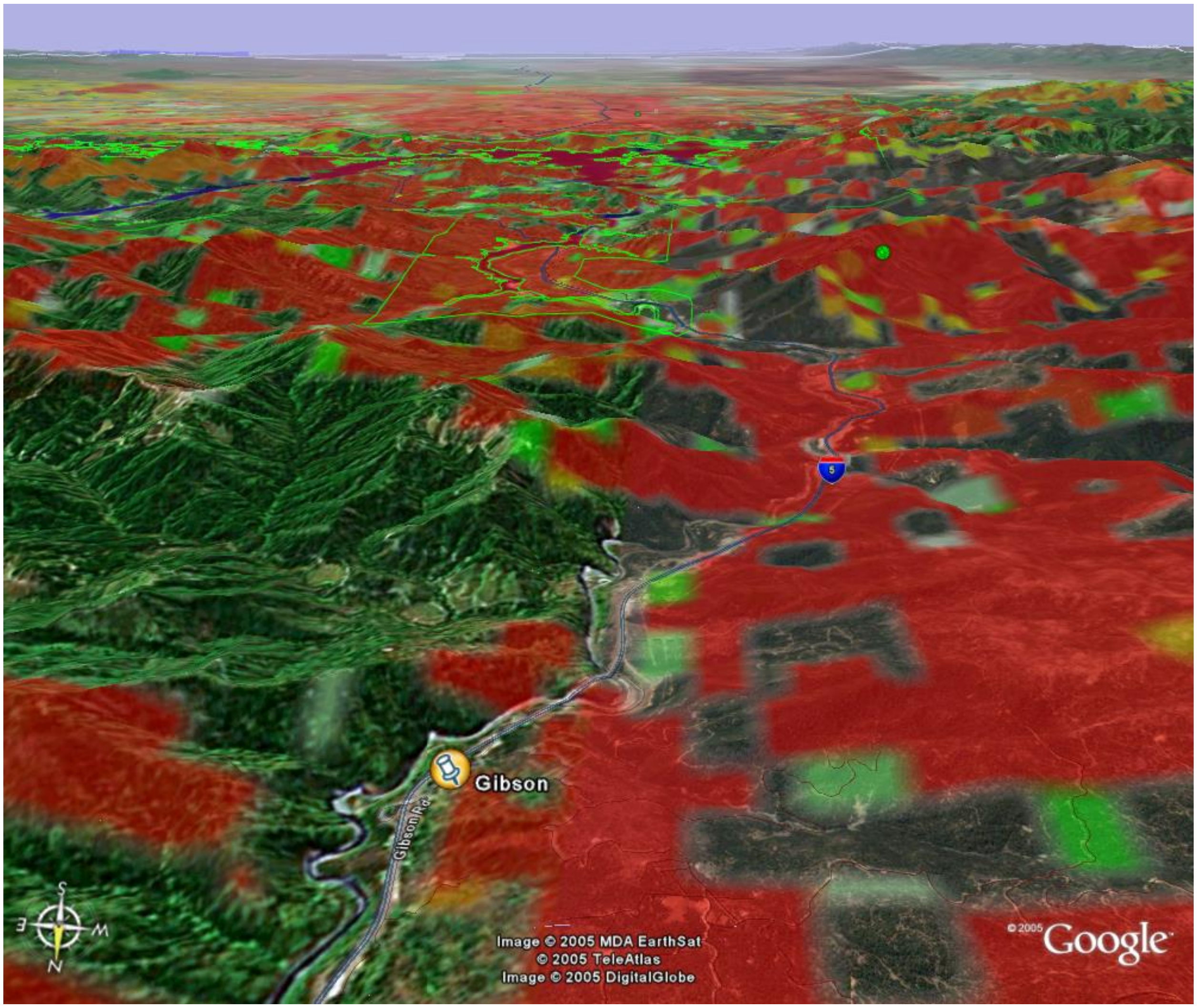

Figure 86: Modeled Cellular Coverage from Gibson South to Lake Shasta, Redding and South

8.5.4.2. Radio Coverage in the Redding and Oroville to Quincy

Similar analyses (Figure 87 and Figure 88) were conducted for the Feather River Canyon area following State Route 70 between Oroville (southwest/lower left corner) and Quincy (east/right central corner). Six known cellular tower locations (Table 13) were used for this analysis. Note that a significant portion of SR-70 has limited to non-existent coverage in these scenarios due to the rugged nature of the canyon. The towers in the Southwest corner of each plot provide substantial coverage to the South and West, but limited coverage in the canyon to the East.

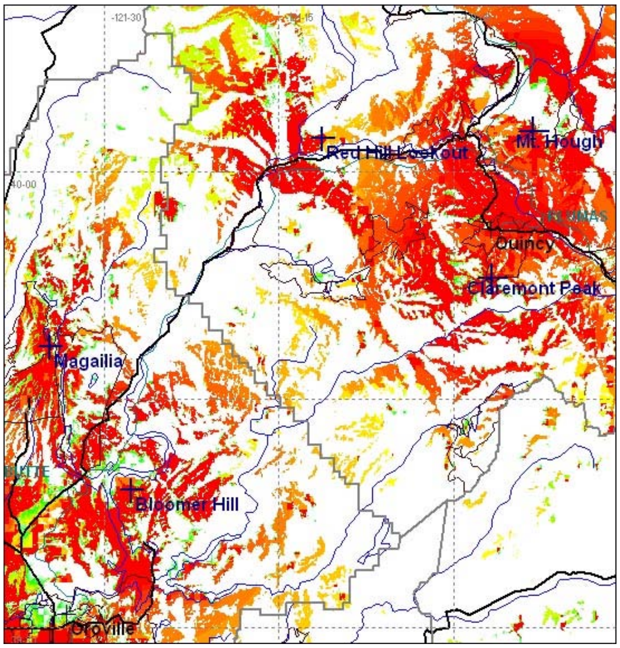

Figure 87: SR-70 Cellular Coverage Plot

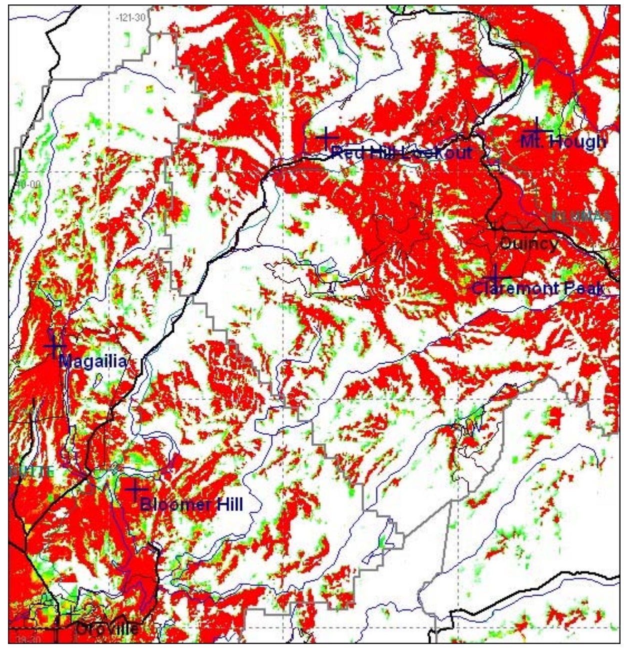

Figure 88: SR-70 800 MHz Land Mobile Coverage Plot

30 dBu – Excellent Coverage
20 dBu – Fair Coverage
10 dBu – Marginal Coverage

20 dBu - Excellent land mobile coverage
10 dBu -Good land mobile coverage
0 dBu -Acceptable land mobile coverage

Table 13: Tower Locations for SR-70 Propagation Analyses

Tower Site	Latitude	Longitude
Bloomer Hill Cell Tower	39° 39' 2" N	121° 27' 45" W
Red Hill Lookout Cell Tower	40° 2' 13" N	121° 11' 18" W
Magalia Cell Tower	39° 48' 32" N	121° 34' 43"W
Claremont Peak	39° 52' 59" N	120° 56' 43" W
Mt. Hough	40° 2' 39" N	120° 53' 8" W
Beckwourth Peak*	39° 46' 8" N	120° 26' 11" W
* Not visible on maps above. Falls to east of displayed region.		

The three-dimensional surface plot in Figure 89 demonstrates the impact of terrain on coverage in the Feather River Canyon. Note how the ridge in the southeast portion blocks coverage to the northwest. Note too how the valley floor is generally uncovered as it extends to the northeast.

The location of the SR-70 landslide is on a hillside, and appears to be on the fringe of prospective cellular coverage.

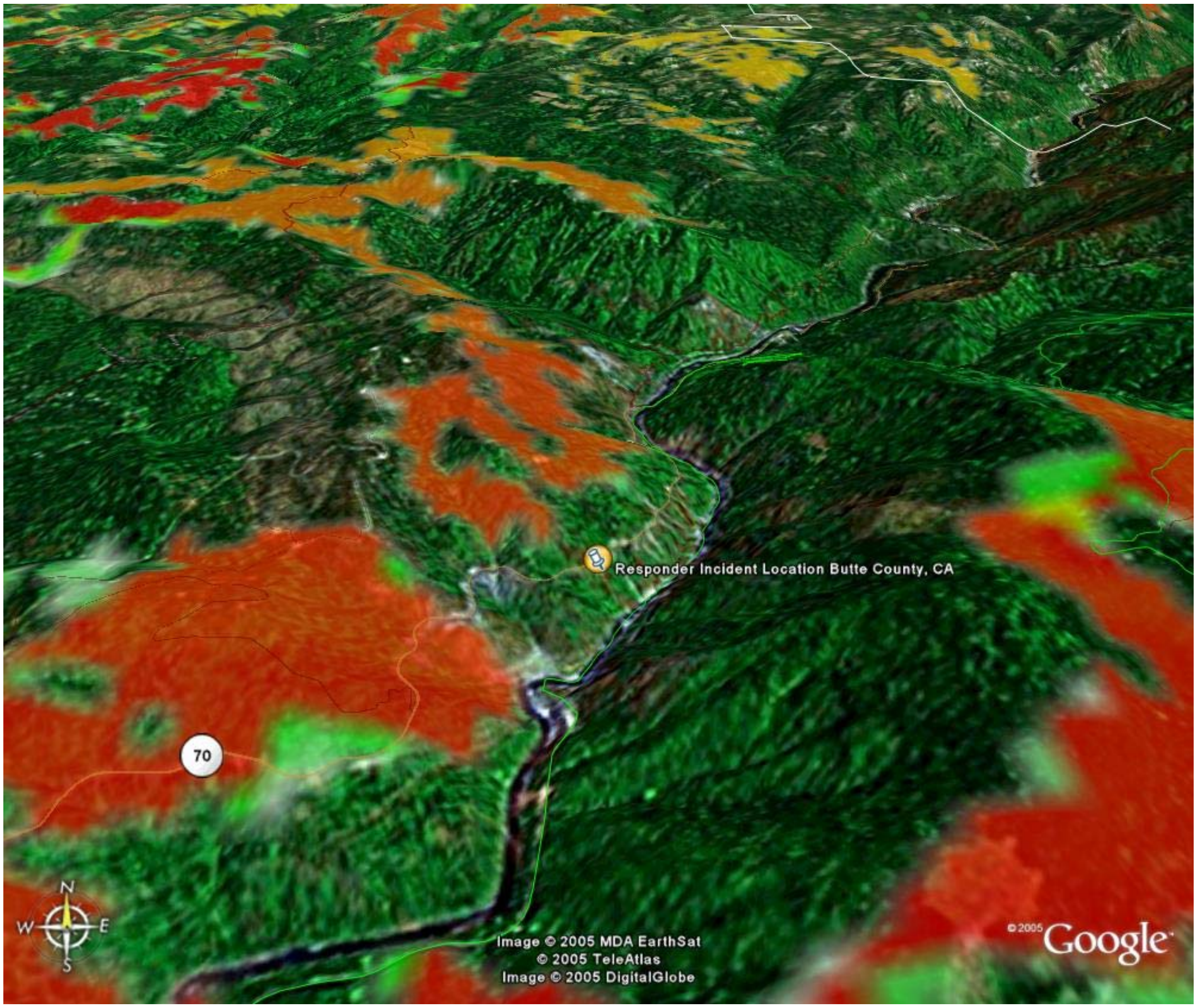

Figure 89: 3D Surface Plot of Cellular Coverage at Incident Location on SR-70 and North

Figure 90 shows coverage to the Southwest, particularly greater coverage near Oroville.

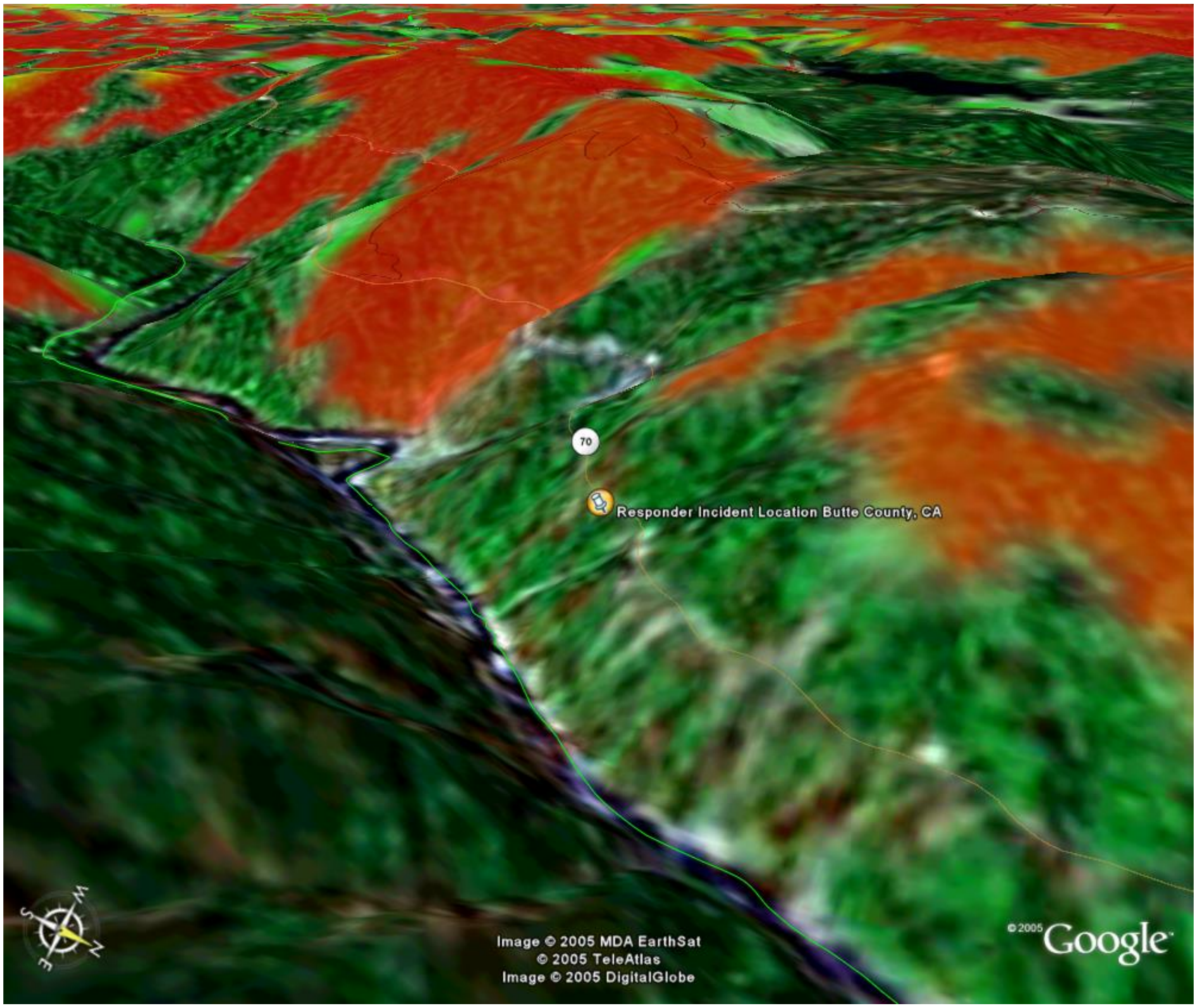

Figure 90: 3D Surface Plot of Cellular Coverage at Incident Location on SR-70 and Southwest

8.5.5. Northern California Cellular Signal Strength Drive Tests

In May 2005, signal strength readings were collected on over 1200 miles of state and federal roadways in Districts 2 and 3 (Figure 91 and Table 14). This process was automated using the LandCellular modem from the Responder system and a custom application on the Tablet PC that polled the modem for signal strength readings and recorded those readings with the associated time and location. Thus, it was possible to measure and record signal strengths "on-the-fly," while driving. The same setup was used for the Tablet and the other devices as was used for the Responder application.

On a related note, there were only several instances in which communication between the Responder tablet and the communication box was broken. In one case, on SR-70 near Oroville, communication mysteriously dropped. In a repeat visit to that location, it dropped again. This loss of communication was likely due to interference with the 802.11 system. However, this location exhibited no unusual characteristics such as power lines directly overhead or other obvious devices or communication systems. These are the only instances during this testing in which 802.11 communications was spontaneously lost. In another case, the box lost power after suddenly braking for deer on SR-3 between Weaverville and Yreka. After reconnecting, devices continued to function normally.

The Verizon CDMA network was used for this testing. Note that no distinction was made between analog and digital signal readings. Thus, the results indicate greater coverage for data communication than is truly available. It was observed manually that a large portion of this area, particularly the more remote locations, had analog cellular service rather than digital service. Other providers would likely exhibit different coverage with similar characteristics.

In general, coverage was good to excellent on Interstates 5 and 80, as well as along SR-70, SR-149, and SR-99 between Sacramento, Oroville, Chico and Red Bluff. There were a few gaps in coverage, particular in the mountainous areas of I-5 north of Redding and along I-80 near Truckee.

Coverage along US-50 and US-395 was fair, although there were significant coverage gaps on each. Coverage in other areas such as the Feather River Canyon (SR-70), the vicinity of Lake Almanor (SR-89), and SR-3 between Weaverville and Yreka was poor to non-existent.

These results were generally consistent with the results of the propagation analysis models in these areas.

Figure 91: Cellular Signal Strengths in Districts 2 and 3

Table 14: Routes Followed for Cellular Signal Strength Readings in Districts 2 and 3

From	To	Route	Mileage
Sacramento	Junction SR-70 & SR-149 Northwest of Oroville	SR-70	75
Junction SR-70 & SR-149 Northwest of Oroville	Red Bluff	SR-149, SR-99	60
Red Bluff	Redding	I-5	30
Redding	Weaverville	SR-299	50
Weaverville	Yreka	SR-3	100
Yreka	Redding	I-5	100
Redding	Alturas	SR-299	150
Alturas	Truckee	US-395, SR-70, SR-49, SR-89	200
Truckee	Reno	I-80	35
Truckee	Auburn, via South Lake Tahoe and Placerville	SR-267, SR-28, SR-89, US-50, SR-49	130
Sacramento	Auburn	I-80	40
Auburn	Truckee	I-80	70
Junction SR-70 & SR-149 Northwest of Oroville	Junction SR-70 & SR-89 near Paxton	SR-70	70
Junction SR-70 & SR-89 near Paxton	Red Bluff	SR-89, SR-36	100
		Total	**1210**

Figure 92 shows further detail for the loop between Oroville, Lassen National Park, and Red Bluff. This route follows SR-70, SR-89, and SR-36. Note the gap of nearly 30 solid miles having no coverage along SR-70 in the Feather River Canyon. From that point on, coverage is sporadic at best until near Red Bluff, which corresponds to emergence from the mountains.

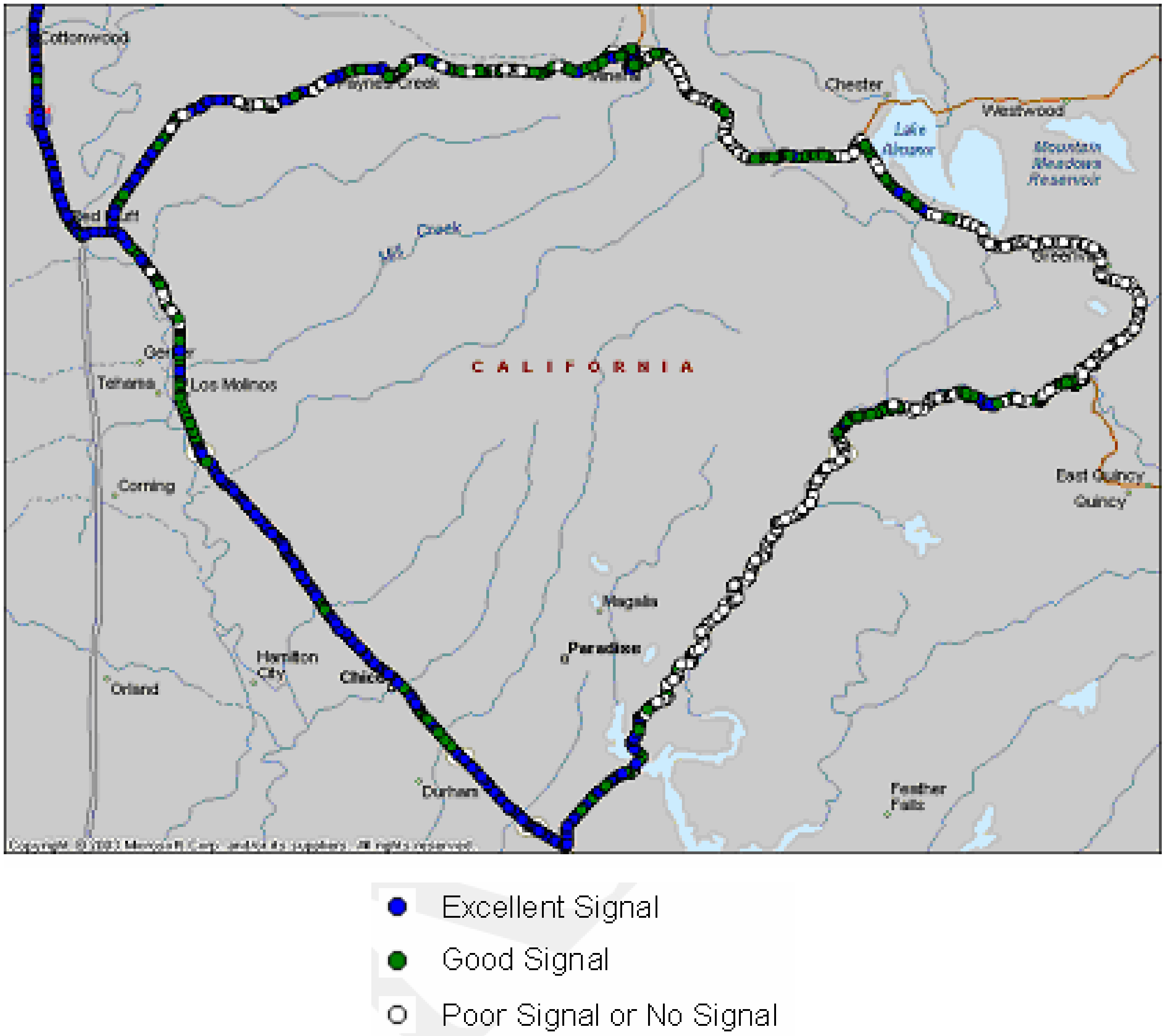

Figure 92: Cellular Signal Strengths on Loop between Oroville, Lassen and Red Bluff

8.5.6. Northern California Satellite and Cellular Signal Strength Site Tests

During site visits in October 2004 and May 2005, signal strength readings were recorded onsite at Gibson as well as at the SR-70 Butte County Landslide incident site. These readings were measured while parked for an extended period of time (approximately an hour). Readings were recorded both for satellite and cellular. Note that the October 2004 cellular readings were obtained using the Motorola V120 cell phone without an external roof-mount antenna. The May 2005 readings were obtained using the LandCellular modem with an external roof-mount antenna. Satellite readings were obtained using the Globalstar 1600 phone and the external roof-mount antenna. The data collection and recording process was automated during each site visit, with devices polled for signal strength at regular short intervals.

8.5.6.1. Gibson (I-5 between Redding and Mount Shasta)

Gibson is located off I-5 approximately 35 miles to the north of Redding and approximately 30 miles to the south of Mount Shasta. The maintenance yard is adjacent to I-5 and is in a moderately wooded area. Site tests were conducted near trees on the east side of the lot. Figure 93 shows a 360 degree panoramic image of the Gibson site. Figure 94 shows the same panoramic image of the site with a horizon profile and direction overlay. This overlay shows an approximate profile of surrounding geography altitudes, at eye level, excluding vegetation. (The horizon profile for Gibson and other sites were used in subsequent analysis, and are particularly relevant to the analysis of satellite coverage.)

Figure 93: 360 Degree Panoramic Image of Gibson Site

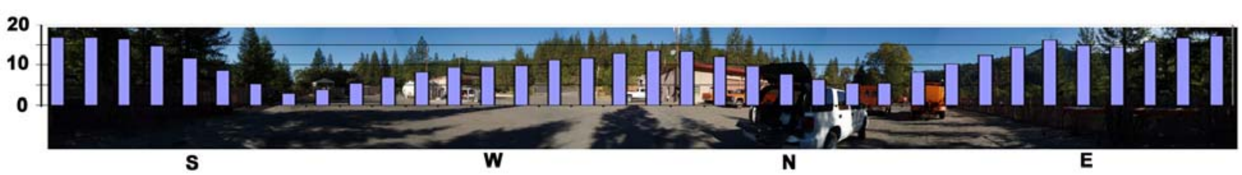

Figure 94: 360 Degree Panoramic Image of Gibson Site with Horizon Profile

As seen in Figure 94, the horizon is generally visible at angles above 20 degrees, except to the southeast, where trees obstruct the horizon more severely. Primary obstruction occurs between East and South, and North and West. In general, this area can be considered a North-South canyon. When viewing the North and South, clearings are observed in which the horizon is visible at angles less than 10 degrees.

Cellular Signal Strength Readings at Gibson

Cellular readings at Gibson exhibited irregular fluctuation during the October 2004 site visit. This behavior is likely attributable to a phenomenon known as “cellular breathing.” Cellular breathing is the expansion and contraction of “cells” dependent on usage. The coverage of a cell contracts with increased usage and expands with increased coverage.

Figure 95 shows cellular signal strength readings measured over a 36 minute period at Gibson in October 2004. Signal strength can range from a minimum of 0 to a possible maximum of 31. The maximum signal strength recorded during this time was 18 and the minimum was 0. Readings fluctuated between 0 and 18, with only two noticeable periods of relatively stable signal strengths. The most likely explanation for this is there were times of increased use by drivers on the nearby interstate. If that is the case, then the corresponding tower appears to have limited capacity that is saturated quite easily.

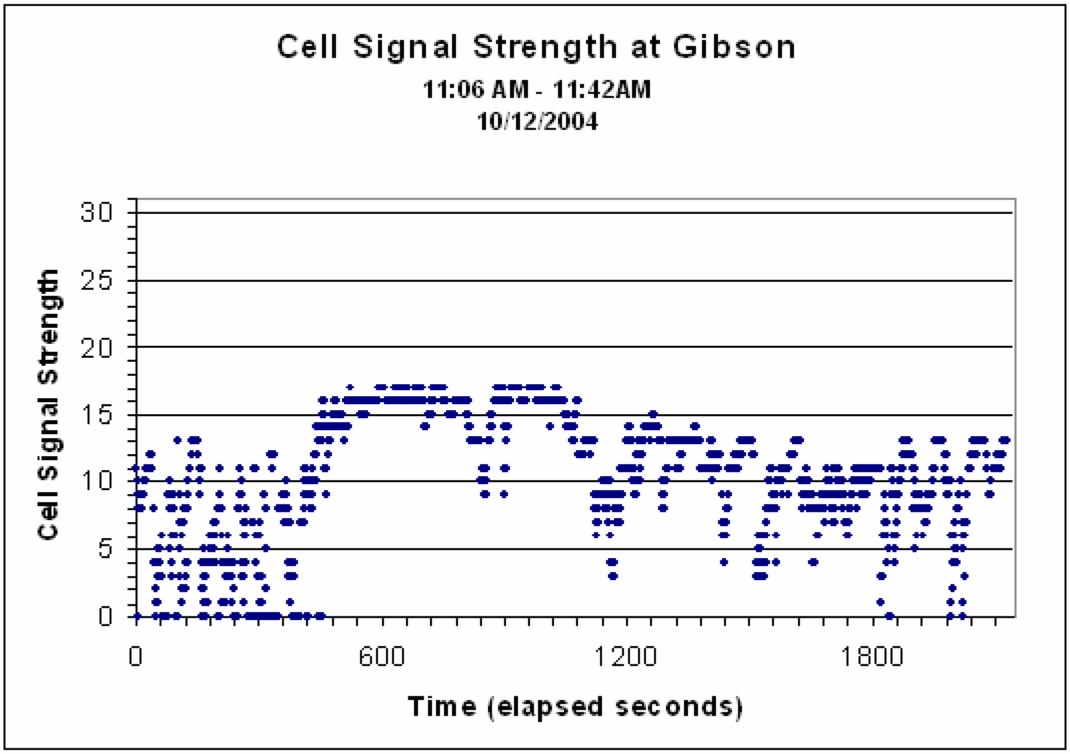

Figure 95: Cellular Signal Strength Readings at Gibson, October 2004

In data transmission testing subsequent to the observed “cellular breathing” phenomenon, it was further observed that data rates were very low at the Gibson location in comparison to other locations. In fact, the satellite connections provided better overall data rates and download success rates.

Note that in subsequent testing in May 2005, signal strength was observed at Gibson at the maximum, and a tower was noticed in proximity of the station. It appears that the network had been expanded to increase capacity at this location. Subsequent data transmission tests using cellular were successful in every case.

The difference in coverage between October 2004 and May 2005 can be seen by comparing Figure 96 to Figure 97 and Figure 98 to Figure 99. Note that the use of different equipment during these two site visits is a partial reason for differences in readings. However, relative readings show improved service in proximity of several locations including Gibson and Dunsmuir.

In October 2004, Gibson may have been on the fringe of cellular coverage and, if so, would have been more susceptible to noticeable "cellular breathing." The apparent new tower and observed increase in signal strength definitely improved coverage and reliability at Gibson.

Having cellular signal strength is not a sufficient indication that cellular can be used effectively for data transmission. At minimum, a threshold should be set for signal strength such that if readings fall below that threshold, cellular service may exhibit poor performance. Further investigation would be required to set such a threshold, which may be dependent on equipment, provider, and underlying technologies.

Table 15: Legend for Cellular Signal Strength Readings

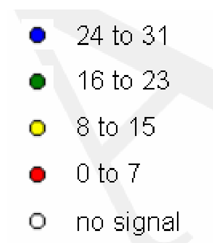

Figure 96: Cellular Signal Strength Readings, I-5 Redding to Mount Shasta (Motorola V120 Phone) 10/12/2004

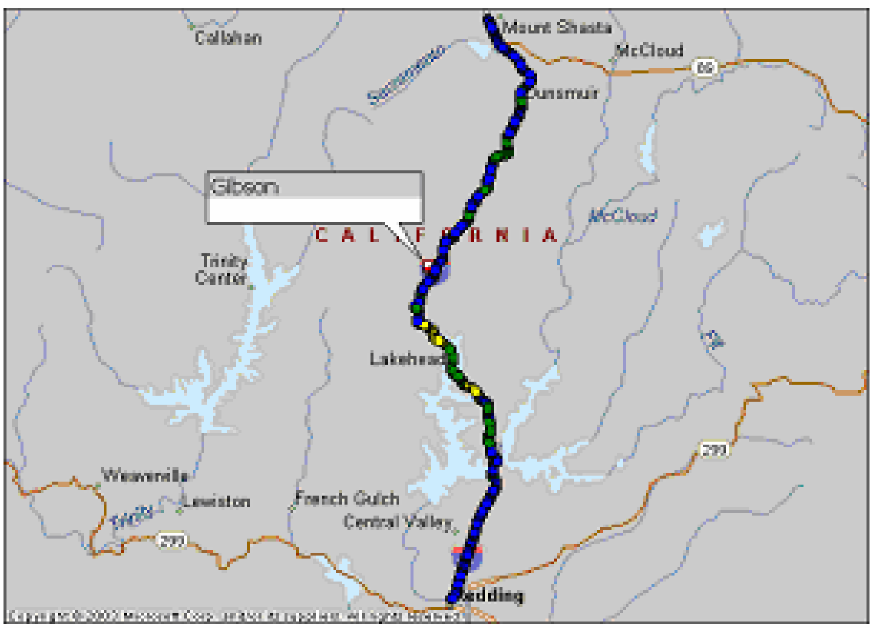

Figure 97: Cellular Signal Strength Readings, I-5 Redding to Mount Shasta (LandCellular Modem with Roof Mount Antenna) 5/12/2005

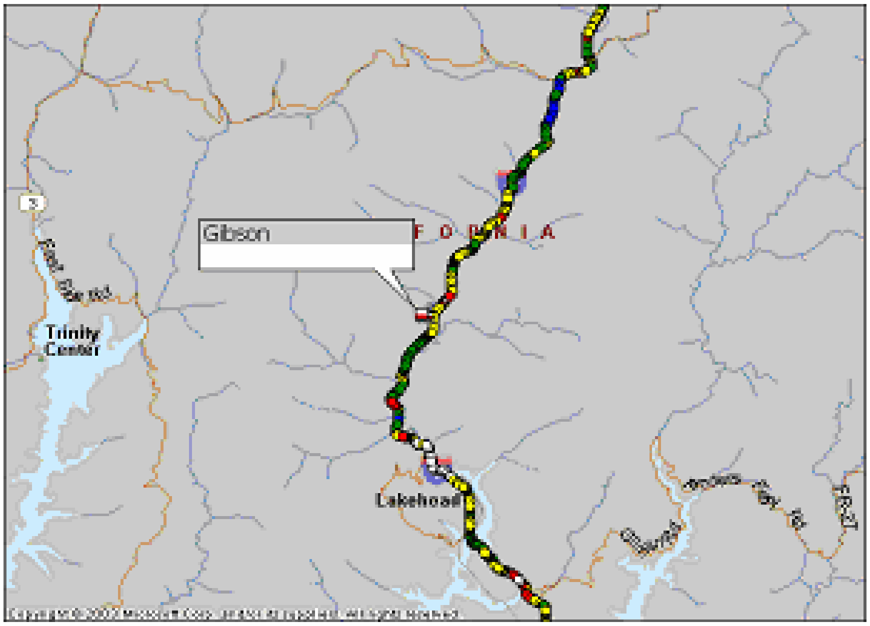

Figure 98: Cellular Signal Strength Readings, I-5 Gibson Area (Motorola V120 Phone) 10/12/2004

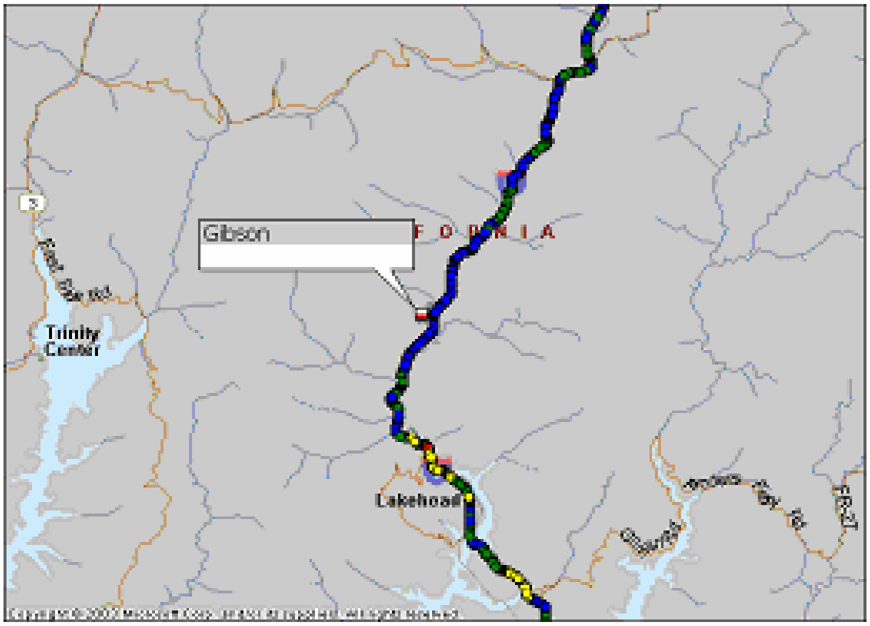

Figure 99: Cellular Signal Strength Readings, I-5 Gibson Area (LandCellular Modem with Roof Mount Antenna) 5/12/2005

Satellite Signal Strength Readings at Gibson

Satellite signal strength readings were excellent at Gibson, with little variation from a maximum possible 4 signal strength.

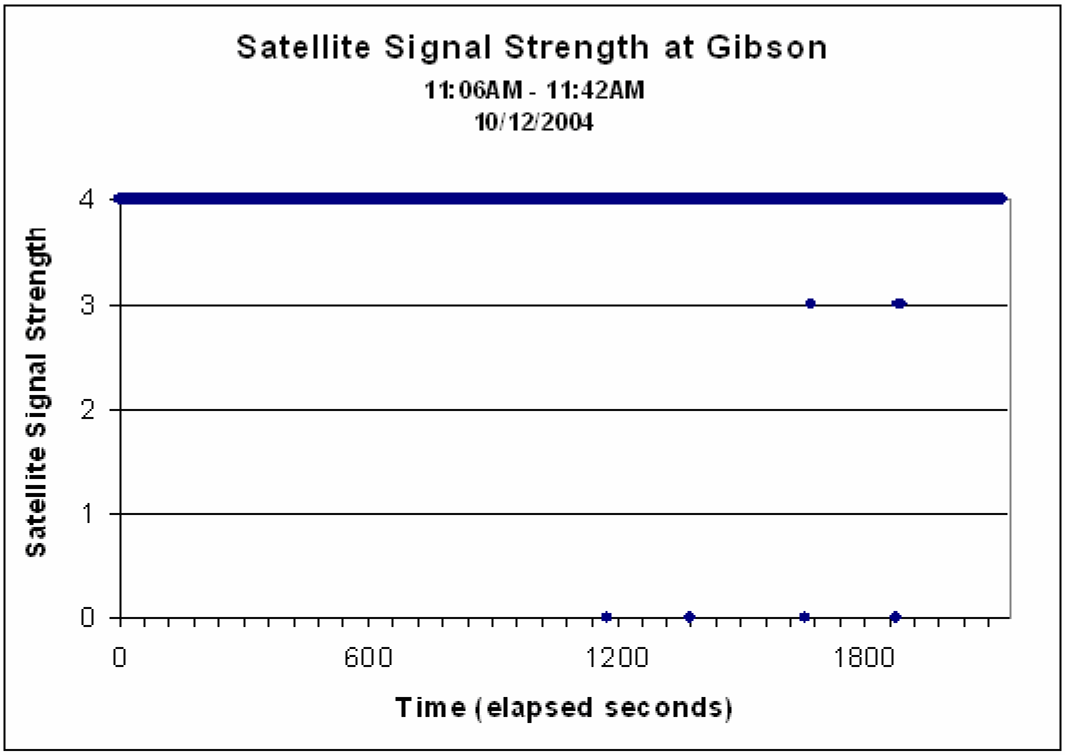

Figure 100: Satellite Signal Strength Readings at Gibson, October 2004

Table 14 shows the signal strength readings and times in which satellite signal strength was not at the maximum of 4. Note that there was no outage long enough to break a connection. (Generally, more than five seconds of 0 signal strength would break a connection.)

Table 16: Satellite Signal Strength Readings Less than Maximum 4 at Gibson, October 2004

Time	Signal (Other than 4)
1181	0
1657	0
1672	3
1674	3
1675	3
1880	0
1882	3
1885	3
1886	3
1888	3
1889	3
1890	3
1892	3

8.5.6.2. SR-70 Butte County (Landslide Incident Location)

This test site is located at a pull-off adjacent to the SR-70 incident used as a primary example in this document. It is 25 miles to the northeast of Oroville and 55 miles west of Quincy. Figure 101 shows a 360 degree panoramic image of the SR-70 Butte County site. Figure 102 shows the same panoramic image of the site with a horizon profile and direction overlay. This overlay shows an approximate profile of surrounding geography altitudes, at eye level, excluding vegetation. (The horizon profile for this site and other sites were used in subsequent analysis, and are particularly relevant to analysis of satellite coverage.)

Figure 101: 360 Degree Panoramic Image of SR-70 Butte County Site

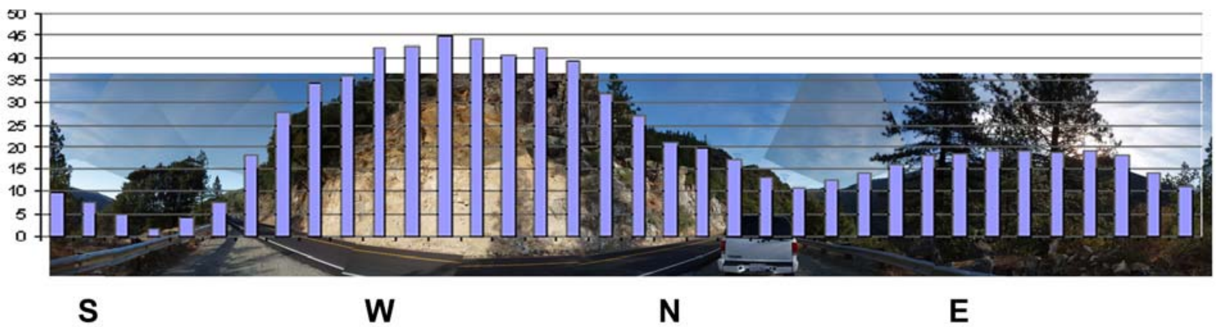

Figure 102: 360 Degree Panoramic Image of SR-70 Butte County Site with Horizon Profile

As seen in Figure 102, the rock-face to the west-northwest causes significant obstruction of the sky, up to a 45 degree angle of elevation. Further obstruction appears to the east-southeast, where a mountain reaches nearly a 20 degree angle of elevation. Vegetation in that direction causes further obstruction. To the south-southwest, there is a partial clearing, with obstruction from several trees. There is a lesser clearing to the northeast.

Due to their wide coverage, these panoramic images distort the significance of the obstruction caused by the rock-face as would be seen by someone standing at the side of the road. This rock-face, the source of the example rockslide, appears nearly vertical to someone standing at its base. Figure 103 show SR-70 in the southwest direction from the test site. Note that this photo shows where the sample rockslide occurred. Figure 104 shows the rock-face to the west-northwest. The camera was tilted at approximately a 25 degree angle of elevation when taking this photo. Not shown is an equally steep drop-off to the rear, which descends to the valley floor and the Feather River.

Figure 103: SR-70 Butte County Incident Location / Test Site

Figure 104: SR-70 Butte County Incident Location / Test Site View of Rock-Face

Cellular Signal Strength Readings at SR-70 Butte County Incident Site

In October 2004, no signal strength was available at this site. The Motorola V120 phone was used for testing, and no external antenna was used.

In May 2005, the LandCellular modem was used for testing with the roof-mount, external antenna. Signal strength was measured and recorded, as shown in Figure 105.

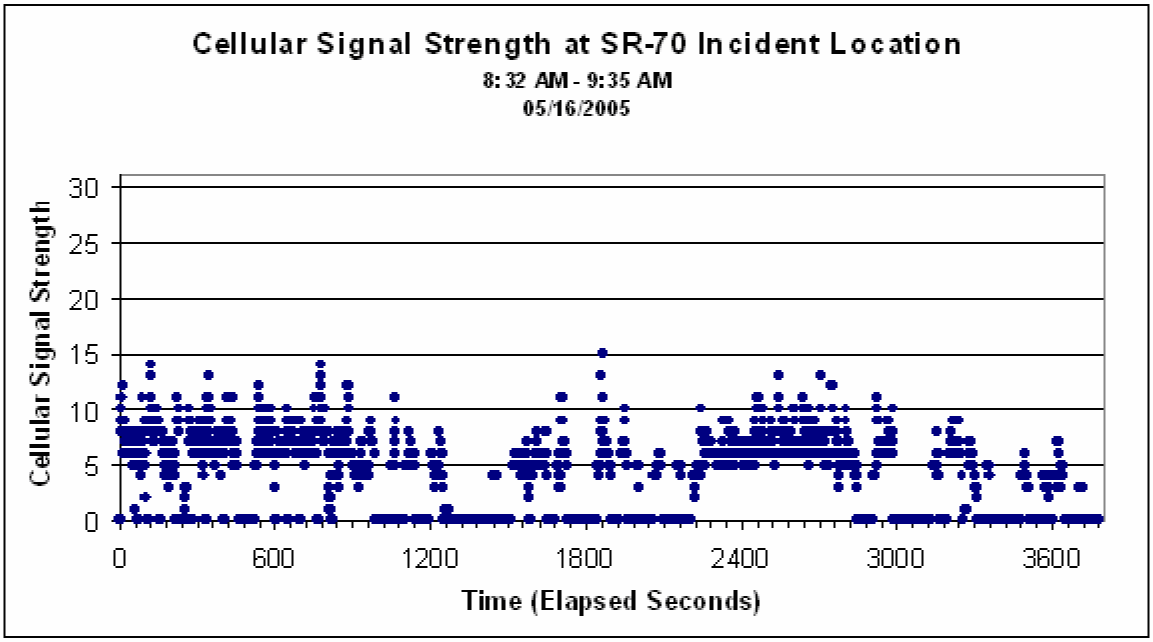

Figure 105: Cellular Signal Strength Readings at SR-70 Butte County Incident Location May 2005

These readings appear similar to those taken at Gibson in October 2004 (Figure 95), although they are somewhat lower in general, with more readings of 0. Since this area is on the fringe of cellular coverage at best, “cellular breathing” is likely the cause of these fluctuations.

Note that in May 2005, all attempts to transmit data via cellular failed.

Satellite Signal Strength Readings at SR-70 Butte County Incident Site

It was anticipated that satellite signal strength readings would be adversely impacted at this location, and interesting fluctuations were observed. Furthermore, apparently significant differences were noted between readings taken in October 2004 and May 2005.

Figure 106, Figure 107, Figure 108, and Figure 109 show 124 minute, 44 minute, 10 minute, and 3 minute intervals of signal strength readings from October 11th, 2004. These intervals overlap and show the first portion of the overall interval in which readings were taken on that date. The greatest variation in signal strength readings was observed at the beginning of monitoring, and the shorter intervals show this variation in greater detail.

As seen in Figure 106, most fluctuation occurred in the first ten minutes, with another short drop in signal strength after 40 minutes. With the exception of that drop, signal strength was excellent for over 110 minutes. Considering the significant obstruction of the sky at this site and subsequent measurements in May 2005, this lengthy period of good service was surprising, particularly in light of the early fluctuations. While these readings might be questionable, they are not beyond possibility when considering that there is a significant portion of unobstructed sky at this site. No equipment malfunctions were noticed during this time period, although invalid readings are a possibility as well. The brief recorded outage after 40 minutes would lead one to believe that valid readings were being recorded.

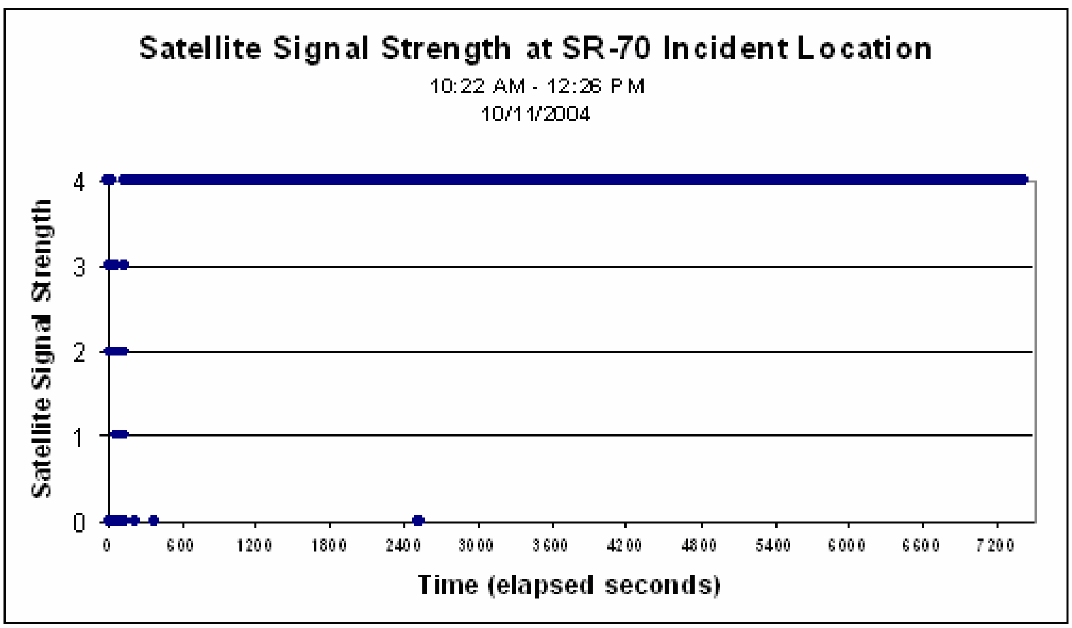

Figure 106: Satellite Signal Strength Readings at SR-70 Butte County Incident Location October 2004 (124 minute interval)

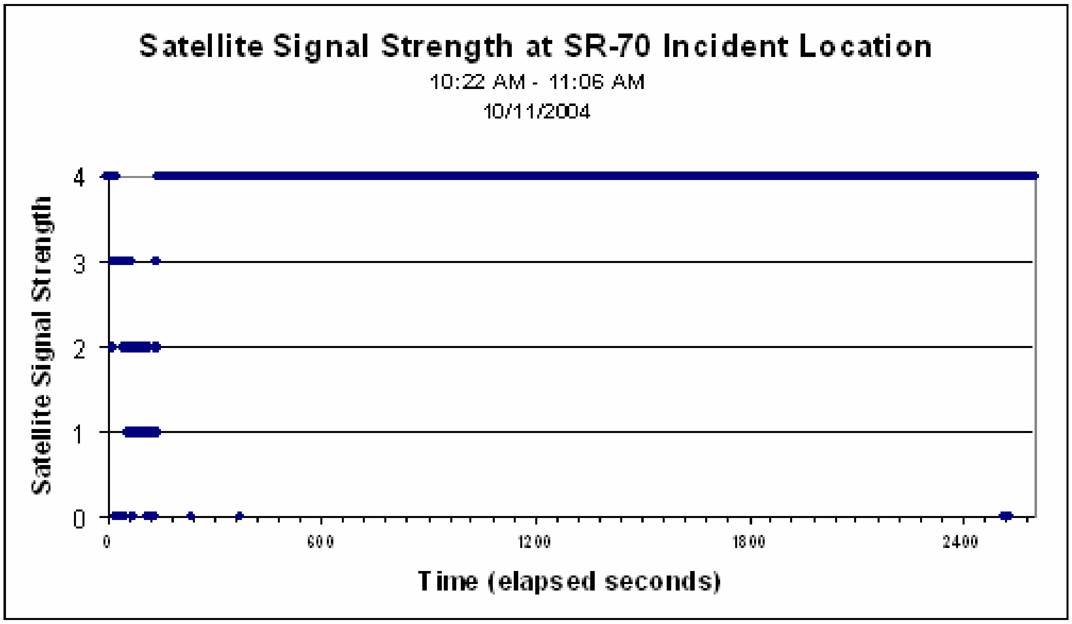

Figure 107: Satellite Signal Strength Readings at SR-70 Butte County Incident Location October 2004 (44 minute interval)

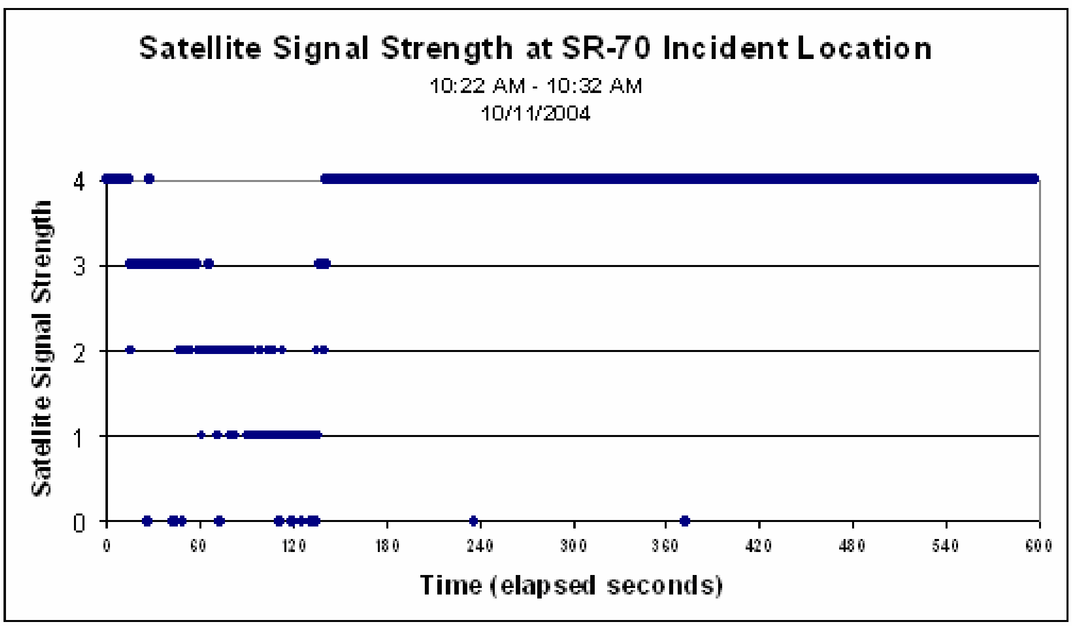

Figure 108: Satellite Signal Strength Readings at SR-70 Butte County Incident Location October 2004 (10 minute interval)

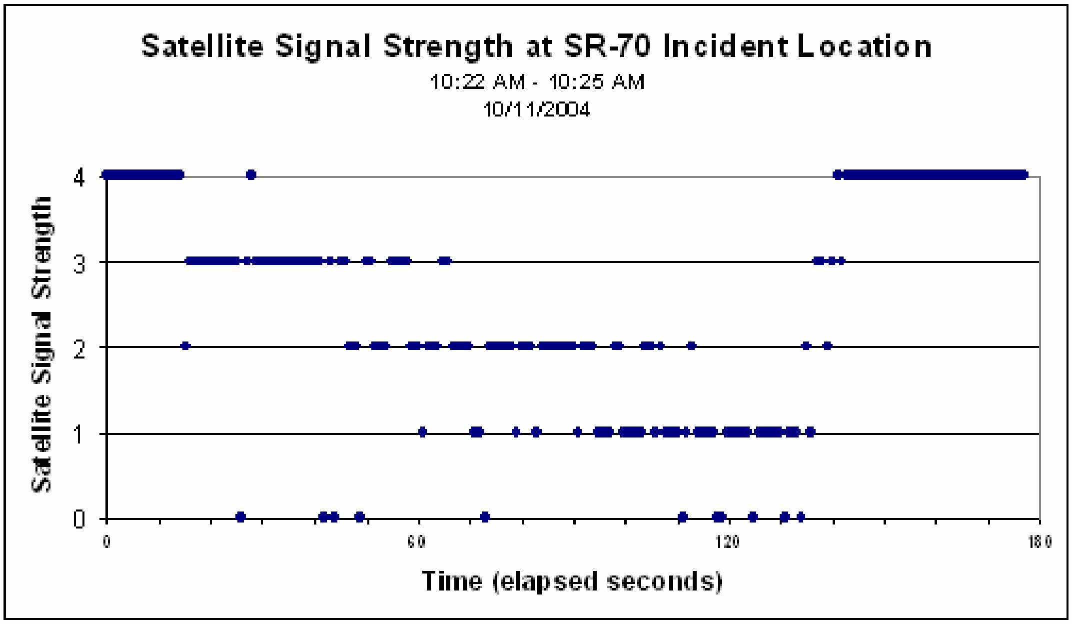

Figure 109: Satellite Signal Strength Readings at SR-70 Butte County Incident Location October 2004 (3 minute interval)

Signal strength readings were recorded at the SR-70 Butte County Incident Location again in May 2005 on an interval of just over one hour (Figure 110). In comparison to the October 2004 readings, observations showed fluctuation over the entire interval, with short periods of steady coverage. As will be demonstrated later in this report, significant variation in signal strength at a given location over extended periods of time should be expected at locations with a severely obstructed view of the sky. But, patterns in this variation may be difficult to identify. Thus, it can not be said conclusively that the results of October 2004 and those of May 2005 are inconsistent. For instance, it may be that at this location there are extended periods (one or several hours) of excellent coverage and extended periods of fluctuating coverage. However, it should be noted that changes in the Globalstar constellation[105] may have contributed to observed differences.

Definite fluctuations were observed during the May 2005 monitoring interval, and these fluctuations were characteristic of use of the satellite system in areas with an obstructed view of the sky. That does not mean however that use of the system is impossible in the presence of such fluctuations. For a signal to be dropped there generally must be a period of five seconds or more in which signal strength has dropped to zero. Table 17 shows intervals of signal availability/unavailability within the observation interval. During this time, there were intervals in which signal strength was available for as little as 1 minute and as much as 20 minutes. Thus, there were windows of opportunity for connectivity during this time interval. However, some intervals were short, and they did not appear to be predictable.

[105] Globalstar SEC Filing: http://www.sec.gov/Archives/edgar/data/933401/000089161803004420/f92214e10vq.htm

Conclusions that can be drawn from these observations are that a number of redials would likely be necessary in order to establish a connection long enough to make a data transmission, and that the size of that data transmission should be constrained if it were to be transmitted entirely in one interval.

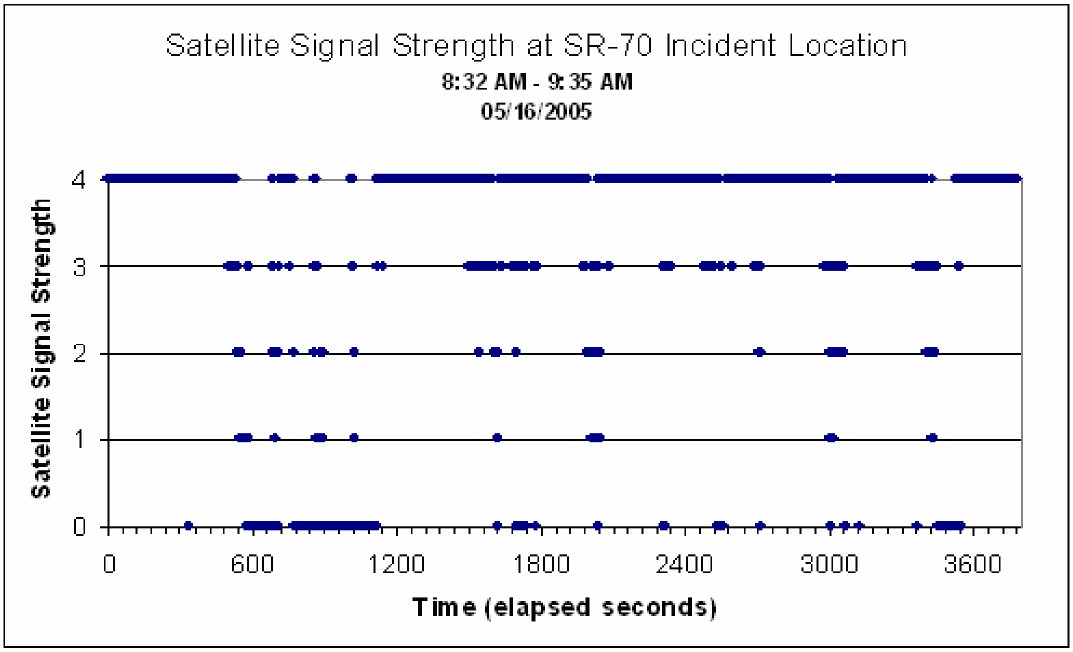

Figure 110: Satellite Signal Strength Readings at SR-70 Butte County Incident Location May 2005 (63 minute interval)

Table 17: Signal Availability/Unavailability Intervals Determined by Losses of 5 Seconds or More

signal available	duration (min)	elapsed (min)	elapsed (sec)
yes	**5.57**	5.57	**334**
no	0.18	5.75	**345**
yes	**3.82**	9.57	**574**
no	2.05	11.62	**697**
yes	**1.08**	12.70	**762**
no	5.75	18.45	**1107**
yes	**19.80**	38.25	**2295**
no	0.25	38.50	**2310**
yes	**3.75**	42.25	**2535**
no	0.23	42.48	**2549**
yes	**8.27**	50.75	**3045**
no	0.13	50.88	**3053**
yes	**6.33**	57.22	**3433**
no	1.25	58.47	**3508**
yes	**4.32**	62.78	**3767**

8.5.7. Northern California Satellite Signal Strength Modeling and Analysis

There are a number of pros and cons to satellite service, some technical, and others financial. The goal of this analysis is to model, characterize, and quantify technical performance in rugged terrain and, if possible, compensate for this performance within the application. Compensation might include determining optimal sizes of data for transmission, or setting redial or timeout parameters. A numerical model was created to conduct this analysis. The advantage of this approach is that extensive data could be generated and evaluated over a greater number of sites and time than would be feasible for empirical measurement. The resulting data should be interpreted in light of the actual measured observations provided in previous sections.

8.5.7.1. Overview of the Globalstar Constellation

The Globalstar constellation can be described as follows[106]:

- There are 48 total satellites, 6 per orbit plane.
- There are 8 orbit planes, each with a declination of 52 degrees.
- The satellites orbit at approximately 1410 km above the earth and with a period of approximately 114 minutes.
- The satellite nominal footprint is 5850 km.

Globalstar phones communicate with these satellites using CDMA technology in a manner similar to that of cell phones communicating with cell towers. Handoffs from satellite to satellite provide the handset with continual coverage, where possible. For instance, when a satellite providing the current connection nears the horizon, the signal should be handed off to another satellite. Under ideal circumstances, the handset communicates with multiple satellites and this handoff occurs without disruption of service to the handset. However, situations can occur in rugged areas when a satellite passes out of sight over a mountain and no other satellite is immediately visible for handoff. In part, if not entirely, this explains the dropped calls and signal fluctuations that were observed. This phenomenon seems quite likely in narrow canyons. A given satellite's visibility to a fixed location, even in flat areas, lasts only a matter of minutes. In addition, the orbit planes are separated by a great enough distance to make this explanation viable. Dense vegetation could cause similar problems.

NOTE: Globalstar has subsequently transitioned from a 6 satellite per orbit plane configuration to a 5 satellite per orbit plane configuration called a "Walker 40." This was done to fill coverage gaps caused by satellite failures. This situation as well as Globalstar's financial situation should be monitored closely. Former Globalstar partner, Loral QUALCOMM Satellite Services, L.P. filed voluntary Chapter 11 bankruptcy in 2002.[107]

In their Securities and Exchange Commission Filings, Globalstar reports the following potential causes of future failures:[108]

[106] http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/tables/tables.html
[107] Globalstar SEC Filing: http://www.sec.gov/Archives/edgar/data/933401/000089161803004420/f92214e10vq.htm
[108] Globalstar SEC Filing: http://www.sec.gov/Archives/edgar/data/933401/000089161803004420/f92214e10vq.htm

- component failure;
- loss of power or fuel;
- inability to control positioning of the satellite;
- solar and other astronomical events; and
- space debris.

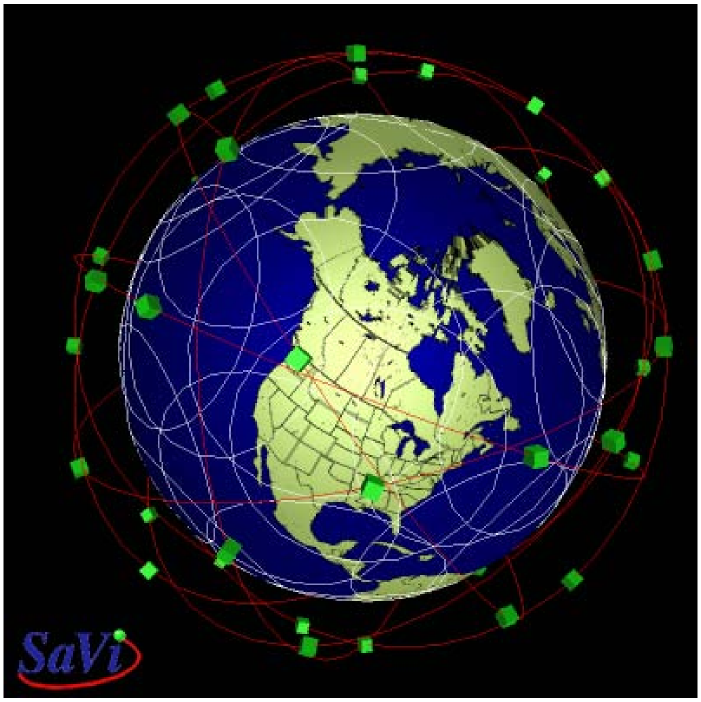

Figure 111: Globalstar Constellation Generated with SaVi[109,110]

In March, 2003, Globalstar reported the following regarding voice quality of service:

> *Call success rates for phones used in the system by an experienced operator with a clear view of the sky should exceed 98% based on Globalstar's extensive testing program. The actual average for January 2003 based on call data processed through Globalstar's billing system was 83% for all phone types. In Globalstar's highest traffic gateway, as the call volume has significantly increased, the call success rate has climbed to 90%. Globalstar believes that the lower system average is due to a substantial number of users attempting calls in adverse environments and circumstances. Fixed phones, not unexpectedly, had much higher success rates (average of 92%). An individual phone's actual call success rate is highly dependent upon its use, with variables being the physical*

[109] SaVi: http://www.geom.uiuc.edu/~worfolk/SaVi/
[110] http://www.ee.surrey.ac.uk/Personal/L.Wood/constellations/globalstar.html

> *surroundings (e.g., the presence of tall buildings or trees), location of the phone in the service area (e.g., a phone on the very edge of a large coverage area, as opposed to closer to the gateway) and operator experience. The system consistently demonstrates excellent voice quality. Single calls lasting more than two days have been made to confirm the effectiveness of the system's soft hand-off from satellite to satellite and the completeness of the satellite coverage.*[111]

Note the comments regarding capacity, physical surroundings, and operation on the edge of large coverage areas. These are all factors that must be accounted for in evaluating service. Globalstar and other providers recently experienced significant challenges during hurricane Katrina and other hurricanes in 2005 and claim to have faired well. In fact, Globalstar states that their, " network was designed from the start to provide uninterrupted service regardless of events on the ground."[112] Globalstar further noted that they doubled capacity for calls to landline phones, increased active spectrum allocation to handle increased volume, re-allocated gateway coverage footprints to increase capacity in the Gulf region, and continually monitored usage to accommodate usage increases.[113] Tony Trujillo, Chairman of the Satellite Industry Association (SIA) testified before the Committee on Energy and Commerce Subcommittee on Telecommunications and the Internet of the United States Houses of Representative on September 29, 2005 that over 20,000 phones from three vendors including Globalstar were deployed to the Gulf region immediately following Hurricane Katrina and that subscribers and volume increased dramatically. Despite these dramatic increases, he stated that "mobile satellite service providers performed nearly flawlessly."[114] The obvious reason that satellite was so widely used during these catastrophes was that other service simply was not available – infrastructure had been destroyed or severely damaged, and service could not resume until it was replaced or repaired.

8.5.7.2. Characteristics of the Globalstar Constellation

The Globalstar constellation is referred to as a "Big LEO," where LEO standards for Low Earth Orbit. Unlike Geosynchronous (GEO) satellites, satellites in the Globalstar constellation do not remain at a fixed point in the sky. Instead, they rapidly move across the sky in a matter of minutes, appearing on one side of the horizon and disappearing on the other side soon afterwards. Thus, the communication network is very dynamic and sensitive to obstruction.

The ground track plot in Figure 112 shows the path of the Globalstar M001 satellite for approximately 10 minutes on November 21st, 2005, relative to the SR-70 (Butte) incident location. In the absence of surrounding terrain, the satellite would be visible from the incident location at that time and would be available to provide service. Note that this path, which enters and crosses Canada from the west, shows very nearly the most northern extent the satellite can follow. This satellite would be relatively low on the horizon and would be sensitive to obstruction.

The ground track plot in Figure 113 shows the path of Globalstar M002 on the morning of November 24th, 2005. This satellite is far from the incident location, but visible as well. It

[111] Globalstar SEC Filing: http://www.hoovers.com/free/co/secdoc.xhtml?ipage=2086630&doc=0&attach=on
[112] http://www.globalstarusa.com/en/about/newsevents/press_display.php?pressId=50
[113] Open Letter from the Desk of Jay Monroe, Chairman and CEO Globalstar LLC, September 2, 2005.
[114] http://energycommerce.house.gov/108/hearings/09292005Hearing1648/Trujillo.pdf

appeared to the south and disappeared to the east, remaining low on the horizon the whole time. It too would be sensitive to surrounding terrain, in this case between south and east.

The ground track plot in Figure 114 shows the path of Globalstar M003 on the evening of November 29th, 2005. In this case, the satellite passes almost directly over the incident location, and it would certainly be visible above surrounding terrain as it passes overhead.

The ground track plot in Figure 115 shows the path of the Globalstar M001 on the evening of November 30th, 2005. Note here that it is traveling from the northwest to the southeast.

So, with either a 40 or 48 satellite configuration, the situation is very dynamic. Satellites may be visible low on the horizon, directly above, and in-between. Terrain will have an impact if it blocks the view of satellites, which it certainly will in some cases.

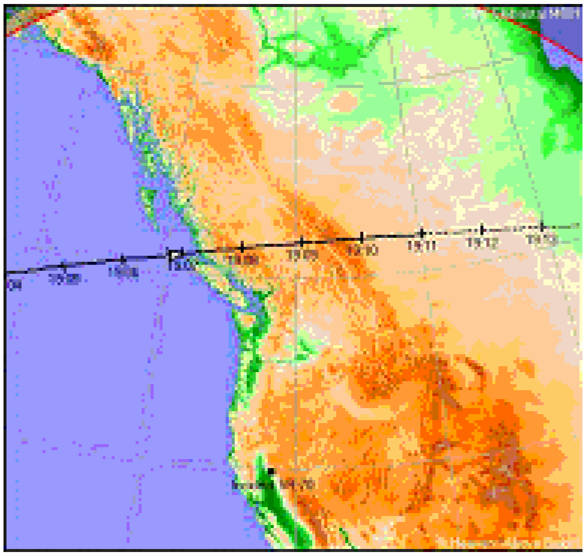

Figure 112: Globalstar M001, 7:04PM to 7:13PM, November 21st, 2005 - Relative to SR-70 (Butte) Incident Location[115]

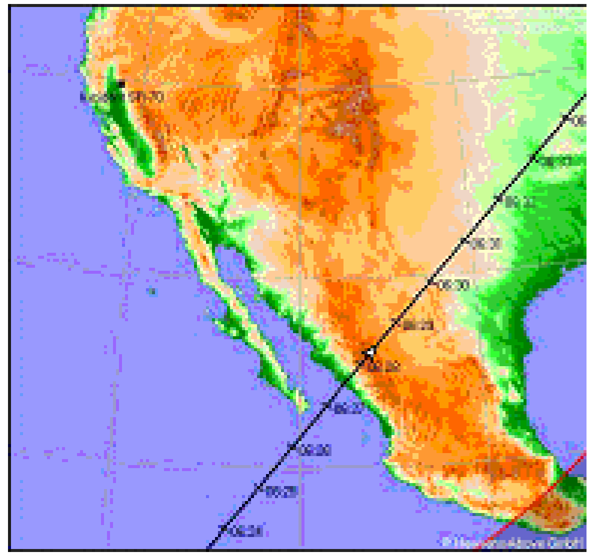

Figure 113: Globalstar M002, 6:24AM to 6:34AM, November 24th, 2005 - Relative to SR-70 (Butte) Incident Location[116]

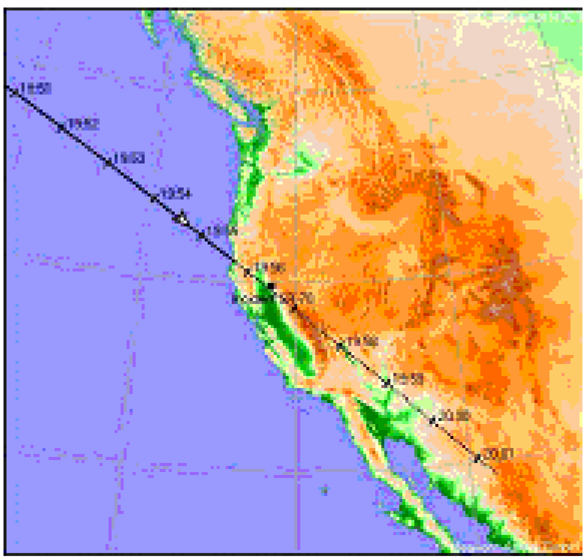

Figure 114: Globalstar M003, 7:51PM to 8:01PM, November 29th, 2005 - Relative to SR-70 (Butte) Incident Location[117]

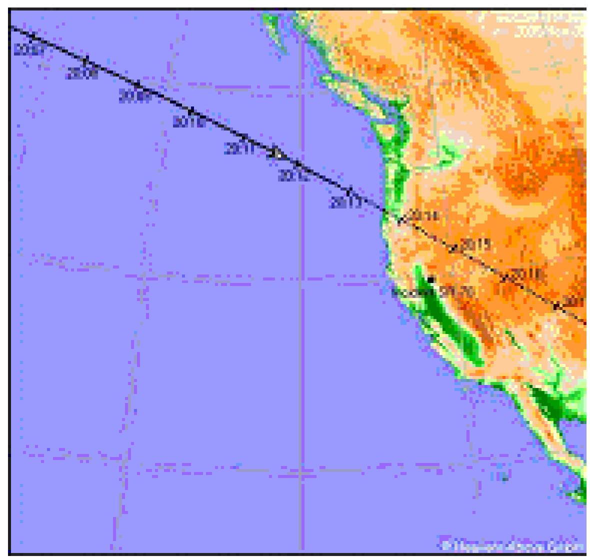

Figure 115: Globalstar M001, 8:07PM to 8:17PM, November 30th, 2005 - Relative to SR-70 (Butte) Incident Location[118]

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115 http://www.heavens-above.com/
116 http://www.heavens-above.com/
117 http://www.heavens-above.com/
118 http://www.heavens-above.com/

8.5.7.3. Model Test Sites

Nine sites were chosen to test modeled satellite visibility and signal strength. Eight of these sites are in the Feather River Canyon (Figure 116), including the SR-70 (Butte) incident location. As shown earlier, that site is located on the side of a mountain, with a large rock face to the northwest. Other sites chosen in this canyon are generally near the bottom of the canyon, with significant surrounding canyon walls. The ninth site is Gibson, off I-5 north of Redding (Figure 117). Note Mount Shasta in the upper right of Figure 117. This imposing figure is barely visible at Gibson, obstructed by hills and mountains closer to Gibson. These sites, can be considered extreme for prospective use of the Responder system, with the exception of Gibson. Thus, if the system could perform to a reasonable level of reliability at these locations, it would be expected to perform far better in less extreme terrain.

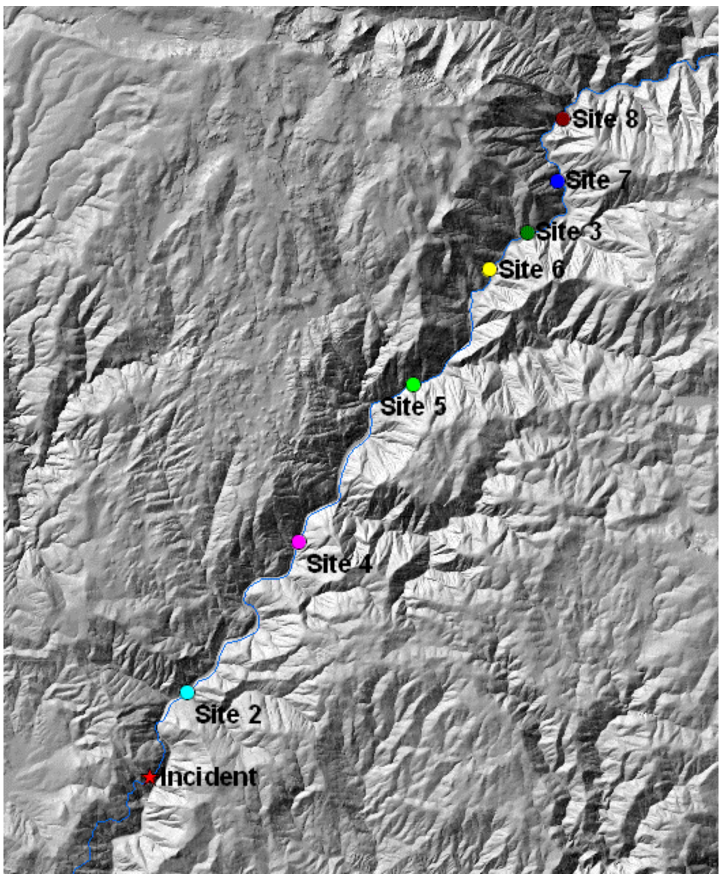

Figure 116: Feather River Canyon Model Test Sites

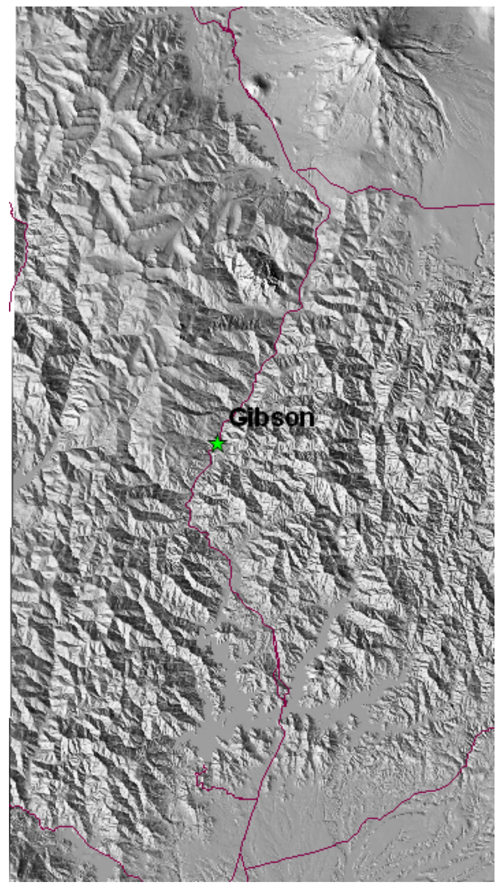

Figure 117: Gibson Test Site

Furthermore, communication options at these sites are limited. Figure 118 shows these sites in relation to modeled cellular coverage. (Tower locations are indicated with green icons.) Note that these sites are at best on the fringe of coverage. In general though, they appear to be uncovered, largely due to surrounding terrain.

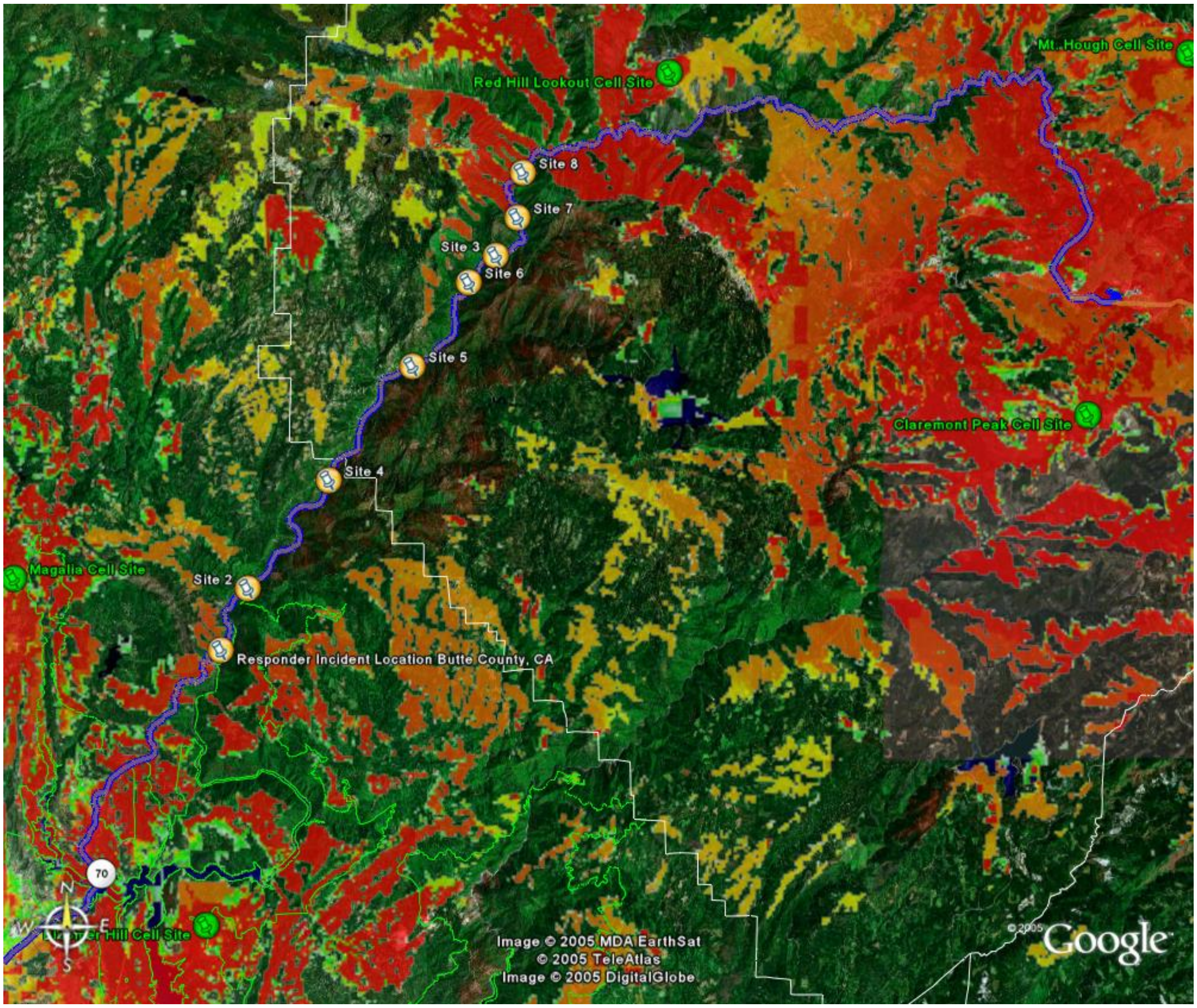

Figure 118: Feather River Canyon Test Sites Relative to Modeled Cellular Coverage

Figure 119 shows four of the Feather River Canyon sites relative to terrain. Site 6, Site 3, Site 7 and Site 8 are all deep within the Canyon.

Using a digital elevation model from the USGS, horizon profiles were calculated for each of these sites. These horizon profile models appear to be sufficiently accurate for the purpose of this model.

The horizon profiles overlaid in Figure 120 and Figure 121 for Gibson and the SR-70 incident location, respectively, appear to be a very close model of surrounding land. Note in particular that the rock-face at the SR-70 incident location appears to be accurately reflected in the model. Note also that vegetation is not accounted for in these horizon profiles.

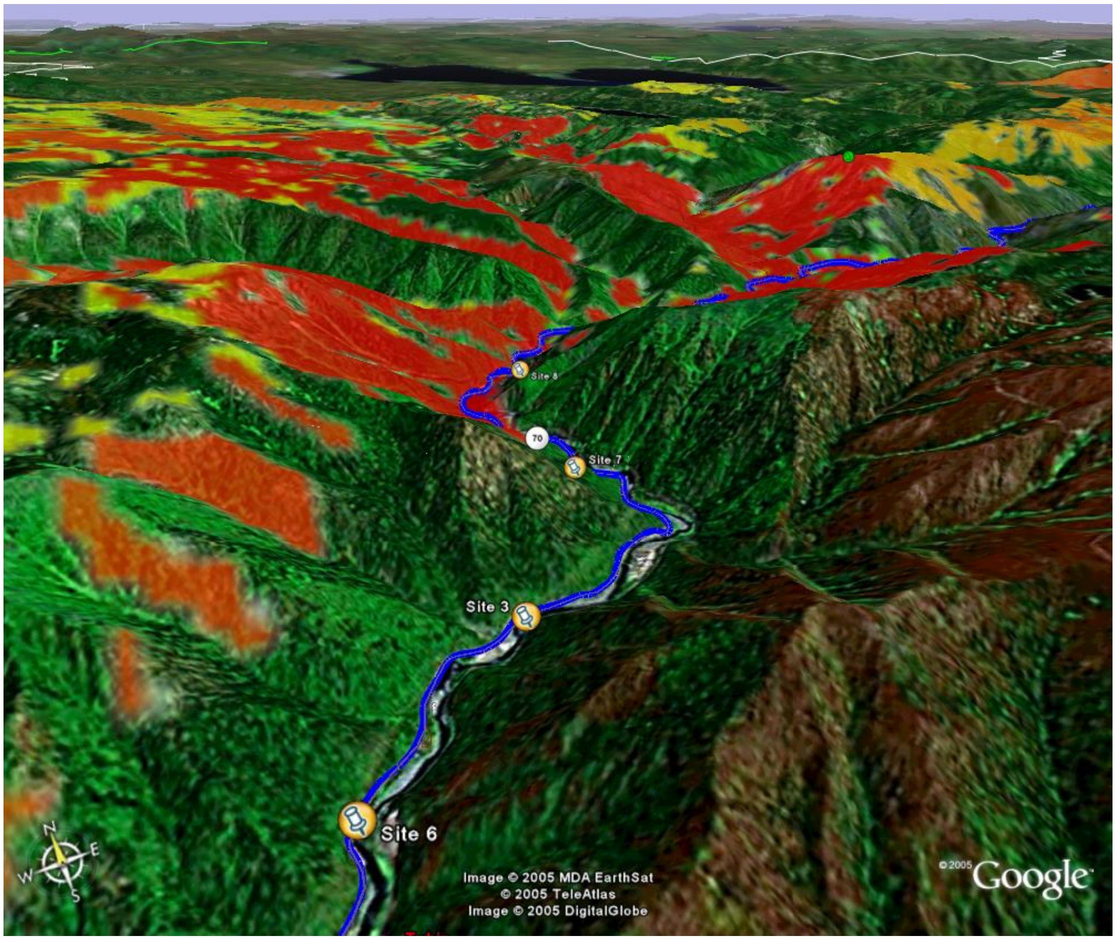

Figure 119: Feather River Canyon Test Sites Relative to Surrounding Terrain

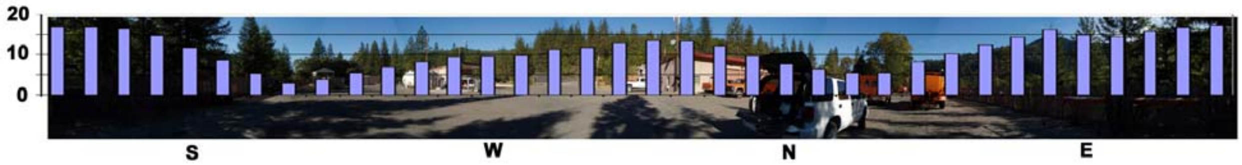

Figure 120: 360 Degree Panoramic Image of Gibson Site with Horizon Profile Overlay

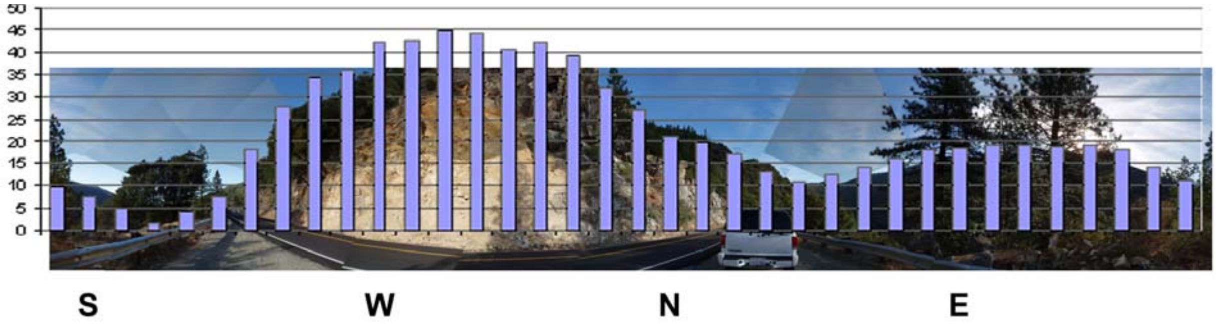

Figure 121: 360 Degree Panoramic Image of SR-70 Butte County Site with Horizon Profile Overlay

Several additional horizon profiles were generated for the sake of comparison. A horizon profile for the SR-70 incident location was created to include terrain. Angles of elevation were estimated using apparent obstruction from vegetation as shown in the panoramic image in Figure 121. In addition, profiles were created for that location to model no obstruction (0 degree angles in all directions), moderate obstruction (15 degree angles in all directions), significant obstruction (30 degree angles in all directions), and severe obstruction (45 degree angles in all directions.) These profiles were used as "control" cases. Table 18 shows the names assigned to the sites and scenarios. "Incident" refers to the SR-70 incident location. "Incident No Elevation" refers to the scenario modeling the SR-70 incident location assuming there was no surrounding vegetation. "Incident Vegetation" includes vegetation that obstructs the sky within the model. Sites 2 through 8 are the other sites shown in previous figures. Note that Site 3 actually falls between Site 6 and Site 7 along SR-70. With that exception, the remaining numbered sites are sequential along that roadway and "Incident" precedes Site 2.

Table 18: Model Site Names and Locations

	Latitude	Longitude	Elevation (m)
Gibson	41.02261	-122.39877	496
Incident	39.77616	-121.45572	555
Incident No Elevation	39.77616	-121.45572	555
Incident Bowl 15	39.77616	-121.45572	555
Incident Bowl 30	39.77616	-121.45572	555
Incident Bowl 45	39.77616	-121.45572	555
Incident Vegetation	39.77616	-121.45572	555
Site 2	39.80453	-121.43974	422
Site 3	39.95749	-121.29116	624
Site 4	39.85434	-121.39110	462
Site 5	39.90676	-121.34105	534
Site 6	39.94519	-121.30733	619
Site 7	39.97464	-121.27799	662
Site 8	39.99533	-121.27485	693

In addition to the vertical bar graph representations of the horizon profiles for the sites and scenarios, radial plots were generated to show "sky maps" corresponding to the horizon profiles. Figure 122 shows a visible sky map for the SR-70 incident location. The center point corresponds to the point in the sky directly above that location. The points on the outer circle represent the horizon, in the absence of obstruction. The heavy dashed line is a 10 degree angle of elevation across the sky, which represents the elevation at which satellites come into or go out of visibility. The blue area represents obstruction at this location due to terrain.

Corresponding to the panoramic image (Figure 121), the sky map (Figure 122) shows significant obstruction to the west and northwest. To the northeast and southwest there is relatively little obstruction. The sky map is useful in identifying how much overall sky (represented by the whole circle) is obstructed by terrain, and how much of the sky in which satellites are visible (represented by everything inside the circle corresponding to 10 degrees) is obstructed.

Further measures that take into account corresponding signal obstruction can also be determined. Figure 123 shows the relationship between the angles of elevation at which a satellite is visible to relative signal strength, as measured by the inverse square of distance to the satellite normalized so that a satellite directly overhead would have a signal measurement of 1. Satellites appearing on the horizon at 10 degrees would have a (proxy) signal strength measure of less than 20% that of one overhead. From this, a potential signal strength measure can be calculated that covers the entire sky, and this measure can also be used in obstruction calculations. For angles of elevation less than 10 degrees, potential signal strength is indicated as 0, because satellites when below 10 degrees are out of range.

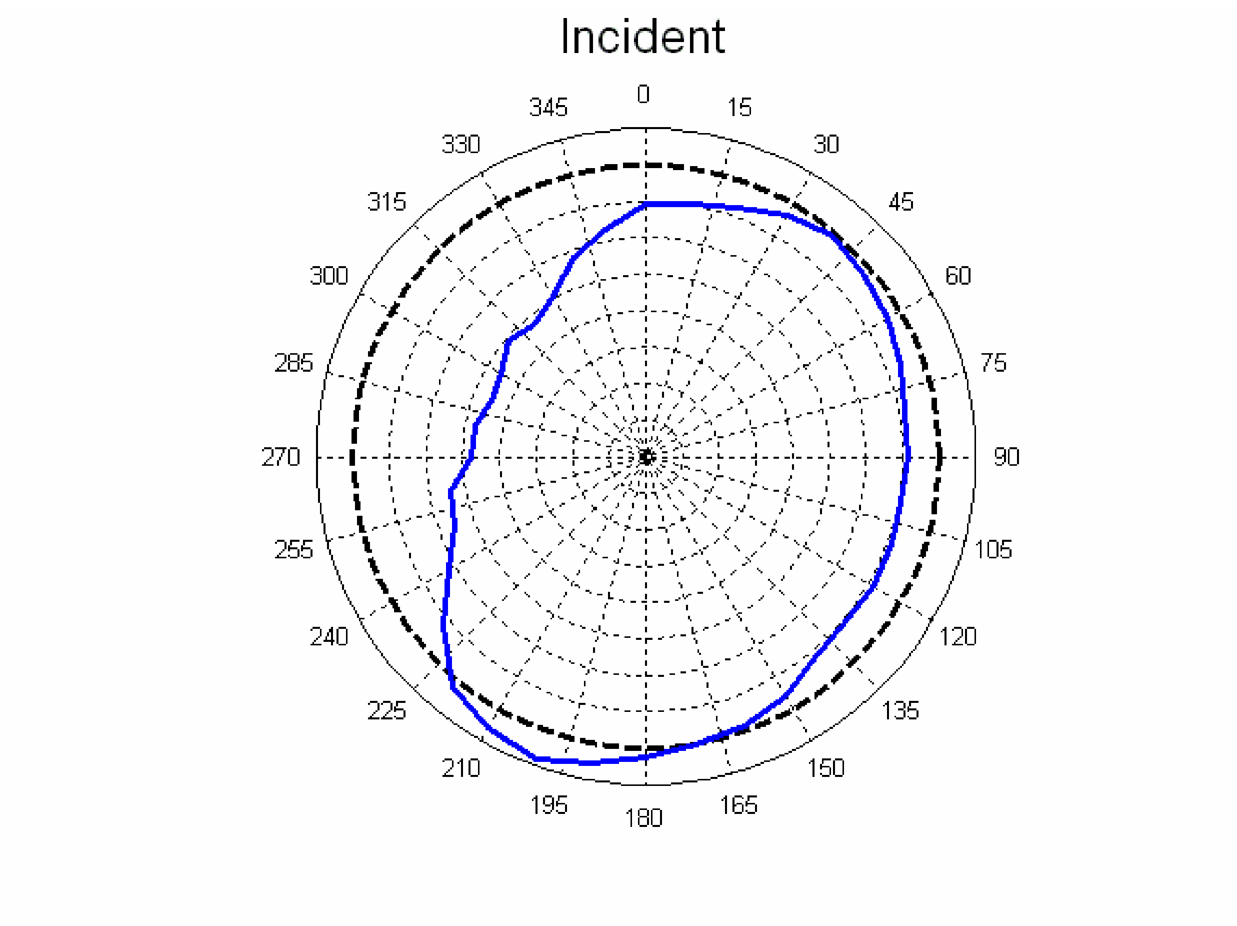

Figure 122: Incident (SR-70) Visible Sky Map

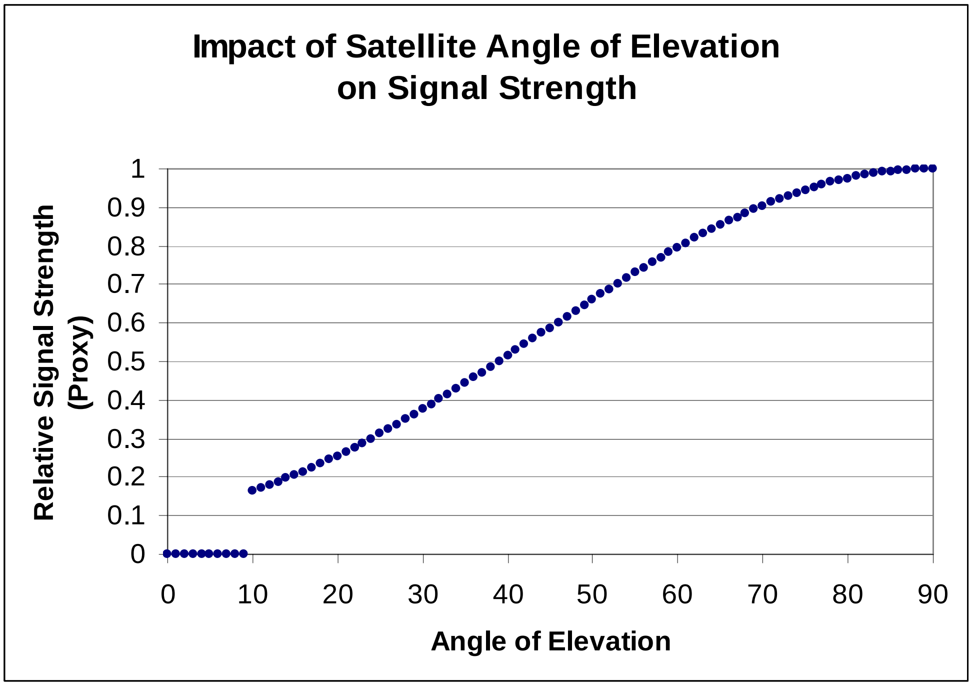

Figure 123: Impact of Satellite Angle of Elevation to Signal Strength

Table 19 and Table 20 characterize the sites and scenarios by the corresponding blockage of the sky. The mean, standard deviation, minimum and maximum angle of elevation for sky blockage is listed for each site. Also listed are three measures that characterize sky blockage in general and in relationship to the satellites. “Block. Sky %” indicates the percentage of the sky that is blocked by the horizon profile associated with each site. “Block. Sat. Sky %” indicates the percentage of the sky in which satellites would normally be visible (10 degrees and above) that is blocked by the horizon profile associated with each site. “Block. Sig. Potential %” characterizes, as a percentage, the amount of potential signal strength that is blocked. This latter measure is experimental and accounts for the relationship between angle of elevation of satellites and signal strength. Such measures could further be quantified by using a distribution of satellite positions based on the paths traveled by those satellites. These measures weren’t calculated within this study, but would be beneficial in more accurately characterizing the impact of terrain on single sites with single measures. Note too that the direction and shape of the obstruction will have an impact on signal blockage. Neither is accounted for in these general measures, but is reflected, by nature, in simulated model results.

Note that in Table 19 all of the sites are shown to have sky obstruction of 23% or greater. Gibson exhibits the least obstruction and far less than that of the SR-70 incident location. In terms of sky obstruction that impacts satellite visibility, the corresponding numbers are all less than that at Gibson, where only 6% of the related area of the sky is obstructed. Sites 4, 5, 7, and 8 appear to be most severely impacted by surrounding terrain. Gibson exhibits an even lesser blocked signal potential at 2%. These measures coincide with good performance measured at Gibson. They also coincide with less than optimal performance observed at the incident location.

Table 19: Sites and Sky Blockage Statistics

	Gibson	Incident	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Mean	11.0	21.9	18.1	22.5	26.1	26.0	23.2	27.9	27.6
Std Dev	4.2	12.8	5.8	6.7	9.6	8.9	7.2	7.7	9.0
Min	2.9	1.8	7.3	8.9	8.7	9.8	9.8	12.6	7.8
Max	17.2	45.1	28.8	31.4	41.3	36.8	33.8	40.1	40.7
Block. Sky %	0.23	0.41	0.36	0.43	0.49	0.48	0.44	0.52	0.51
Block. Sat. Sky %	0.06	0.27	0.19	0.28	0.35	0.35	0.29	0.39	0.38
Block. Sig. Potential %	0.02	0.15	0.08	0.14	0.19	0.19	0.15	0.21	0.21

Table 20 shows similar measures comparing various scenarios at the incident location.

Table 20: Incident Location Scenarios and Sky Blockage Statistics

	Incident	Incident No Elevation	Incident Bowl 15	Incident Bowl 30	Incident Bowl 45	Incident Vegetation
Mean	21.9	0.0	15.0	30.0	45.0	26.1
Std Dev	12.8	0.0	0.0	0.0	0.0	12.2
Min	1.8	0.0	15.0	30.0	45.0	7.6
Max	45.1	0.0	15.0	30.0	45.0	45.1
Block. Sky %	0.41	0.00	0.31	0.56	0.75	0.48
Block. Sat. Sky %	0.27	0.00	0.12	0.44	0.68	0.34
Block. Sig. Potential %	0.15	0.00	0.05	0.23	0.48	0.20

See the Horizon Profiles and Statistics for Sites section in Appendix VII – Site Satellite coverage analysis for the corresponding horizon profiles and statistics for these sites, as well as sky maps and various measures of obstruction. These profiles and associated statistics characterize the sites and corresponding obstruction.

8.5.7.4. Satellite Model Parameters

For the purposes of this model, the earth was assumed to be a sphere with a radius of 6378.16 kilometers. Points on the earth were mapped to points on the spherical model corresponding to their latitudes and longitudes.

Eight orbit planes each at 52 degree angles of inclination were evenly spaced about the sphere.

Satellites were evenly spaced within each orbit plane. The positions of satellites within each orbit plane were uniform across the eight orbit planes. Configurations of both 5 and 6 satellites per orbit plane were modeled.

Satellites were rotated about the earth within their orbit planes, each with a 114 minute period.

Rotation of the earth was factored into the model by rotating the sphere accordingly.

Distance, direction and angle of elevation from a given vantage point/site to each satellite were calculated at one second intervals. Only those satellites for which the angle of elevation was greater than 10 degrees were considered visible. Further qualification for visibility included comparison against the horizon profile for each site.

Each site was represented by its location (latitude and longitude). Elevations of sites were ignored in calculations of angle and distance to satellites because, relative to the elevation of the orbiting satellites, differences in site elevations are insignificant. Site elevations were accounted for in the horizon profiles.

The model was run at 1 second intervals over the equivalent of 1 week: 604800 seconds.

Factors such as system capacity and proximity to system gateways were not considered within the model. These factors do, however, have an impact on system performance.

8.5.7.5. Model Results

Figure 124, Figure 125, and Figure 126 modeled satellite paths on sky maps for short periods of time: 15 to 17 minutes.

Figure 124 shows the path of a single satellite, identified by the number 3. This satellite appears from the northwest (above the corresponding rock-face), travels across the sky to a point that is nearly overhead, and proceeds to go out of view over the mountains to the southeast. Note that a large part of this satellite’s path across the northwest sky is obstructed by the rock-face.

Figure 125 shows the same time period and all of the satellites that are visible during this time period. In addition to satellite #3, seven other satellites are visible within this time period, although not necessarily at the same time. Satellite #31 rises over the mountains to the southwest, nearly passes overhead as well, and drops out of view over the mountains to the east-northeast. Note that several satellites; numbers 4, 24 and 30; would otherwise be visible if it were not for obstruction of the sky due to terrain.

Figure 126 shows another time period. Note in this case that none of the satellites goes near the point directly over head during this time. And, visibility of satellites 3, 4 and 32 are significantly obstructed by the rock face to the west and northwest.

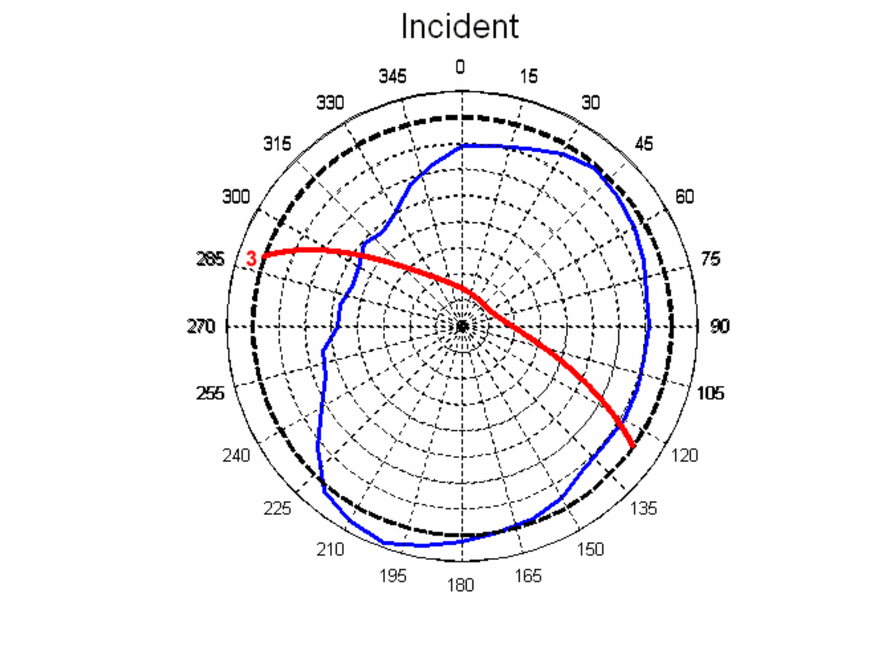

Figure 124: Modeled Single Satellite Path on Sky Map over 17 Minute Period (t = 6940 to 7985)

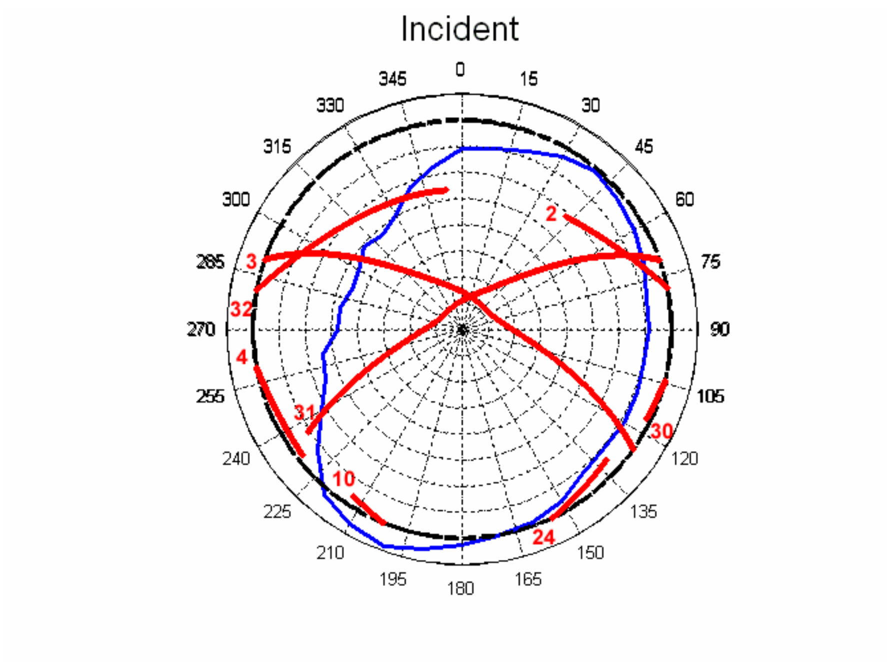

Figure 125: Modeled Satellite Paths on Sky Map over 17 Minute Period (t = 6940 to 7985)

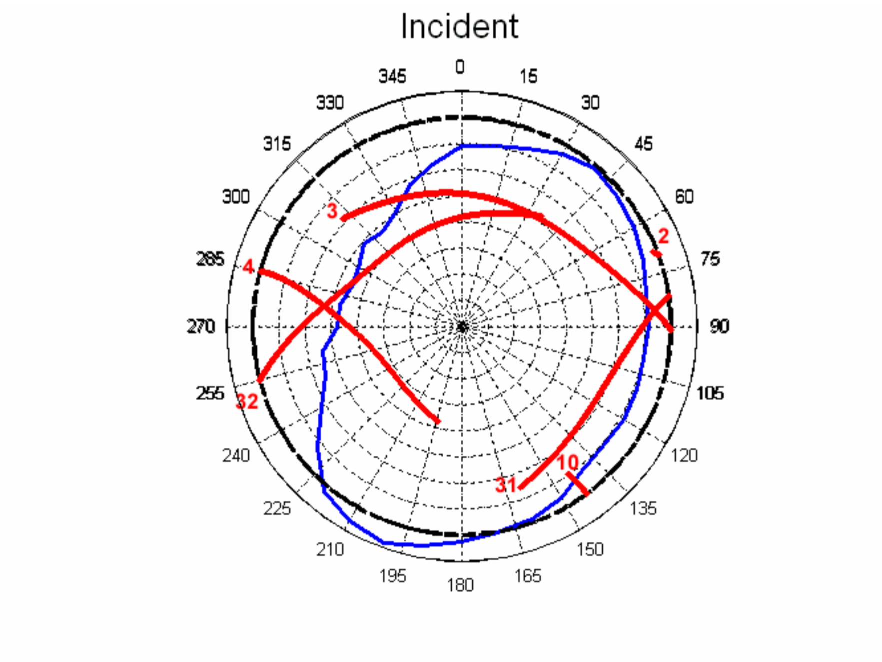

Figure 126: Modeled Satellite Paths on Sky Map over 15 Minute Period (t = 0 to 899)

The number of visible satellites and a proxy measure of signal strength were calculated and recorded for each simulated second. Figure 127 shows the number of satellites visible at the incident location during the first four hours simulated. Note that there are as many as 3 satellites visible at times and as few as zero at others. Most often, two satellites are visible.

Figure 128 shows a proxy for signal strength, modeled as the sum of normalized inverse square distance to satellites. Note the dramatic fluctuations throughout the displayed four hours. A time at which signal strength is zero corresponds to a time at which no satellites are visible. Note that a maximum occurs at approximately 7200 seconds. This corresponds to the time in which satellites 3 and 31 are both nearly directly overhead shown in Figure 125.

For the sake of comparison and to visualize the impact terrain has on signal strength at this location, Figure 129 shows what signal strengths would be at this location if there was no obstruction due to surrounding terrain. Note that there are no instances in which zero signal strength occurs. In other words, there is always at least one visible satellite. There still are some dramatic fluctuations, but signal strength remains 0.7. Thus, when compared with Figure 128, this figure reveals that terrain has a significant impact on signal strength at this location and does cause some outages to occur.

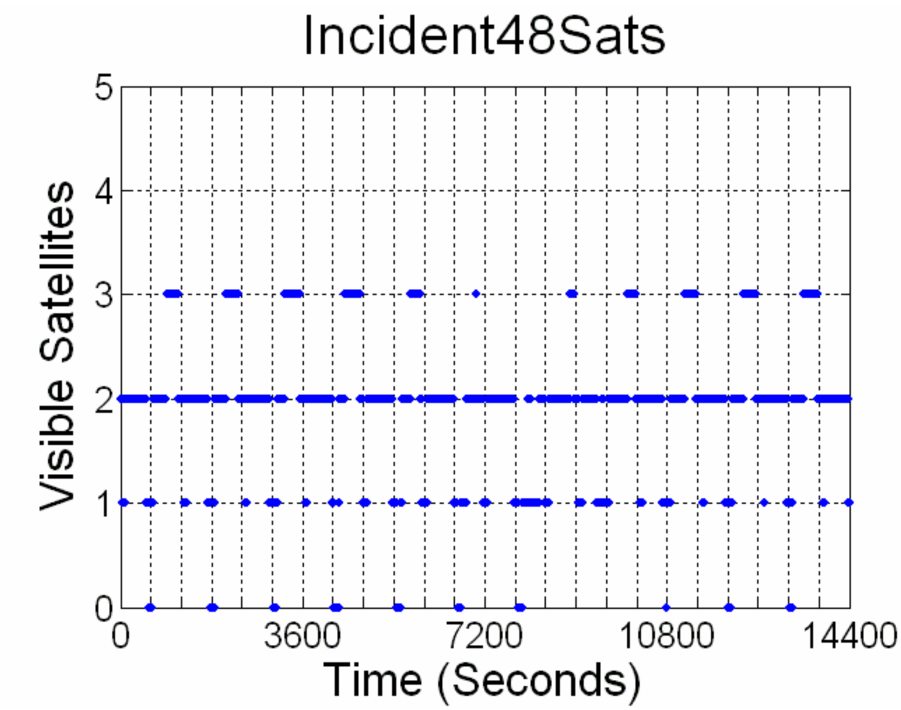

Figure 127: Modeled Visible Satellites at Incident Location

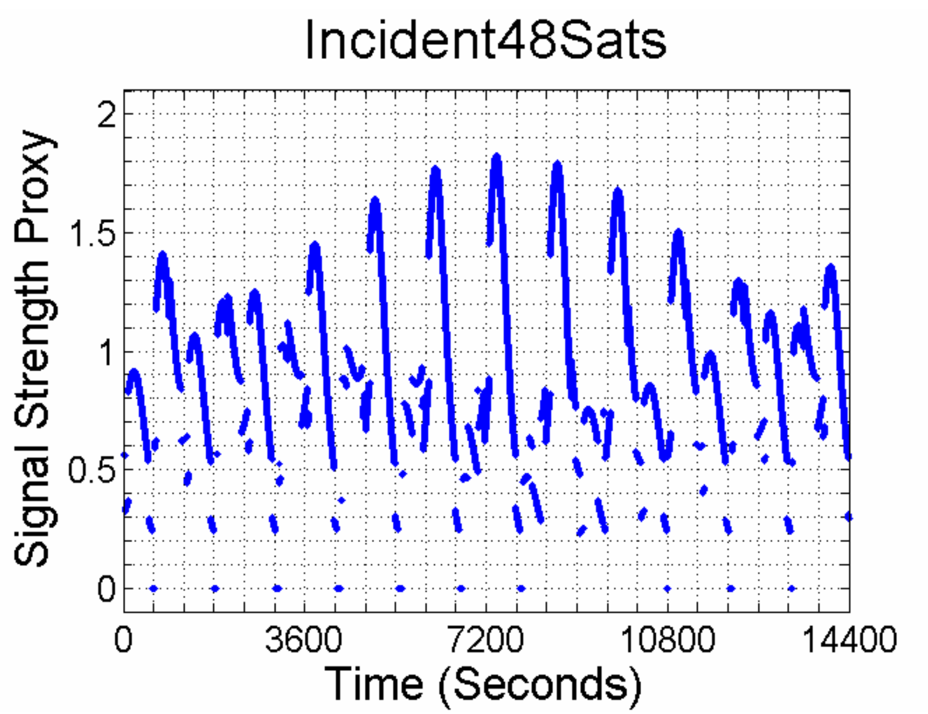

Figure 128: Modeled Signal Strength at Incident Location

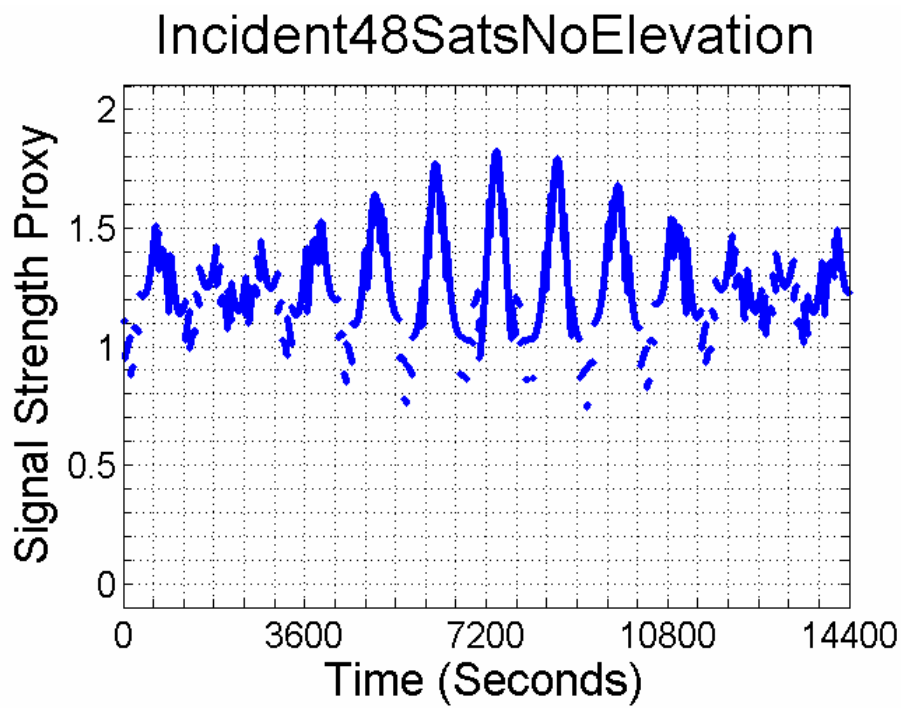

Figure 129: Modeled Signal Strength at Incident Location, Assuming no Surrounding Terrain

Table 21 and Table 22 show statistics from the model simulation for the sites and scenarios corresponding to a 48 satellite configuration. Notice that at Gibson, the average signal strength is 1.19, meaning that on average, signal strength is greater than that of having a single satellite directly overhead. The minimum modeled signal strength at Gibson was 0.43 and the maximum was 1.91, nearly the equivalent of having two satellites directly overhead. In no case did signal strength drop below 0.5 and 76% of the time it was greater than 1. Certainly Gibson exhibits good results, better than those for any of the other sites. The only scenario that outperformed Gibson is the Incident No Elevation scenario, which would be expected to exhibit the best performance. In terms of averages, there wasn't a big difference between this scenario and Gibson. However, the distribution of signal strengths did differ, and 88% of the time proxy signal strength would be 1 or greater under the no elevation scenario.

Expectedly, other sites did not perform as well. At the incident location with the corresponding horizon profile, signal strength averaged 0.88. While this appears to be good (it's nearly as good as having a satellite directly overhead), the distribution indicates problems. 5% of the time signal strength is zero at this location, indicating that service would not be available at this time. 12% of the time proxy signal strength was available, but was less than 0.5, indicating possible weak service. Despite comparable averages, Site 8 exhibited the worst performance, having no signal strength 16% of the time. There certainly would be problems at this site.

The various scenarios at the incident location also show interesting results. A constant 15 degree obstruction is definitely worse than no obstruction, yet it never experiences proxy signal strength of zero and only 1% of the time experiences proxy signal strength less than 0.5. A constant 30 degree obstruction is significant, with 13% of all signals being zero. A constant 45 degree obstruction presents very difficult circumstances, with zero proxy signal strength being recorded 67 percent of the time. Note that that when there is a signal under these circumstances, it is good because satellites are passing relatively close to the point directly overhead.

When vegetation is accounted for at the incident location, signal strength degrades further. In this case, there is zero signal 12% of the time, as compared to 5% when vegetation is not accounted for. Thus, vegetation, if it truly blocks signal strength, can have a significant impact.

Similar results are found in Table 22, which shows statistics for the number of visible satellites at these sites and under these scenarios. Note that in the no elevation scenario as many as 5 satellites can be visible at once. For sites 7 and 8, no more than 2 satellites are visible at any given time. At the incident location, as many as 3 satellites are visible at once.

Table 23 and Table 24 show statistics from the model simulation for the sites and scenarios corresponding to a 40 satellite configuration. With this configuration, similar behavior is observed. However, performance is impacted by the lesser number of available satellites.

Note that in this case, Site 7 performed worse than Site 8, now having zero signal strength 21% of the time. Direction of obstruction may have caused this discrepancy. Further note that under these circumstances; no more than two satellites are visible at the incident location with normal obstruction. In this case, surprisingly, zero satellites were visible only 4% of the time, compared to 5% when there are 48 satellites. This discrepancy is likely attributable again to direction of obstruction rather than error in the model.

Table 21: Site Statistics for 48 Satellites - Signal Strength

Site	Signal Mean	Signal Min	Signal Max	Signal Std Dev	Signal Percent = 0	Signal Percent 0<x<=0.5	Signal Percent 0.5<x<=1.	Signal Percent 1.0<x<=1.	Signal Percent 1.5<x<=2
Gibson 48 Sats	1.19	0.43	1.91	0.27	0.00	0.00	0.24	0.62	0.14
Incident 48 Sats	0.88	0.00	1.83	0.43	0.05	0.12	0.49	0.23	0.10
Incident 48 Sats No Elevation	1.24	0.71	1.83	0.22	0.00	0.00	0.12	0.75	0.13
Incident 48 Sats Bowl 15	1.13	0.44	1.83	0.27	0.00	0.01	0.33	0.56	0.10
Incident 48 Sats Bowl 30	0.77	0.00	1.83	0.51	0.13	0.34	0.16	0.26	0.10
Incident 48 Sats Bowl 45	0.38	0.00	1.83	0.59	0.67	0.00	0.17	0.06	0.10
Incident Vegetation 48 Sats	0.79	0.00	1.83	0.49	0.12	0.20	0.36	0.21	0.10
Site 2 - 48 Sats	1.04	0.27	1.83	0.31	0.00	0.02	0.49	0.38	0.11
Site 3 - 48 Sats	1.00	0.00	1.84	0.37	0.02	0.07	0.46	0.35	0.11
Site 4 - 48 Sats	0.80	0.00	1.83	0.50	0.12	0.23	0.28	0.26	0.11
Site 5 - 48 Sats	0.97	0.00	1.84	0.41	0.01	0.11	0.39	0.37	0.11
Site 6 - 48 Sats	0.89	0.00	1.84	0.44	0.04	0.23	0.36	0.27	0.11
Site 7 - 48 Sats	0.78	0.00	1.84	0.50	0.11	0.30	0.24	0.24	0.11
Site 8 - 48 Sats	0.76	0.00	1.84	0.52	0.16	0.22	0.28	0.22	0.11

Table 22: Site Statistics for 48 Satellites - Visible Satellites

Site	Sats Mean	Sats Min	Sats Max	Sats Std Dev	Sats Percent = 0	Sats Percent = 1	Sats Percent = 2	Sats Percent = 3	Sats Percent = 4	Sats Percent = 5
Gibson 48 Sats	2.88	1	4	0.85	0.00	0.01	0.41	0.28	0.31	0.00
Incident 48 Sats	1.88	0	3	0.71	0.05	0.18	0.62	0.16	0.00	0.00
Incident 48 Sats No Elevation	3.24	2	5	0.84	0.00	0.00	0.25	0.27	0.46	0.01
Incident 48 Sats Bowl 15	2.62	1	4	0.76	0.00	0.01	0.53	0.30	0.17	0.00
Incident 48 Sats Bowl 30	1.34	0	2	0.70	0.13	0.39	0.48	0.00	0.00	0.00
Incident 48 Sats Bowl 45	0.50	0	2	0.76	0.67	0.17	0.16	0.00	0.00	0.00
Incident Vegetation 48 Sats	1.57	0	3	0.83	0.12	0.28	0.49	0.10	0.00	0.00
Site 2 - 48 Sats	2.30	1	4	0.57	0.00	0.02	0.69	0.25	0.04	0.00
Site 3 - 48 Sats	2.13	0	4	0.65	0.02	0.07	0.72	0.16	0.03	0.00
Site 4 - 48 Sats	1.49	0	3	0.77	0.12	0.32	0.51	0.05	0.00	0.00
Site 5 - 48 Sats	2.11	0	4	0.73	0.01	0.12	0.66	0.15	0.05	0.00
Site 6 - 48 Sats	1.74	0	3	0.66	0.04	0.26	0.62	0.08	0.00	0.00
Site 7 - 48 Sats	1.40	0	3	0.68	0.11	0.39	0.50	0.00	0.00	0.00
Site 8 - 48 Sats	1.36	0	3	0.75	0.16	0.31	0.52	0.00	0.00	0.00

Table 23: Site Statistics for 40 Satellites - Signal Strength

Site	Signal Mean	Signal Min	Signal Max	Signal Std Dev	Signal Percent = 0	Signal Percent 0<x<=0.5	Signal Percent 0.5<x<=1.(	Signal Percent 1.0<x<=1.!	Signal Percent 1.5<x<=2
Gibson 40 Sats	0.99	0.37	1.81	0.35	0.00	0.05	0.49	0.37	0.10
Incident 40 Sats	0.73	0.00	1.82	0.45	0.04	0.33	0.38	0.17	0.08
Incident 40 Sats No Elevation	1.03	0.39	1.82	0.34	0.00	0.02	0.48	0.38	0.11
Incident 40 Sats Bowl 15	0.94	0.31	1.82	0.37	0.00	0.13	0.44	0.35	0.08
Incident 40 Sats Bowl 30	0.64	0.00	1.82	0.52	0.23	0.30	0.18	0.21	0.08
Incident 40 Sats Bowl 45	0.31	0.00	1.82	0.53	0.70	0.00	0.19	0.04	0.08
Incident Vegetation 40 Sats	0.66	0.00	1.82	0.48	0.10	0.36	0.30	0.15	0.08
Site 2 - 40 Sats	0.87	0.00	1.82	0.42	0.02	0.26	0.32	0.32	0.08
Site 3 - 40 Sats	0.83	0.00	1.82	0.44	0.02	0.33	0.27	0.30	0.08
Site 4 - 40 Sats	0.66	0.00	1.82	0.50	0.18	0.28	0.29	0.17	0.08
Site 5 - 40 Sats	0.81	0.00	1.82	0.45	0.02	0.35	0.26	0.29	0.08
Site 6 - 40 Sats	0.74	0.00	1.82	0.46	0.07	0.36	0.29	0.21	0.08
Site 7 - 40 Sats	0.65	0.00	1.82	0.51	0.21	0.27	0.27	0.17	0.08
Site 8 - 40 Sats	0.63	0.00	1.82	0.51	0.18	0.34	0.20	0.19	0.08

Table 24: Site Statistics for 40 Satellites - Visible Satellites

Site	Sats Mean	Sats Min	Sats Max	Sats Std Dev	Sats Percent = 0	Sats Percent = 1	Sats Percent = 2	Sats Percent = 3	Sats Percent = 4	Sats Percent = 5
Gibson 40 Sats	2.40	1	4	0.77	0.00	0.08	0.55	0.28	0.10	0.00
Incident 40 Sats	1.57	0	2	0.57	0.04	0.35	0.61	0.00	0.00	0.00
Incident 40 Sats No Elevation	2.70	1	4	0.79	0.00	0.02	0.44	0.35	0.19	0.00
Incident 40 Sats Bowl 15	2.18	1	4	0.71	0.00	0.13	0.61	0.21	0.05	0.00
Incident 40 Sats Bowl 30	1.12	0	2	0.75	0.23	0.43	0.34	0.00	0.00	0.00
Incident 40 Sats Bowl 45	0.42	0	2	0.69	0.70	0.19	0.11	0.00	0.00	0.00
Incident Vegetation 40 Sats	1.31	0	2	0.65	0.10	0.48	0.42	0.00	0.00	0.00
Site 2 - 40 Sats	1.91	0	4	0.72	0.02	0.23	0.59	0.14	0.02	0.00
Site 3 - 40 Sats	1.77	0	4	0.72	0.02	0.33	0.52	0.13	0.01	0.00
Site 4 - 40 Sats	1.24	0	2	0.74	0.18	0.39	0.43	0.00	0.00	0.00
Site 5 - 40 Sats	1.76	0	4	0.79	0.02	0.40	0.41	0.16	0.02	0.00
Site 6 - 40 Sats	1.45	0	2	0.62	0.07	0.41	0.52	0.00	0.00	0.00
Site 7 - 40 Sats	1.17	0	2	0.75	0.21	0.41	0.38	0.00	0.00	0.00
Site 8 - 40 Sats	1.14	0	2	0.70	0.18	0.49	0.32	0.00	0.00	0.00

Graphs corresponding to these model simulation runs can be found in Appendix VII – Site Satellite coverage analysis, for all of the sites and scenarios under both 40 and 48 satellite configurations.

8.5.7.6. Further Analysis of Model Results

Results of the model do not appear to be promising under these circumstances. If for instance proxy signal strength is zero 20% of the time, and low (above zero, but less than 0.5) 40% - 50% of the time, then the system would appear unusable at these locations, particularly for data communications in which a dropped call requires restarting transmission from the beginning.

However, multiple attempts can be made by redialing and attempting to transmit. If a window of opportunity presents itself in which service is available long enough to make the transmission, then the transmission can succeed, albeit with multiple attempts. This process can be automated (it already is within the Responder application.) What remains to be determined is whether this approach significantly increases the odds of successful transmission and what the corresponding parameters for success are.

Data from the model was analyzed to determine the percentage of the time transmissions of a given size would succeed given fixed time limits for overall transmission attempts. For this analysis, it was assumed that it takes 60 seconds to dial and establish a connection. This is an overestimate, but includes a sufficient buffer to account for time needed for software to disconnect the phone, etc.

In this analysis, points in time during the modeled week were analyzed with equal probability as potential starting points for attempted transmission. The last day of model data was omitted from the sample space of start points because of the potential overlap into time that went beyond that which was modeled. So, six days worth of potential transmission starting times were analyzed. For these starting times, dial and connection time was included as an initial time, and then the time necessary to transmit the data item, assuming 9600Kbps, was added to that. If at any time during this period zero signal strength was recorded, the call was considered to have disconnected. Note that the assumption of 9600 Kbps, the maximum for the Globalstar network is optimistic. However, results for lower data rates can be derived from these results through dividing the data sizes by the appropriate factor. Note further that the use of a single zero signal strength reading to drop a call is less than that observed in real experiments and noted earlier. However, within the model, zero proxy signal strength generally occurred over periods of at least several consecutive seconds.

All sites and scenarios where analyzed in this manner. Data sizes ranging from 0 to 1000 KB and time limits of 5, 10, 15, 20, 25 and 30 minutes were used. Percentage success rates were calculated for each. For instance, the percentage success rate of sending a 500 KB file within each of the time limits while allowing for reconnections within those time limits was calculated.

Recall that Sites 7 and 8 exhibited the worst behavior of all sites. Site 7 results with a 40 satellite constellation are shown in Figure 130 and Site 8 results are shown in Figure 131. Time limits are color-coded as follows:

Time Limit	
5 minutes	blue
10 minutes	green
15 minutes	red
20 minutes	cyan
25 minutes	magenta
30 minutes	yellow

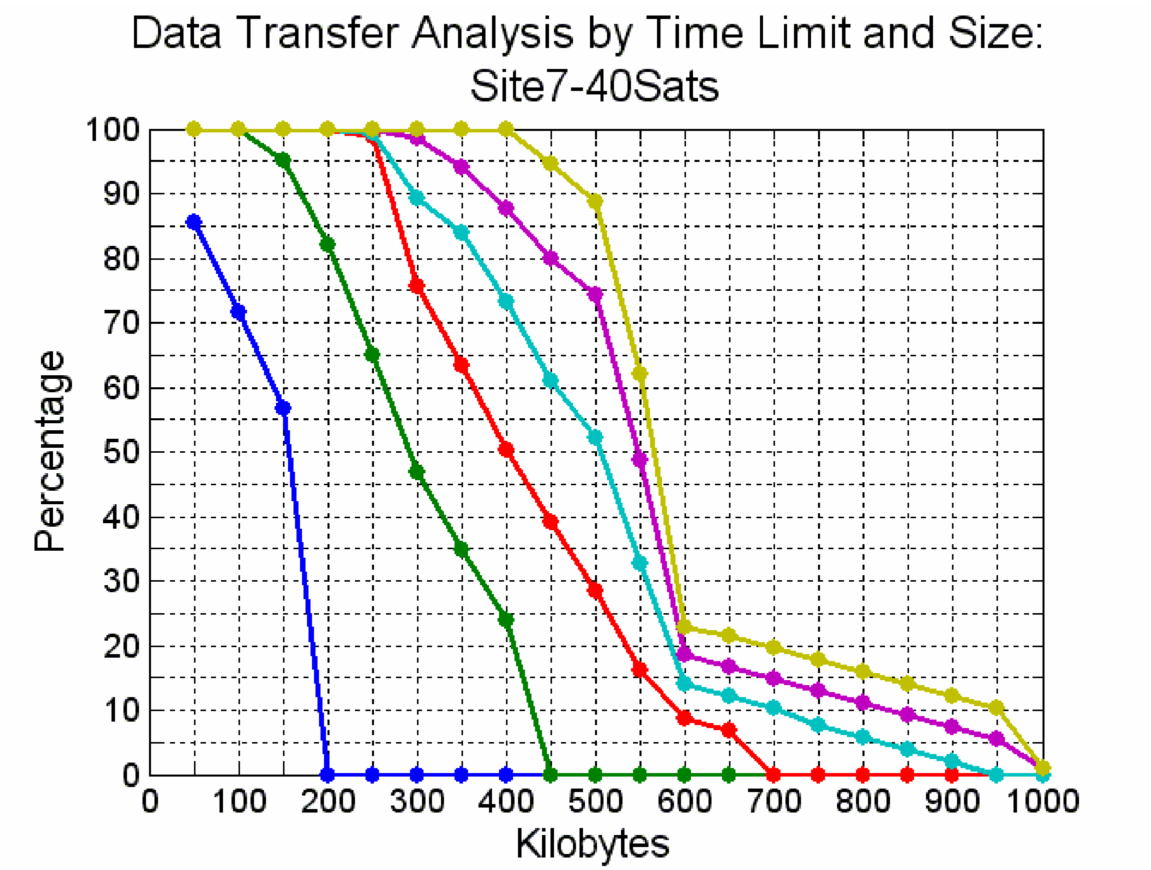

Figure 130: Data Transfer Analysis for Site 7 with 40 Satellite Constellation

For Site 7, note that it is virtually impossible to transmit a 1000 KB file within these time constraints. Under ideal conditions and with no transmission failure, it would take approximately 15 minutes to send this file. However, even when given 20, 25 or 30 minutes, this file will not be successfully transferred. File sizes of 600 KB and above exhibit poor performance as well. For a 600 KB file, there would be about a 10% chance of successful transmission in 15 minutes, approximately a 15% chance in 20 minutes, almost 20% chance in 25 minutes, and a little less than 25% of success in 30 minutes. Results are better for smaller files.

Two types of limitations can be used as variables to determine reasonable file sizes: time limit and percent success rate. If 30 minutes are allowed for transmission, then a 500 KB file can be transmitted with a 90% chance of success. But with 20 minutes allowed for transmission, only 300 KB can be transmitted with the same 90% success rate. To achieve a 90% success rate within a 10 minute time limit, only files less than 200 KB would work.

Figure 131 shows similar results for Site 8. Several conclusions can be drawn from these results. If data transmission is to be attempted at these locations, then sufficient time needs to be allocated for reconnections, and the size of the transmission needs to be minimized. In general, data sizes should be 500 KB or less, preferably 250 KB or less. In addition, 15 or more minutes should be allowed for transmission.

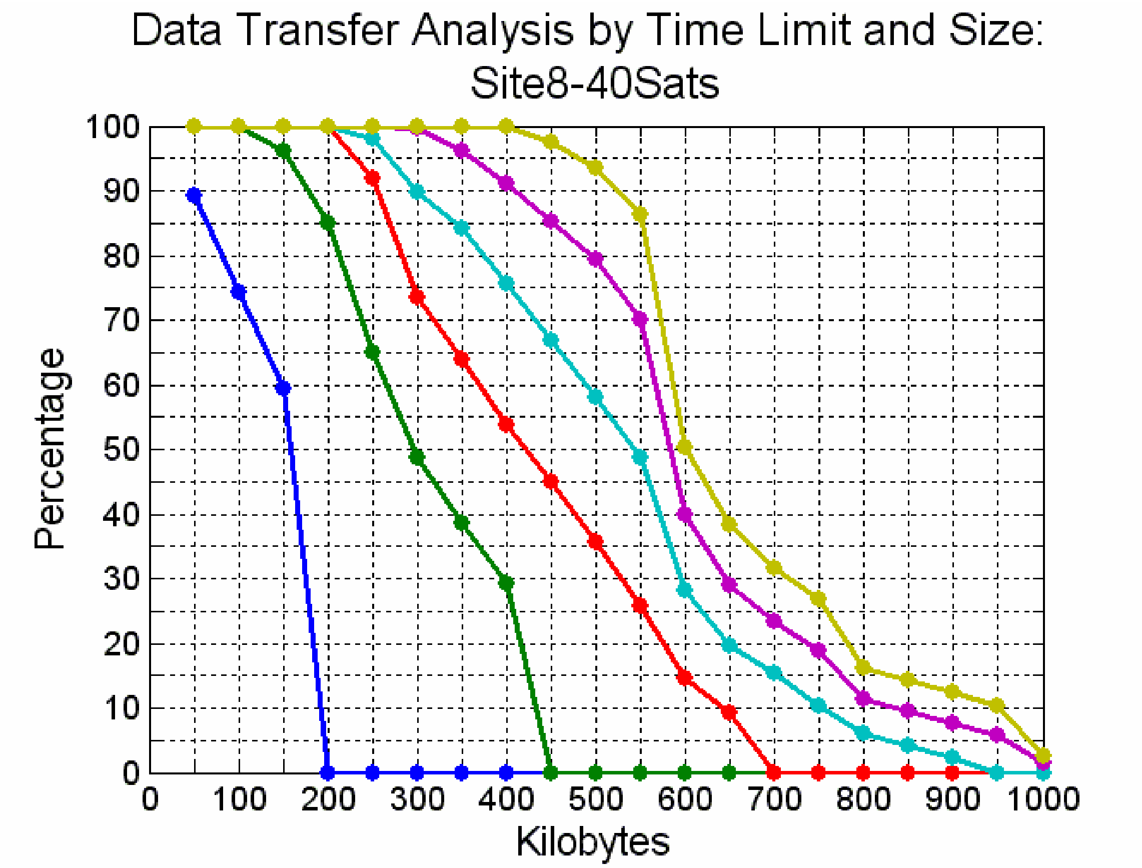

Figure 131: Data Transfer Analysis for Site 8 with 40 Satellite Constellation

Results are more promising even at the SR-70 (Butte) (Figure 132) incident location and especially at Gibson (Figure 133). For Gibson, where no drops to zero signal strength occurred, the only limiting factor is time. Data transmission does not fail in the model for this site, but it just may not be possible to transfer data within time limitations due to the low data rate. For instance, it is not possible to transmit a 700 KB file in less than 15 minutes, even under ideal circumstances. For the incident location, it would be possible to transfer a 250 KB file in 10 minutes or less with a 90% chance of success. 450 KB could be transferred in 20 minutes with approximately 90% success rate as well.

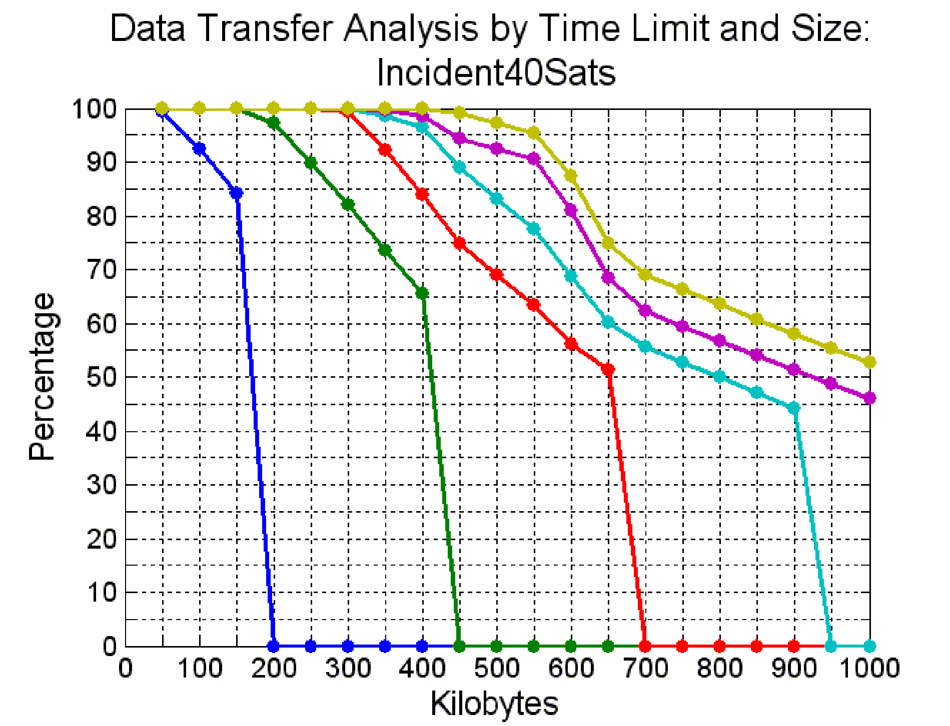

Figure 132: Data Transfer Analysis for SR-70 Incident Location with 40 Satellite Constellation

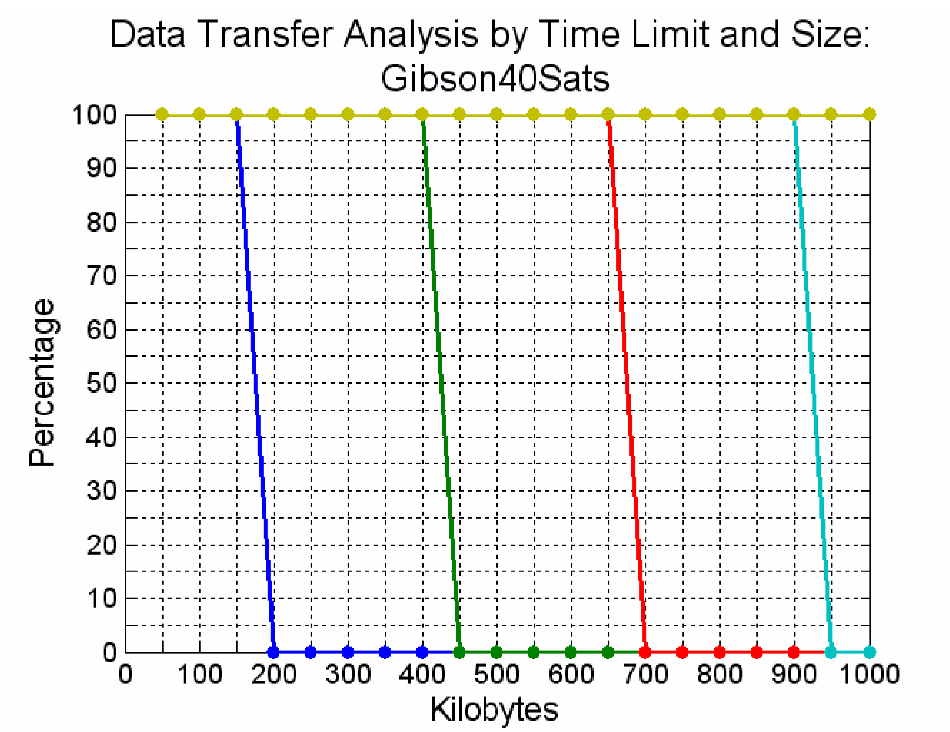

Figure 133: Data Transfer Analysis for Gibson with 40 Satellite Constellation

8.5.7.7. Conclusions from the Model

While signal strength measurements used in this model were based on a proxy measurement that does not necessarily equate to actual measured signal strength, which may also be influenced by system usage, these measures do bear similarity to actual measurements and help to explain observed fluctuations. At a more basic level, visibility of satellites as modeled should be similar to reality with the exception that actual satellites may not coincide to the locations used in the model. This would cause discrepancies, yet obstruction of the sky would still be problematic.

The data collected from the model verifies that obstruction of the sky can have an adverse impact on system performance, particularly significant obstruction of the sky. However, with certain limitations, the system may be usable under these circumstances. In particular, if an upper limit is placed on time allowed for transmission and if re-connects are allowed following disconnects during transmission, reasonably-sized files (less than 500 KB) can be successfully transmitted.

These observations have several technical implications. First, reconnects can be automated and are already automated in the Responder application. The current algorithm allows for three re-connects after which the application will cancel transmission attempts. This algorithm should be modified to use a fixed time limit rather than a fixed reconnection limit. Second, while it is not desirable, data could be broken into smaller chunks and transmitted individually to further improve performance under adverse conditions. This could be accomplished as described previously by transmitting incident images and sketches individually. This would present it as disjoint pieces rather than present incident information as a complete record.. However, if it helped to facilitate transmission where it would otherwise not be possible, it may be worthwhile. This approach could be taken one step further, with data broken in even smaller pieces (partial files), transmitted, and then re-assembled. It would be necessary in this case to have a special application to reassemble the information.

There is commercial connection management software available to help address these problems as well. NetMotion Wireless offers a product called "Mobility"[119,120] which enables seamless cross network roaming, application session persistence, compression, security, VPN, and optimal choice of fastest available connection. Through the use of what might be considered to be a specialized proxy server, this product handles connections even in adverse conditions. The company indicates Globalstar compatibility as well as compatibility with other satellite and cellular providers, equipment and technologies.[121] Further investigation into this product and alternatives[122] would be necessary prior to recommending it for use. The benefits are apparent. The drawbacks include the requirement of using a special server and the prospective purchase cost and licensing fees.

[119] http://www.netmotionwireless.com/product/mobility_keys.asp
[120] http://www.netmotionwireless.com/assets/NMW_trifold.pdf
[121] http://www.netmotionwireless.com/resource/compatibility.asp
[122] http://www.netmotionwireless.com/assets/nwc5762_final.pdf

9. CONCLUSIONS

The results of this study have shown enough promise for Caltrans to proceed with a second phase. The purpose of the second phase will be to prepare the Responder system for production use and to make a business case for the use and deployment of the system. Interest has been shown in the system by other organizations including regional fire and EMS agencies. Perhaps those areas of application can be examined as well, which would be consistent with goals of the RIME program.

Key features of this study include the application of the systems engineering methodology and the spiral model to the development of the system, the elicitation of user requirements, the development of a usable and useful user interface, and the maximization of the use of scarce resources such as storage space and limited communications capability.

While this system was built using off-the-shelf products, it should not be concluded that one could replicate it by simply buying the same products. Ease of use, utility, integration, and communications challenges/limitations (making the most of these resources) were all keys. This has been a process of analysis, systems engineering, integration, development and evaluation.

Beyond the system itself, there are several over-arching conclusions that can be made. First, this project could not have been accomplished in the same manner without readily available information such as maps and weather data. Web services and general availability of data in multiple, “computer friendly” formats make it possible to reuse this data within the Responder application. It may be found that other similar data is available and useful within the context of the project. It will also be the case that other useful data could be made available in the same manner for use in this project and other projects. Making data available for applications such as this goes beyond simply publishing information on the web in “human friendly” formats.

Second, despite communications challenges, it is possible to make effective use of communication when it is available. Data communication is a powerful tool, and infrastructure to facilitate it is scarce in the most rural areas in the RIME region. Nonetheless, that is where this capability could be of most use. This project demonstrates such usefulness.

Finally, ease of use and utility are perhaps the two most desired aspects of the system resulting from this study. It was known from the beginning that if the system was not easy to use, it would not be used. A simple and intuitive interface played a significant role in efforts to achieve ease of use. But beyond that was the goal of both hardware and software integration to the point where all pieces truly function as a system. An observation was made at one point that when people use the system, they will have no idea how complex it truly is. The answer to that observation is that this is the way it should be. Users should not be concerned with what goes on behind the scenes, they should simply be concerned about whether the system does what it is supposed to do and does it effectively to make their jobs easier.

10.APPENDIX I – CALTRANS DISTRICT 2 INCIDENTS

10.1. Rockslide, SR-70, Butte County, 2/26/2004

Caltrans

News Release

#04-026

Contact: Michael Mayor
Public Information Office
Caltrans - (530) 225-3071

California Department of Transportation
District 2, Redding
Brian Crane, District Director

February 26, 2004

Highway Info - 1-800-427-7623
http://www.dot.ca.gov/hq/roadinfo

FOR IMMEDIATE RELEASE

Emergency Slide Removal on State Route 70 Butte County

REDDING – The California Department of Transportation (Caltrans) will begin immediate emergency road work to remove soil and rocks, some measuring more than 15 feet in diameter from State Route (SR) 70 in Butte County. The slide occurred February 25, 2004 at approximately 7:40 p.m. near Lake Oroville, 1.5 mile west of Pulga. The roadway is open to one-way traffic control and it is anticipated that it will reopen to normal traffic at 8 p.m., Friday, February 27, 2004.

The slide includes more than 200 yards of material, much of which are large pieces of rock, some weighing well over 200 tons. Explosive devices will be used in the slide removal and during the blasting operations, the roadway will be completely closed for up to 20-minute intervals.

In order to complete the blasting process, more than 40 holes must be drilled into the rock. Drilling will begin this afternoon and continue through the night. Beginning Friday morning the slow process of blasting will be completed in small sections to limit the amount of rock that is dispersed. Extra pre-cautions will be taken due to the location of a major electrical transmission line just below the blast area. Caltrans personnel are handling the removal process with the exception of the drilling. Certified Blaster, Mark Vukich, who is a Caltrans Maintenance Supervisor, will conduct the blasting and other Caltrans maintenance staff will remove the roadway debris.

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NOTE: An electronic version of this news release and photos of the slide are available on the internet at the following web address: http://www.dot.ca.gov/dist2/news_releases.htm

The Caltrans employee pictured in the photo is Guy Hinrichs, Caltrans Maintenance Supervisor for the Pulga Maintenance Station in District 2.

Figure 134: Press Release - Rockslide on SR-70, Butte County, 2/26/2004[123]

[123] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/pdf%20files/04-026nr.pdf, http://www.dot.ca.gov/dist2/archives.htm

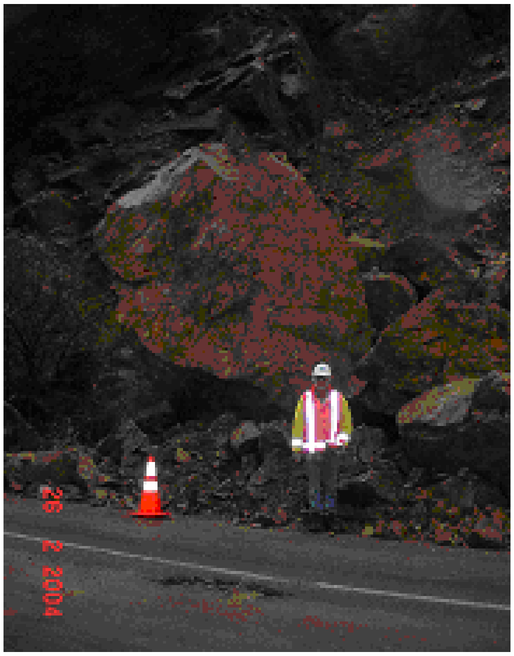

Figure 135: Photograph[124] - Rockslide on SR-70, Butte County, 2/26/2004

Figure 136: Photograph[125] - Rockslide on SR-70, Butte County, 2/26/2004

[124] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/butte1.jpg
[125] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/butte2.jpg

10.2. Rockslide, SR-70, Plumas County, 1/22/2004

News Release

#04-007

Contact: Michael Mayor
Public Information Officer
Caltrans - (530) 225-3071

California Department of Transportation
District 2, Redding
Brian Crane, District Director

January 22, 2004

Highway Info - 1-800-427-7623
http://www.dot.ca.gov/hq/roadinfo

FOR IMMEDIATE RELEASE

Emergency Slide Work to Begin on State Route 70 in Plumas County

REDDING – The California Department of Transportation will begin emergency roadwork on State Route (SR) 70 in Plumas County near Rich Bar, approximately 20 miles west of Quincy between Belden and the Greenville Wye, Monday, January 26, 2004. This project is expected to take up to one week for completion, with closures of SR 70 of at least one hour during blasting operations. Work will be completed between 7 a.m. and 5 p.m., Monday through Friday, with blasting occurring between the hours of 10 a.m. and 2 p.m.

Due to damage caused by extreme weather conditions in this area, blasting must be completed to prevent further dirt and rock slides and damage to the roadway. In addition to blasting operations, workers will be scaling the rock wall to remove loose dirt and rocks by hand. During this hand operation, the roadway will be closed for up to 20-minute intervals.

The cost of this emergency work is expected to be approximately $200,000. This cost is in addition to the 48 hours of initial work performed by the Caltrans maintenance crew out of Pulga, which worked around the clock to clear the rocks from the roadbed. The major blasting and rock scaling will be performed by a private contractor, releasing the six-person Caltrans crew to resume normal highway maintenance operations. The Pulga crew is responsible for nearly 50 centerline miles of State Route 70 maintenance from the State Route 191 junction in Butte County to 7 miles west of the Greenville Wye in Plumas County.

The Feather River Canyon is especially prone to rock slides due to the steep canyon walls. Nearly every year, rock slides big enough to warrant an emergency construction contract are necessary. "We work very hard at trying to keep State Route 70 open with minimum delays, but when large rocks begin to fall we have to do whatever it takes to stabilize the situation", said Russ Wenham, Deputy District Director for Caltrans in Redding.

Figure 137: Press Release[126] – Rockslide, SR-70, Plumas County, 1/22/2004

[126] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/pdf%20files/04-007nr.pdf

Figure 138: Photograph[127] – Rockslide, SR-70, Plumas County, 1/22/2004

Figure 139: Photograph[128] - Rockslide, SR-70, Plumas County, 1/22/2004

127 Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/slide1.jpg
128 Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/slide2.jpg

10.3. Rock on SR-70, Butte/Plumas County Line, 12/8/2004

State of California • Department of Transportation

NEWS RELEASE

Caltrans

Date: Wednesday, December 8, 2004 04-132
District: District 2 - Redding
Contact: Michael Mayor
Phone: (530) 225-3260
FOR IMMEDIATE RELEASE

Blasting Necessary to Remove Rock on State Route 70

REDDING – California Department of Transportation (Caltrans) is reporting a rockslide, approximately ½ mile west of the Feather River Bridge near the Butte/Plumas county line. The slide was discovered by the Caltrans Pulga Maintenance Crew around 5:13 am and both eastbound and westbound lanes were blocked.

One lane of travel was cleared and the roadway was restored with one-way traffic control by 7 a.m. One rock, too large to move with heavy equipment, is still blocking the westbound lane and blasting will be necessary to clear the roadway. At present there is no estimated time when the roadway will open to normal traffic.

For more information please contact the Public Information Office at 225-3260.

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NOTE: An electronic version of this news release is available on the internet at the following web address: http://www.dot.ca.gov/dist2/news_releases.htm

SLOW FOR THE CONE ZONE
CALTRANS

Figure 140: Press Release[129] – Rockslide, SR-70, Butte/Plumas County Line, 12/8/2004

[129] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/pdf%20files/04-132nr.pdf

10.4. Mudslide, I-5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

Caltrans

News Release

#04-018

Contact: Michael Mayor
Public Information Officer
Caltrans - (530) 225-3071

California Department of Transportation
District 2, Redding
Brian Crane, District Director

February 18, 2004

Highway Info - 1-800-427-7623
http://www.dot.ca.gov/hq/roadinfo

FOR IMMEDIATE RELEASE

Slide Removal Work on Southbound Conant Road Off Ramp on Interstate 5

REDDING – The California Department of Transportation (Caltrans) is conducting emergency removal work on a slide, approximately 75-ft wide by 200-ft tall, of which 10,000 cubic yards of mud, rock and trees came down on the roadway. This occurred on the southbound Interstate 5, Conant Rd. off ramp, near the Shasta/Siskiyou County line just south of Dunsmuir, during the morning hours of February 17, 2004.

The off ramp is currently closed and the slide area is being monitored. Access to northbound I-5 is still available at Conant Road, southbound traffic must exit at Flume Creek, return to I-5 north and exit Conant Road. There is no estimated time of reopening. Once work begins it will take approximately one week before the ramp is opened and up to six weeks for the completion of the work.

Work may begin as soon as Saturday, February 21, 2004, but will not begin until worker safety can be assured. "The current conditions of the slide material prevent us from beginning removal work immediately," said Tim Huckabay, District Maintenance Engineer. "It isn't safe to put personnel and equipment under the slide while it's still so wet and active."

The project will include removal of the slide material, new drainage, installation of a 10-ft. tall rock buttress the length of the slide and re-vegetation of the hillside. The start of work is dependent on the weather and the activity of the slide. Caltrans maintenance staff is monitoring the slide and has placed barrier rail to help protect the southbound lanes of I-5 from falling debris. Currently all lanes of I-5 are open, however saturated soil conditions increase the possibility of further slide activity, and impacts to southbound I-5. The estimated cost to clean up and repair the hillside is $1.2 million.

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NOTE: Photos and video clips of the slide, as well as an electronic version of this news release are available on the internet at the following web address: http://www.dot.ca.gov/dist2/news_releases.htm

Figure 141: Press Release[130] – Mudslide, I- 5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

130 Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/pdf%20files/04-018nr.pdf

Figure 142: Photograph[131] – Mudslide, I- 5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

Figure 143: Photograph[132] – Mudslide, I- 5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

[131] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/conant1.jpg

Figure 144: Photograph[133] – Mudslide, I- 5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

Figure 145: Photograph[134] – Mudslide, I- 5 Off Ramp, Shasta/Siskiyou County Line, 2/18/2004

[132] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/conant2.jpg
[133] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/conant3.jpg

10.5. Rockslide on SR-299 in Trinity County, 1/12/2005

State of California • Department of Transportation

NEWS RELEASE

Caltrans

Date: Thursday, January 13, 2005 05-003
District: District 2 - Redding
Contact: Michael Mayor
Phone: (530) 225-3260
FOR IMMEDIATE RELEASE

MEDIA UPDATE

ROUTE: State Route (SR) 299 – Closed due to rock slide.

CLOSED AT: ½ mile west of Burnt Ranch in Trinity County

CLOSURE TIME: January 12, 2005 – 4:23 p.m.

UPDATE: ROUTE OPEN TO NORMAL TRAFFIC

State Route 299 has be re-opened to normal traffic. Caltrans continues to monitor the slide. Motorists may experience some delays.

CONTACT INFORMATION: Michael Mayor – 949-4654 (cell phone)
Denise Yergenson – 255-3485 (pager)
Web Page: http://www.dot.ca.gov/dist2/

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NOTE: Electronic versions of this news release and photo are available on the internet at the following web address: **http://www.dot.ca.gov/dist2/news_releases.htm**

SLOW FOR THE CONE ZONE
CALTRANS

Figure 146: Press Release[135] - Rockslide on SR-299, Trinity County, 1/12/2005

[134] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/conant4.jpg
[135] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/pdf%20files/05-003nr.pdf

Figure 147: Photograph[136] - Rockslide on SR-299, Trinity County, 1/12/2005

[136] Caltrans District 2 Press Release Archives: http://www.dot.ca.gov/dist2/images/Photos/slide.jpg

11. APPENDIX II – MAY 2004 SURVEY

Participants:

- Cheryl Gorewitz / Myrlane Wederbrook : Caltrans D2 Communications Center
- James Scott, Caltrans Superviser
- John D'Annunzio, Caltrans Redding Maintenance Area Superintendent
- Mike Zolotoff, Caltrans, District 2 – Area Supt, Specialist, Hazmat Manager
- Rick Resh, Caltrans Maint
- Tim Croom, Caltrans / Acting Supervisor

Background

The Redding District Incident Management Responder Study will provide the necessary framework for the pilot deployment of two data communication tools to assist at-scene personnel responsible for incident response and management. One tool will provide the means for at-scene incident information collection and sharing while the second tool will provide incident support information to responders. The two tools will be developed and piloted jointly and will incorporate a means to communicating the information between the at-scene responders and the Redding Transportation Management Center (TMC), as shown in Figure 1.

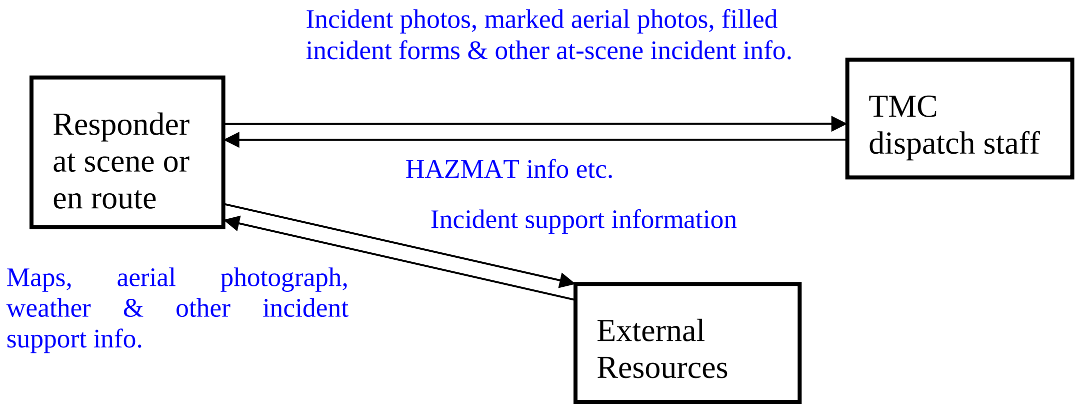


Figure 1: Exemplary information flow involving the responder tools

As one of the lead projects of the Redding Incident Management Enhancement (RIME) program, the Responder Study aims to develop, deploy and evaluate such a prototype system, for the purpose of concept demonstration and requirements analysis. This questionnaire seeks to identify requirements of the system from the standpoint of end users.

Questions & Answers

1. Currently, what means do you use for the communication between the TMC and the responders at scene or en route? What are the pros and cons of each?

   Radio and cell phone: only good if person is in mobile unit and in coverage area; Pager: only good if person is in coverage area. (D-2 Communications Center)

   We use the radio and in some areas we use cell to communicate with TMC; The pro with the radio and cell is an immediate line of communication, which aids in knowing what might be needed for the incident before arriving on scene; The con is the radio in some areas does not transmit or receive well, cell service is very limited in our area. (Acting supervisor)

   Caltrans radio dispatch: reliable during normal business hours, unreliable during off hours; CHP dispatch: mostly reliable during off Caltrans hours; Cellular telephone: reliable depending on location. (Supervisor)

   Radio – Pro - Easiest, quickest, safest, most responsive Con – Not able to communicate details as well as phone; Cell phone – Pro – Good for details of incident, Con – Reception, hard to find numbers, dial and drive at the same time. (Redding Maintenance Area Superintendent)

   State two way radio and cell phone. The pros are that we can talk to each other from remote areas. The cons are that they don't work very well. (Maintenance staff)

   D-2 Radio and/or Cell Phone; D-2 Radio – doesn't work everywhere, better than nothing; Cell Phone – ATT – doesn't work everywhere, better than none, satelite phone when needed would be better coverage. I had a satelite phone at one time, the company went belly-up and I never got another one (D-2 Area Superintendent, Specialist, Hazmat Manager)

2. What incident support data would improve the efficiency and accuracy of your operations, or facilitate the site management and incident clearance, if you were

   a) en route to an incident scene?

   Improvements to our radio and cell service. (Acting supervisor)

   Real time information, exact location, type of incident, responders all ready en route (tow truck, fire/rescue, CHP, etc.) (Supervisor)

   What traffic control is needed. What equipment is needed to clear, including haz-mat cleanup. How big, how far, how long (Redding Maintenance Area Superintendent)

   Better information about the location of the incident. (Maintenance staff)

   I have 2 cell phones right now, the analog (it doesn't work) was to be replaced with a digital with two different companies) or cell phones and a satellite phone would be best coverage; Text messages on my pager, it seems to work in many areas my cell phone doesn't; Home storage permit, would save approx ½ hour per incident of response time for me. (D-2 Area Superintendent, Specialist, Hazmat Manager)

b) at the incident scene?

Improvements to our radio and cell service. (Acting supervisor)

Weather forecasts, traffic volumes expected, if a hazmat availability to research the product. (Supervisor)

What Caltrans personnel are responding, what equipment. What contract personnel and equipment are responding. ETA for everything to be on scene. (Redding Maintenance Area Superintendent)

More and better information about what has happened so I can start the proper response of personal and equipment needed. (Maintenance staff)

FAX machine to receive and send MSDS and chemical info over permanently mounted cell phone in my van. I still have the analog phone & FAX in my van but no longer works, it was to be upgraded after budget crisis, FAX is now available with digital cell phone, although maybe not district wide, also laptop computer hookup through cell phone to better communicate with and update everyone and get chemical information over the internet. Also get yagi antenna for cell phone/computer/FAX to better bring in signal where none is available. Equipment to download digital/video photos to e-mail to TMC so they would have up to date info for better scene management; D-2 radio extender does enhance on scene coordination/communication. (D-2 Area Superintendent, Specialist, Hazmat Manager)

3. What data collected by the at-scene responders would help the TMC in the processes of incident response, site management, and incident clearance?

P.M. Location; Status of road – closure or direction of travel affected; Any spill involved: If cargo, what type, what's needed for cleanup; Any unknown substance involved; Any injuries. (D-2 Communications Center)

Giving the TMC clear, precise and accurate information will help the TMC with all three items mentioned above. (Acting supervisor)

Same as 2a and 2b: Real time information, exact location, type of incident, responders all ready en route; Weather forecasts, traffic volumes expected, if a hazmat availability to research the product. (Supervisor)

How big, how long, how far. What short term or long term options should be considered. (Redding Maintenance Area Superintendent)

Photos to quicker/better access severity of incident/situation for detours and closures for TMC and HQ; Quicker/better updated info with better communication capabilities, communications with satellite phone where we don't have service now – better info for TMC and HQ. (D-2 Area Superintendent, Specialist, Hazmat Manager)

4. In what scenarios would image data such as maps, aerial photos and incident photos be of use in terms of incident management? Please give examples (for instance, landslide, storm event, etc.).

   Aerial photos might help in the event of a major slide in determining where the slide originated; Maps can be used as a tool for a detour around the incident. (Acting supervisor)

   Wild land fires we could determine route and wind direction, to better determine our needs; Storm related events , help TMC understand the severity of the incident. (Supervisor)

   Road maps for closure and subsequent detour. As builds' to locate and identify facilities affected. (Redding Maintenance Area Superintendent)

   Haz-mat spills, major accidents. (Maintenance staff)

   Chemicals traveling down river from a spill along highway, photos/map may help with location of traffic control, command post. During the Canterra spill coordination was terrible, our people were conducting traffic control breathing fumes, when something like this is known, TC should be relocated immediately.

   For major disasters such as numerous storm damage locations, road closures, flooding, earth quakes etc. having a spread sheet with each location & photos plus Caltrans people working on each location is very important. Up to date information for rescue personnel, how to get to the scene, etc. (D-2 Area Supt, Specialist, Hazmat Manager)

5. Are you familiar with the following items? Would you feel comfortable and capable to use the following items? (Y=Yes, M=Maybe, N=No)

	Familiar		***Comfortable?***			***Capable?***		
Cellular phone	Y (4)	N (0)	Y (3)	M (0)	N (0)	Y (3)	M (0)	N (0)
Satellite phone	Y (3)	N (1)	Y (1)	M (1)	N (1)	Y (2)	M (0)	N (1)
Pocket PC, Handheld PC, Palm Pilot, etc.	Y (2)	N (1)	Y (0)	M (2)	N (1)	Y (2)	M (1)	N (1)
Portable PC (Notebook computer)	Y (4)	N (0)	Y (2)	M (1)	N (0)	Y (2)	M (1)	N (0)
Tablet PC (Computer with touch screen & pen)	Y (2)	N (2)	Y (1)	M (2)	N (0)	Y (3)	M (0)	N (0)
Digital camera	Y (4)	N (0)	Y (3)	M (0)	N (0)	Y (3)	M (0)	N (0)
GPS module	Y (2)	N (2)	Y (1)	M (1)	N (1)	Y (3)	M (0)	N (1)

6. Would you be willing to use tools like those described in the beginning of the questionnaire? Why or why not?

   Yes. However, caution must be utilized whenever requiring dispatch to use "other" tools in addition to present responsibilities. We are only capable of handling/operating a certain number of components at any given time. (D-2 Communications Center)

   I would be willing to use any tool needed or supplied by the department to complete my job more efficiently. (Acting supervisor)

   While at the incident it would be helpful to access the internet for information (weather, product info, etc.). (Supervisor)

   *"One tool will provide the means for at-scene incident information collection and sharing" – **No**. I rely on direct information from an at scene employee from my department for accurate and pertinent scene info. When a serious incident is happening, no one from my department has time to enter info on a laptop. We are busy saving lives and property.*

   *"The second tool will provide incident support information to responders." – **Yes**. When a responder has time, and is in a place during the event sequence, that they can safely request support information they can do so. . (Redding Maintenance Area Superintendent)*

   Yes. (Maintenance staff)

   YES-Communications is very important, knowing what is going on at any minute may save lives and will save time and money for us and the public, by knowing what and when detours are available and when the road will close or re-open. (D-2 Area Superintendent, Specialist, Hazmat Manager)

7. If answered yes to question 6, please answer the following questions:

   a) If you were at an incident scene, how much time would you have to download relevant data from the Internet or to obtain it from the TMC?

   At the scene of the incident many of these tools might take too much time. Many of our decisions are split second ones. The TMC in my opinion is our best option for information given their experience dealing day in and day out with these situations. (Acting supervisor)

   Once the scene has been stabilized and a plan implemented, time is what you make of it. (Supervisor)

   Normally I don't have much time until after the hwy. is taken care of. (Maintenance staff)

   The least amount of time possible, it would me great if you could down load info in just a few, 10-20 minutes if available, with today's technology. For a hazmat event it would depend on where the TMC is getting the info to send me, if available probably 30-90 minutes if they have staff available to work on it. (D-2 Area Superintendent, Specialist, Hazmat Manager)

b) How much time would you have to collect and transmit the incident data to the TMC?

I would have a short period of time to collect and transmit information to the TMC in most cases. (Acting supervisor)

Once the scene has been stabilized and a plan implemented, time is what you make of it. (Supervisor)

Normally I don't have much time until after the hwy. is taken care of. (Maintenance staff)

Depending on incident 15-30 minutes. (D-2 Area Supt, Specialist, Hazmat Manager)

c) Should the tools like those described at the beginning of the questionnaire be fixed in your vehicle or usable outside the vehicle? Please explain.

Useable outside the vehicle – limited access to equipment generally renders it a nuisance rather than a tool. (D-2 Communications Center)

Some of the items mentioned above could be fixed in the vehicle; some should be able to be mobile outside the vehicle. Many times we are needed outside of our vehicles aiding with traffic control issues. (Acting supervisor)

I think these tools should be portable, with the ability to be plugged into the vehicle. GPS, Cell phone, Palm pilots, and Digital cameras should be mobile depending on the incident to relay pertinent information. Laptops? A response gear bag that could be stored out of the way until the need arises would clear up the front of the cab during non-use. (Supervisor)

Don't know. (Maintenance staff)

Both – pager, cell phone (booster in vehicle), radio extender, satellite phone can be packed with you on scene, when you are out of your vehicle, it has always been hard to locate a supervisor at the scene outside of their vehicle. These can also be plugged into vehicle for booster capabilities; I also have an inverter in my van so that I can use the FAX and printer, scanner, copier. (D-2 Area Superintendent, Specialist, Hazmat Manager)

8. Please list any additional related comments/concerns you have, in terms of hardware and communications, incident support information, and at-scene incident information collection, etc.

   Timely and accurate updates from field personnel provided to Dispatch/TMC … 30 minute rule applies; ONLY ONE primary in-field contact person to receive, request and/or disseminate information from and to Dispatch. Standardized Emergency Management System rules should apply on ALL major incidents, including but not limited to Winter Storm Operations/Closures on I-5, Fawndale to Oregon state line. (D-2 Communications Center)

   A checklist could be a good tool to help on scene. (Acting supervisor)

   Will all this stuff work in remote areas? (Maintenance staff)

   Portable command posts are available for minor / major incidents, some of the other Districts have them; I also have a small old printer, scanner, copier that I can use with my lap top to make copies for the other agencies involved; With all of this new technology & a laptop and internet e-mail you could also keep other agencies updated and request their help in gathering info. (D-2 Area Superintendent, Specialist, Hazmat Manager)

12.APPENDIX III – OCTOBER 2004 SURVEY

Participants:

- Jeff Kiser, D2 Field Region Manager, Maintenance Operations
- Mandy Chu, Caltrans Project Manager
- Ian Turnbull, D2 ITS Engineer

Please evaluate the **Summary** section using the following criteria:

	poor	fair	average	good	excellent
Usefulness of Information:			1	2	
Clarity of Information:				2	1
Ease of Use:			1	1	1
Comments / Suggestions:					
Organization should auto-populate with "Caltrans".					
District should auto-populate with "2".					
Could use a spot for post mile.					
Organization: Instead of filling out "Caltrans" every time, auto-populate.					
Time: Clarify what time this is. When you started the program? When you arrived?					
Need post mile and direction added.					
For organization and district, they should be pre-populated for the group.					
Seems like other data/information could be added on this page, example: Post Mile.					
Analysis:					
Organization and District should be pre-populated. If multiple organizations and districts use Responder systems, then there must be an initialization file for the program in which default values can be entered.					
Post Mile and Direction should be added. This would be difficult to autopopulate. Thus, a free-form text field adds the greatest flexibility. Both post mile and direction could be entered into the text field. Alternate, or additional information such as landmarks could be entered.					
Clarification of Time and Date is needed, and conventions for use should be established. It is not certain whether this should be done within the program and through training. These fields were included for record-keeping purposes. No action will be taken without further discussion.					
These changes should improve the rankings of this section, by making it easier to use, and more precise.					

<u>Please evaluate the **Photos** section using the following criteria:</u>

	poor	**fair**	**average**	**good**	**excellent**
Usefulness of Information:					3
Clarity of Information:					3
Ease of Use:				3	

Comments / Suggestions:
Easy way to grab photographs directly from camera (plug camera in and programs points to all photos on camera.)
Would be nice to be able to write description for picture on the thumbnail page.

Analysis:
It must be easy to retrieve photos from the camera. Navigation to the appropriate drive and folder could be time-consuming, and trouble-shooting would be required if the camera is not connected correctly. It is desirable to implement a method for automatically navigating to the camera's photograph directory, when the camera is connected. Photos should be automatically previewed, allowing selection for inclusion. Other functionality could be included to manage the photos, including the capability to delete photos from the camera. For photos that are chosen for inclusion in the program and deletion from the camera, identical copies (identical resolution) should be copied to the computer for archival purposes.
This section received high rankings, although ease of use was unanimously ranked "good" rather than "excellent." The changes described should improve ease of use. Further consideration should be given to the appropriate use of thumbnails. Thumbnails allow many images to be viewed at once, but in less detail.

Please evaluate the **Mapping** section using the following criteria:

	poor	fair	average	good	excellent
Usefulness of Information:					3
Clarity of Information:				2	1
Ease of Use:				3	

Comments / Suggestions:
Concern of how fast data can be retrieved.
Download time to get aerials and USGS – suggest storing all this data on PC (no downloading).
Suggest aerials are CT aerials, not USGS. (DHIPP – our Internet aerial site.)
Minimize downloading needs.
Looks into interfacing with Caltrans images.

Analysis:
Downloading maps and aerial photos over slow data connections does not appear viable. Given higher-speed connections, this might be acceptable. So, this data should be stored locally. This presents a problem in that this data occupies a lot of space. So, it must be chosen judiciously. Possible ways to filter the data include only storing data for particular routes or regions. Maps and aerial photos, as demonstrated in this example are not time-sensitive. Thus, storing them locally is not a problem in terms of timeliness. There may be cases in which map data would contain time-sensitive information such as road conditions, asset locations, etc. Such cases should be considered separately.
The use of Caltrans images, maps and other data should be considered. For the sake of demonstration, the current data sources will be used. In the future, Caltrans data could be integrated in a similar manner.
In general, this section ranked high, Ease of use likely received sub-excellent rankings because of the issues with downloading the maps. Storing this information locally should improve ease of use. The "good" rankings for clarity might be improved by the inclusion of Caltrans maps.

Please evaluate the **Sketches** section using the following criteria:

	poor	fair	average	good	excellent
Usefulness of Information:					3
Clarity of Information:				1	2
Ease of Use:			0.5	0.5	2

Comments / Suggestions:
Appears to be good, would like to see what end user receives on their end.
When you copy photograph to sketches, automatically move photograph description over with it.
Maybe on top of sketches tab have "Add Blank Sketch" and "Add Sketch from Photograph". This would be instead of going to Photograph tab to move over.
Could the user go to the sketches tab, have a thumbnail page of photos, and click on the selected photograph and make sketches?

Analysis:
The primary issues with ease of use appear to stem from the method for copying photos to the sketches section. There are many different ways this could be done. Methods would depend on the sequence in which users carried out actions. Importing photos into the incident organizer will obviously occur prior to use as sketches. When coupled with the desire to copy descriptions given to photos, sketches should be created after descriptions have been assigned, although this is not necessary. The method of copying photos from the photos section rather than using thumbnails or some or preview method has been retained, with several modifications. First, the user will have the choice of whether to the sketch immediately, or to remain in the photos section. This will allow them to select photos and minimize trips back and forth between the photos and sketches sections. Second, the description will automatically be copied to the sketches section. These changes should allow for more efficient operation.
It is anticipated that the changes described will improve usability. There still are a number other of ways this task could be carried out, and these should be investigated. Additional methods could be implemented, but consideration should be given to the increased complexity that would be introduced into the program by doing so. See comments later regarding which photos and sketches are included in email for a related issue.

<u>Please evaluate the **Forms** section using the following criteria:</u>

	poor	**fair**	**average**	**good**	**excellent**
Usefulness of Information:					3
Clarity of Information:					3
Ease of Use:			1	2	

Comments / Suggestions:
Not sure how user-friendly keyboard would be.
Fill out form with the information already input: country, route, post mile, etc.
Consider having both pen input and keyboard options.

Analysis:
The forms section was well-received, in terms of usefulness and clarity. However, ease of use was questionable. A core problem in implementing this functionality is that these forms would likely require keyboard input. If the computer is operating in Tablet mode, it would be a hassle to convert it to keyboard mode. Furthermore, it would not be feasible to use the pen or the on-screen keyboard for most existing forms created in MS-Word or Adobe Acrobat. Creation/conversion of forms conducive to this application should be deferred pending further investigation of existing forms and of alternate programs for form authoring and analysis. Microsoft InfoPath, a relatively new product, offers promise in this area.

<u>Please evaluate the **Manuals** section using the following criteria:</u>

	poor	**fair**	**average**	**good**	**excellent**
Usefulness of Information:					3
Clarity of Information:					3
Ease of Use:				1	2
Comments / Suggestions:					
Good idea.					
Will it stay on the page you drilled down to if you go off of the "manuals" page? May be helpful to stay on drilled-down section unless changed.					
What about phone lists for CT and other Responder groups.					
Analysis:					
Manuals received nearly unanimous excellent ratings, and should be included in a final product. However, it is unclear what manuals would be included, how they would be organized, and how much space they would occupy. Manuals would likely be agency-specific and might even be area-specific. Further consideration should be given before implementing for general use.					
The issue of staying in a location in a manual when retrieved is a valid issue. It does, however present some technical challenges that deserve further exploration. It is unknown if it is possible to save "bookmarks" referencing, but separate from MS-Word or Adobe Acrobat documents. Bookmarks can be saved internally, but require re-saving the document, or saving a copy of the document. The first of these options would be problematic in that it would allow a manual to be overwritten. The second would result in unnecessary saving of copies of documents, which might be large. It may be possible to create code that saves this information separate from the original document.					

Please evaluate the **Internet** section using the following criteria:

	poor	fair	average	good	excellent
Usefulness of Information:				2	1
Clarity of Information:				2	1
Ease of Use:				2	1

Comments / Suggestions:
I like the idea of point-specific locations.
Concern of slow download.
Include CCTV and Chain Control D2 web pages.
Possibly also include Caltrans road conditions web page.

Analysis:
Download time is again a concern, like it was for maps. Unfortunately, the information addressed in this section is time-sensitive, and could not be cached meaningfully for more than an hour or two at most. When working with slow data connections, downloading this information from web pages can be painfully slow because these pages include graphics and text that are not absolutely necessary. Furthermore, it would be undesirable to allow the user to freely surf the web by following links or entering addresses, because response times will be painfully slow, making the program frustrating and the end-user unlikely to use it. Instead, information could be optimized by excluding unnecessary graphics, text, etc., and combined to include relevant information, given the user's location. A central aggregation system is necessary for this task. The WeatherShare system has been used to implement this functionality on a test basis, providing weather information specific to the user's location. National Weather Service point forecasts have also been incorporated.
While restricting the information the user can acquire, the program can be made more efficient. This process also frees the user from making decisions about what information to download and where to download if from. For instance, the user could press a button labeled "Get Weather" and the system could automatically download weather information relevent to them with no further intervention on the user's part.

Please evaluate the **Communications** section using the following criteria:

	poor	**fair**	**average**	**good**	**excellent**
Usefulness of Information:				2	1
Clarity of Information:				3	
Ease of Use:				2	

Comments / Suggestions:
May be more info than we need.
Like email …
Auto-populate send email addresses to user-defined list.
User-defined way of sending only what sketches and photos you want to send.

Analysis:
The comment that this section may include more information than is necessary should be given further consideration. This section, minus the email functionality, was meant for troubleshooting in the event that the user has difficulty in establishing communication with devices such as the cellular modem, satellite modem and GPS. For further testing, this section will be retained for the sake of troubleshooting. In the future, it could be hidden from the user, with an added layer of assistance when troubleshooting is necessary.
Auto-population of email addresses is considered important. Note that there are some technical challenges in sending multiple emails from the system.
Note too the expressed challenges of interfacing with Outlook as a means for sending email from the program. This was the one place where the program had to defer to an outside program's interface, which was problematic. It was also problematic in that there was no way of determining if and when the email had been sent. As a result, it was desirable to find another means for automating email. In all likelihood, this would involve the use of an outside SMTP server/service.

<u>Please evaluate the **Help** section using the following criteria:</u>

	poor	fair	average	good	excellent
Usefulness of Information:					
Clarity of Information:					
Ease of Use:					
Comments / Suggestions:					
None. The help section was left blank.					
Analysis:					
The help section could be omitted altogether. The hope and goal is that the program will be intuitive and user-friendly enough so that a traditional help section is not needed.					

<u>Please evaluate the overall **Responder Incident Organizer** using the following criteria:</u>

	poor	fair	average	good	excellent
Usefulness of Information:					2
Clarity of Information:					2
Ease of Use:			0.5	1.5	
Comments / Suggestions:					
None – comments were made on individual sections above.					
Analysis:					
In general, several keys to successful implementation were discussed. First, and obviously, the system must usable in a vehicle. There are a number of options for making this happen. At the core of all is wireless capability. Second, the system must be easy to use and user-friendly. (See the help section above. It should be so easy to use that help isn't necessary.) The users need to concentrate on the content/information and not the technology.					

13.APPENDIX IV – MAY 2005 SURVEY

Participants:

- Jeff Kiser, D2 Field Region Manager, Maintenance Operations
- Steve Rogers, Chief, D2 Office of Traffic Management
- Bill Stein, D2 PC Coordinator
- Ed Lamkin, D2 Deputy District Director, Maintenance
- Ian Turnbull, D2 ITS Engineer

Please answer the following questions in as much detail as time allows.

Section 1: The Incident Organizer

Please refer to the “canned” demonstration to answer the following:

In general, does the program appear to be user-friendly? Please explain the good and the bad.

D2 Field Region Manager, Maintenance Operations*:*

Yes, looks good.

Chief, D2 Office of Traffic Management*:*

Yes, good! Auto functions are great!

D2 PC Coordinator*:*

Yes!! Very!

D2 ITS Engineer*:*

Yes.

What changes, additions, or deletions would you make to the **Summary** section?

D2 Field Region Manager, Maintenance Operations*:*

So far, so good.

Chief, D2 Office of Traffic Management*:*

None.

D2 PC Coordinator*:*

County – Route – Post Mile=Drop down list.

Landmark=Freeform

D2 ITS Engineer*:*

None.

What maps would you include in the **Mapping** section? Please consider Caltrans-specific maps as well as non-Caltrans maps.

D2 Field Region Manager, Maintenance Operations*:*

Caltrans area/mapping

Chief, D2 Office of Traffic Management*:*

Your 3 choices are great (aerial, street, quad).

D2 PC Coordinator*:*

All District 2 Area.

D2 Deputy District Director, Maintenance*:*

Aerial mapping used in CTS DHIP (?) *or ArcView programs.*

D2 ITS Engineer*:*

I like what you have. Consider displaying quad & date made on the topos, if possible. Some areas of N. California most recent map is early 1950s'.

Please identify several different scenarios in which incident **photos** would be of use with this system. What information would be conveyed?

D2 Field Region Manager, Maintenance Operations*:*

Vehicle accidents – how many cars, how much for clean up

Hazmat spills – size, location

Storm damage – degree of and rough idea to repair

Chief, D2 Office of Traffic Management*:*

-almost every incident (pictures worth 1,000 words)
-to be honest, without photos there is almost no point to this.

D2 PC Coordinator*:*

Hazmat spill – slide – wash out – flood – earthquake – storm damage – major vehicle accident – current conditions – surrounding area impacts – roadway damage

D2 Deputy District Director, Maintenance*:*

Storm damage. Determining extent of damage, need for actios including Emergency Orders, Contracting rough costs, equipment needed, estimated extent of closure, etc. Use for documentation for reimbursement for emergency openings from Feds.

D2 ITS Engineer*:*

Refer to actual user comments.

Please identify several scenarios in which **sketches** might be used, (Include photograph sketches and blank sketches.) What information would be conveyed?

D2 Field Region Manager, Maintenance Operations*:*

Description of what you're really looking at.

Chief, D2 Office of Traffic Management*:*

Most used for damage type incidents.

-highlight items (permanent damage)

-size of things (temp lane width, size of damage, etc.)

D2 Deputy District Director, Maintenance*:*

Sketches would be needed when the picture doesn't convey all the information. They can also be used to outline earth movements in landslides and proposed solutions to correct the problems.

D2 ITS Engineer*:*

Refer to actual user comments.

Please identify **road and weather information** that would be of use to a responder using the program. (Point Forecasts, Warnings/Alerts, and Nearby Conditions have been implemented.) Other examples might include RWIS, chain control, etc.

D2 Field Region Manager, Maintenance Operations*:*

Looks good, may want to look at "Forecast Discussion" on NOAA site

Chief, D2 Office of Traffic Management*:*

Forecasts, Warnings/Alerts are key items. RWIS data would also be helpful, chain control not so much.

D2 PC Coordinator*:*

NOAA Discussions

D2 Deputy District Director, Maintenance*:*

Projected flows within streambeds during flooding events.

D2 ITS Engineer*:*

RWIS, CDEC, Mesowest, Etc, text data within a user selectable radius of incident.

The **Devices** section shows signal strength for the modems and information from the GPS. Do you think this information will help the users of the program to troubleshoot problems or will it be "too much information?" Please explain.

D2 Field Region Manager, Maintenance Operations*:*

Needed, but keep as simple as possible.

Chief, D2 Office of Traffic Management*:*

Too much information, though as long as in training it's pointed out that this is for info only and only for advanced users then ok to show.

D2 PC Coordinator*:*

Add hardwire (Ethernet) & possibly POTS dial up to communications manager. Bluetooth connections (cell phone cameras).

D2 ITS Engineer*:*

I think it is fine. The uninitiated user can ignore the tab if he does not know what to do with it.

The **Messaging** capability automatically sends email to a previously identified address. Will this work, or should the user be given the choice of an address or multiple addresses? (Note that the message could be forwarded from the TMC elsewhere.)

D2 Field Region Manager, Maintenance Operations*:*

Not sure.

Chief, D2 Office of Traffic Management*:*

Need to have a set e-mail list that is changeable for advanced users, but most users just hit 'Send' and don't worry about where it's going.

D2 PC Coordinator*:*

Preview with attachments – use Lotus Notes groups

D2 ITS Engineer*:*

If the mail distribution list (as Bill indicated) can be set up (and modified) on the Notes server then I think a single automated e-mail to that list is best.

A **Help** section has been omitted. Do you think a help section is needed? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

No, keep it simple so no help is needed

Chief, D2 Office of Traffic Management*:*

No help section needed. However, a quick reference guide (laminated) to go in field with user is a must.

D2 ITS Engineer*:*

I think a manual is needed, that is detailed enough that you can figure your way out of a problem. On-screen help would only be worth doing if it is detailed enough that it is essentially a manual. A cursory restating of what is obvious on the screen is not worth doing.

Forms were identified as being very useful. Assuming that technical issues could be resolved to make the completion of forms easy via the system, what forms would you include in the system?

D2 Field Region Manager, Maintenance Operations*:*

Maybe for Hazmat.

Chief, D2 Office of Traffic Management*:*

From the TMC side only, there are certain bits of information we always get (or want), but we can just as easily get this over the radio:

-type of traffic control

-estimated duration to get roadway open to normal traffic

-type of incident

-etc

D2 PC Coordinator*:*

Caltrans E-Forms – FormFlow Software

D2 Deputy District Director, Maintenance*:*

If this is rolled out to teams reviewing storm damage, Damage Assessment Forms would be useful.

Manuals were identified as being very useful. What manuals would you include in the system?

D2 Field Region Manager, Maintenance Operations*:*

Hazmat manuals.

Chief, D2 Office of Traffic Management*:*

From TMC side: none.

D2 PC Coordinator*:*

Maintenance Manuals – Hazmat – First Responder ICS Manuals – Phone Listings

D2 ITS Engineer*:*

- Basic operation & User's Guide

- Detailed troubleshooting, theory of operations & Maintenance

<u>What information or capability is missing from the incident organizer that you would like to see? (For instance, phone numbers for nearby public safety officials could be included.)</u>

Chief, D2 Office of Traffic Management*:*

- *Radio cell book,*

- *For others see comments from maintenance staff.*

D2 PC Coordinator*:*

See Manuals answer

D2 ITS Engineer*:*

Overall I think it is a good job. I think it is better to keep it simple & highly functional at this stage. I would like to see a little cleaner way of seeing what e-mail is sent (preview) & a more intuitive way of selecting what is in the e-mail.

Section 2: Incident Email

Please refer to the sample incident email to answer these questions.

Is the text information in the initial incident email useful? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

Yes, plain and simple.

Chief, D2 Office of Traffic Management*:*

From a TMC standpoint, no (because we likely already have this info). However, for anyone else, yes.

D2 Deputy District Director, Maintenance*:*

Yes, it provides the base information of what and where.

D2 ITS Engineer*:*

Yes – to the point.

Is the quality of the photos and sketches adequate to convey the incident information? Please explain. (Note that photos were compressed to expedite transmission.)

D2 Field Region Manager, Maintenance Operations*:*

Need real world experience to judge quality.

Chief, D2 Office of Traffic Management*:*

They are right at the edge of acceptable quality. A little better quality would be nice – from a media standpoint, it would be nice to have a little better quality (or have the option to send one at a better quality).

D2 ITS Engineer*:*

Yes – overall I do think some slightly better resolution would be worth slightly longer transmission time. The hand written text needs to be cleaner.

Is the Microsoft Word document organized sufficiently for easily reading and locating incident information? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

Yes, looks good.

Chief, D2 Office of Traffic Management*:*

Yes, we all have Word.

D2 ITS Engineer*:*

Yes.

Does a Microsoft Word document, as an attachment, appear to be a viable means for assembling and distributing the incident information to TMC staff? Please explain. (For instance, do TMC staff have access to Microsoft Word and use it regularly?)

D2 Field Region Manager, Maintenance Operations*:*

Yes, user friendly and everyone uses it now.

Chief, D2 Office of Traffic Management*:*

Yes to both questions.

D2 PC Coordinator*:*

Yes. Word is standard software for all Caltrans PC's.

D2 ITS Engineer*:*

Yes to all.

Do you think email, as used in the example, is / could be an effective means for communication between responders and the TMC? Please explain. (For instance, do TMC staff have access to email and will they notice these messages when they come in?)

D2 Field Region Manager, Maintenance Operations*:*

Yes, good method and we have email alerts on our own desktops.

Chief, D2 Office of Traffic Management*:*

Yes to the first question. To the second, Yes and no (if they get busy, they don't monitor their e-mail as much), however field staff should be communicating with TMC that e-mail is being sent, then they can look for it.

D2 PC Coordinator*:*

Yes, along with radio communications.

D2 ITS Engineer*:*

Yes – it gets around many delivery problems getting into Caltrans.

In certain cases, it may be necessary to chunk the information to facilitate transmission. In other words, individual emails might be sent containing one photograph attachment each. Would this be acceptable, if it helped to assure that information could be sent more quickly or without requiring the responder to move to another location? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

One is cleaner, but several would work.

Chief, D2 Office of Traffic Management*:*

Yes, however can the program automatically determine the need to do this and then automatically do it without input needed from user. Also, an automatic pre-e-mail to receivers telling them info is being broken up into several e-mails due to comm signal would be good.

D2 PC Coordinator*:*

Not preferred. Will text be with each photograph?

D2 ITS Engineer*:*

Yes – the summary e-mail would need to clearly identify all the pieces of the whole incident message. This is less desirable.

Section 3: Communications

<u>Do you see this system as a potentially viable means for communication between responders and the TMC? Please explain.</u>

D2 Field Region Manager, Maintenance Operations*:*

Yes, good real time data.

Chief, D2 Office of Traffic Management*:*

We already have communication between field & TMC. However, this is a better way to give the clearest picture of the conditions and in turn respond in the most effective/educated way.

D2 ITS Engineer*:*

Yes.

<u>Under what circumstances might the system be used as an alternative to voice communications?</u>

D2 Field Region Manager, Maintenance Operations*:*

A picture is worth a 1,000 words!

Chief, D2 Office of Traffic Management*:*

If we don't have radio <u>or</u> cell communications at site only.

D2 PC Coordinator*:*

Not an alternative but in conjunction with.

D2 ITS Engineer*:*

Radio/cell dead spot – a chat feature may be useful.

Under what circumstances might the system be used in addition to voice communications?

D2 Field Region Manager, Maintenance Operations*:*

Again, a picture is worth a 1,000 words.

Chief, D2 Office of Traffic Management*:*

Any major long term incident.

D2 PC Coordinator*:*

When incident warrants (many).

D2 ITS Engineer*:*

All circumstances – it augments voice.

What's the maximum amount of time that it could take for the information from the system to reach the TMC and be useful? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

?

Chief, D2 Office of Traffic Management*:*

It somewhat depends on the incident duration, but I'll assume it's several hours, in that case within 15 minutes – too much beyond that and you've already turned on TMC element.

D2 PC Coordinator*:*

1 Hour.

D2 ITS Engineer*:*

½ hour – discuss with operations folks.

Are there any places in District 2 where you have no voice communication capabilities? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

We do have areas that there is no radio or cell communication.

Chief, D2 Office of Traffic Management*:*

Yes… talk to dispatch or maintenance for specific locals.

D2 PC Coordinator*:*

Some dead spots in the district.

D2 Deputy District Director, Maintenance*:*

Yes. We have remote locations in every county where there is no cell phone coverage – we have a few locations with no radio coverage as well.

D2 ITS Engineer*:*

Yes – many areas are dark.

Are you aware of plans to implement digital voice and/or data communications networks for use by Caltrans or or state agencies? If yes, please explain.

D2 Field Region Manager, Maintenance Operations*:*

?

Chief, D2 Office of Traffic Management*:*

No.

D2 PC Coordinator*:*

800 Megahertz radio system.

D2 Deputy District Director, Maintenance*:*

There is an interest in developing cellular networks in remote areas as part of our ITS infrastructure.

D2 ITS Engineer*:*

800 MHz system – supposedly this will be data capable. This has been an ongoing project for years. I would not count on it any time soon.

In the absence of a private radio data network, do you consider cellular and satellite service to be a viable option for service on an application such as this? Please explain.

D2 Field Region Manager, Maintenance Operations*:*

Yes, it's a good option.

Chief, D2 Office of Traffic Management*:*

Yes…what else is there?

D2 PC Coordinator*:*

Yes.

D2 ITS Engineer*:*

Yes – as demonstrated.

Should both cellular and satellite be incorporated into every unit, or should units have one or the other, dependent on their typical service areas? Please explain. (This could reduce the size and complexity of the system.)

D2 Field Region Manager, Maintenance Operations*:*

A few areas could be cell only, very few…

Chief, D2 Office of Traffic Management*:*

If they can be appropriately marked, sure, why have a cell/sat system deployed for an area that has solid cell service (if that can 100% be determined). For our area I don't think that can be done, thus we need both.

D2 PC Coordinator*:*

Yes. Cell coverage is improving every month. New GSM technology.

D2 Deputy District Director, Maintenance*:*

They should have both. Service areas cover a large area where the coverage varies.

D2 ITS Engineer*:*

Both in one unit – the carrier network are changing too much, service areas for cellular changing/improving continually.

Section 4: General Use

Who would use this system?

D2 Field Region Manager, Maintenance Operations*:*

First responder to accidents, hazmat, storm damage.

Chief, D2 Office of Traffic Management*:*

Field maintenance & TMT.

D2 ITS Engineer*:*

Maintenance supervisors & TMT staff.

When and how often would they use it?

D2 Field Region Manager, Maintenance Operations*:*

Major incidents and as needed.

Chief, D2 Office of Traffic Management*:*

For every long term incident which for DZ varies greatly depending on storms.

D2 ITS Engineer*:*

Any incidents.

What uses would you consider in rural areas?

D2 Field Region Manager, Maintenance Operations*:*

Same as above plus you could do some non response communication for other problem solving issues.

Chief, D2 Office of Traffic Management*:*

Long term incidents.

D2 ITS Engineer*:*

Initial and ongoing incident information.

<u>What uses would you consider in urban areas?</u>

D2 Field Region Manager, Maintenance Operations*:*

See rural answer.

Chief, D2 Office of Traffic Management*:*

Same as rural, but I think you'll find we urban areas have less long term incidents than rural areas.

D2 Deputy District Director, Maintenance*:*

Accident reporting, determining travel times.

D2 ITS Engineer*:*

Unknown.

<u>Do you see this tool being useful for other purposes? For instance, documenting incidents?</u>

D2 Field Region Manager, Maintenance Operations*:*

Yes, this could grow into a lot of other functions.

Chief, D2 Office of Traffic Management*:*

Yes, you just may not send the e-mail. What is needed is a database to dump all responder data into (searchable, viewable etc).

D2 Deputy District Director, Maintenance*:*

Yes. Documentation of accidents can be used for defense in lawsuits or in determining accident patterns. Damage information of the roadway can be used for reimbursement efforts when signs or guardrail is damaged by a motorist.

D2 ITS Engineer*:*

Yes, although initial responder applications primary.

<u>What non-DOT applications could the system be used for?</u>

D2 Field Region Manager, Maintenance Operations*:*

Public information.

Chief, D2 Office of Traffic Management*:*

Fine, law enforcement.

D2 Deputy District Director, Maintenance*:*

Fire suppression efforts, supplemented communication for emergency vehicles.

D2 ITS Engineer*:*

Fire & EMS.

<u>Do you see this as an effective tool for collecting and sharing information between agencies? Please explain.</u>

D2 Field Region Manager, Maintenance Operations*:*

Yes, everyone needs to see what the scene looks like.

Chief, D2 Office of Traffic Management*:*

Yes, so they understand (clearly) what the condition is. Also, the media could be very key…

D2 ITS Engineer*:*

Not directly, but via TMC.

<u>How much time could a responder devote to using a system like this while at an incident? Please specify details if it varies by the type of incident and/or responder.</u>

D2 Field Region Manager, Maintenance Operations*:*

Hard to answer, the simpler the better.

Chief, D2 Office of Traffic Management*:*

Minutes (see comments from field maintenance)

D2 ITS Engineer*:*

Not qualified to discuss.

Section 5: Hardware Deployment in Vehicles

<u>Is it best for the computer to be fixed in the vehicle, mobile outside the vehicle, or mobile within the vehicle?</u>

D2 Field Region Manager, Maintenance Operations:

Mobile within the vehicle.

Chief, D2 Office of Traffic Management*:*

Need to be able to move from vehicle to vehicle.

D2 Deputy District Director, Maintenance*:*

Mobile within the vehicle.

D2 ITS Engineer*:*

Mobile outside the vehicle.

<u>Should users have access to a keyboard only, a tablet with pen only, or both a pen and keyboard?</u>

D2 Field Region Manager, Maintenance Operations:

Both a pen and keyboard.

Chief, D2 Office of Traffic Management*:*

Tablet with pen only.

D2 PC Coordinator*:*

Both.

D2 Deputy District Director, Maintenance*:*

Both a pen and keyboard.

D2 ITS Engineer*:*

Tablet with pen only.

<u>Is a tablet too large for reasonable use? (versus a PDA, for instance)</u>

D2 Field Region Manager, Maintenance Operations:

Not sure, would need to demo both…

Chief, D2 Office of Traffic Management*:*

Big is better… maintenance guys don't have delicate hands for precise operations (as heeded with a PDA)

D2 PC Coordinator*:*

No.

D2 Deputy District Director, Maintenance*:*

No if the hardware can be organized within the vehicle.

D2 ITS Engineer*:*

No.

<u>Would it be best for the entire system to be permanently fixed in a vehicle or should it be mobile, such as in a briefcase? (Note that if in a briefcase, setup of antennas, connection to power, etc. would be required prior to use.)</u>

D2 Field Region Manager, Maintenance Operations:

Brief case in most instances

Chief, D2 Office of Traffic Management*:*

Need to be able to move from vehicle to vehicle.

D2 PC Coordinator*:*

Mobile.

D2 Deputy District Director, Maintenance*:*

I would suggest somewhat fixed in the vehicle and use the vehicle as an office.

D2 ITS Engineer*:*

Permanently fixed in vehicle with wireless to tablet (for DOT applications).

Section 6: Cost

The cost of the system, as configured, is approximately $6000 for the hardware, $100 for satellite service (400 minutes per month), and $65 for cellular service (unlimitted data service for the month.) This does not include maintenance and support. Is this viable?

D2 Field Region Manager, Maintenance Operations*:*

That's a little expensive and would need to study the cost effectiveness.

Chief, D2 Office of Traffic Management*:*

Yes.

D2 PC Coordinator*:*

Ask Jeff.

D2 Deputy District Director, Maintenance*:*

This is viable but the funding situation varies from year to year.

How many units could you anticipate deploying?

D2 Field Region Manager, Maintenance Operations:

Depends on real world test! I could see 30-50 units deployed, all supervisor and traffic responders…

Chief, D2 Office of Traffic Management*:*

?? Depends on funding source.

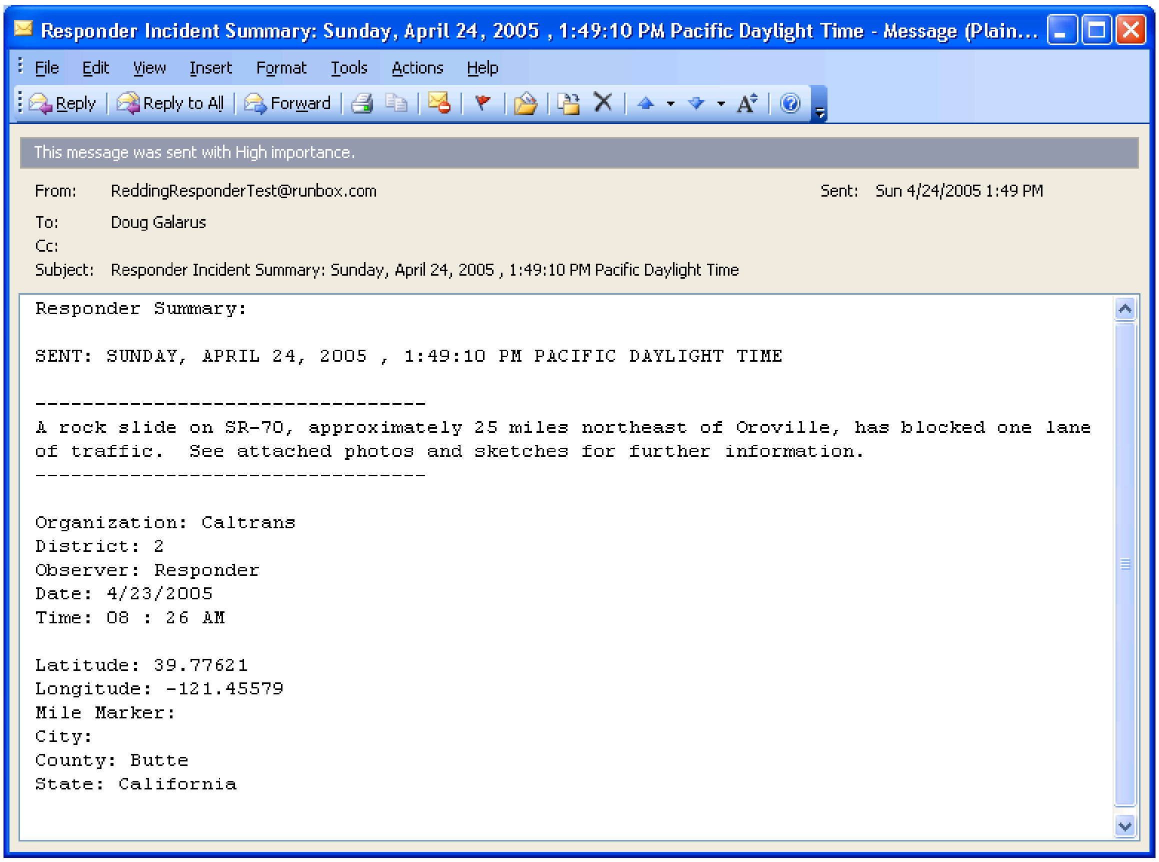
D2 Deputy District Director, Maintenance*:*

We will have to take a hard look at the funding that is available.

14. APPENDIX V – SAMPLE RESPONDER EMAIL

14.1. Responder "Beacon" Email

A text only "beacon" email is sent first. This small email message is sent as a signal that more information will follow, and includes location and description information for the incident. Since the message is small, the chance of successful transmission is high. The message is flagged with "high importance" to draw the attention of the recipient.



Responder Incident Summary: Sunday, April 24, 2005 , 1:49:10 PM Pacific Daylight Time - Message (Plain...

This message was sent with High importance.

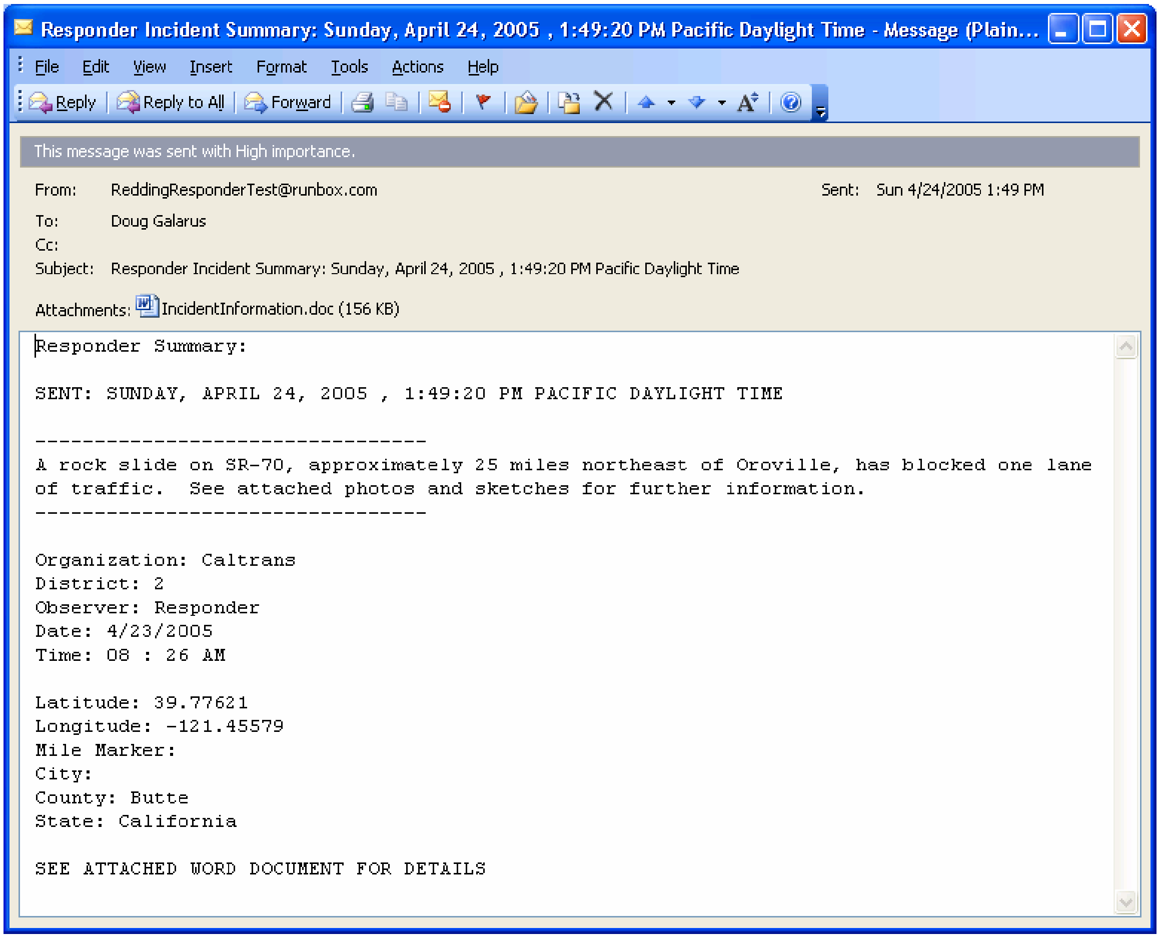
From: ReddingResponderTest@runbox.com Sent: Sun 4/24/2005 1:49 PM
To: Doug Galarus
Cc:
Subject: Responder Incident Summary: Sunday, April 24, 2005 , 1:49:10 PM Pacific Daylight Time

```
Responder Summary:

SENT: SUNDAY, APRIL 24, 2005 , 1:49:10 PM PACIFIC DAYLIGHT TIME

---------------------------------
A rock slide on SR-70, approximately 25 miles northeast of Oroville, has blocked one lane
of traffic.  See attached photos and sketches for further information.
---------------------------------

Organization: Caltrans
District: 2
Observer: Responder
Date: 4/23/2005
Time: 08 : 26 AM

Latitude: 39.77621
Longitude: -121.45579
Mile Marker:
City:
County: Butte
State: California
```

Figure 148: Responder "Beacon" Email

14.2. Responder Email with Attachment

A second identical email message is sent including a Microsoft Word document containing incident information including photos and sketches. The message is flagged with "high importance" to draw the attention of the recipient.


Responder Incident Summary: Sunday, April 24, 2005 , 1:49:20 PM Pacific Daylight Time - Message (Plain...

File Edit View Insert Format Tools Actions Help

Reply Reply to All Forward

This message was sent with High importance.

From: ReddingResponderTest@runbox.com Sent: Sun 4/24/2005 1:49 PM
To: Doug Galarus
Cc:
Subject: Responder Incident Summary: Sunday, April 24, 2005 , 1:49:20 PM Pacific Daylight Time

Attachments: IncidentInformation.doc (156 KB)

```
Responder Summary:

SENT: SUNDAY, APRIL 24, 2005 , 1:49:20 PM PACIFIC DAYLIGHT TIME

---------------------------------
A rock slide on SR-70, approximately 25 miles northeast of Oroville, has blocked one lane
of traffic.  See attached photos and sketches for further information.
---------------------------------

Organization: Caltrans
District: 2
Observer: Responder
Date: 4/23/2005
Time: 08 : 26 AM

Latitude: 39.77621
Longitude: -121.45579
Mile Marker:
City:
County: Butte
State: California

SEE ATTACHED WORD DOCUMENT FOR DETAILS
```

14.3. Responder Microsoft Word Attachment

Following is the contents of the sample Microsoft Word attachment containing incident information. Note that this document contains the same text incident information, one photo, and six sketches. The total size is 156KB.

Responder Summary:

Generated: 4/24/2005, 1:47:27 PM Pacific Daylight Time

Location:

Latitude: 39.77621

Longitude: -121.45579

Road / Address: SR-70, Oroville, CA 95965

Mile Marker:

City:

County: Butte

State: California

Description:

A rock slide on SR-70, approximately 25 miles northeast of Oroville, has blocked one lane of traffic. See attached photos and sketches for further information.

Organization: Caltrans

Date: 4/23/2005

District: 2

Time: 08 : 26 AM

Observer: Responder

Photos:

Incident Image: photo 4

Progress on Smaller Rocks

Sketches:

Incident Sketch: sketch 1

Relative Size of Rockslide

Incident Sketch: sketch 2

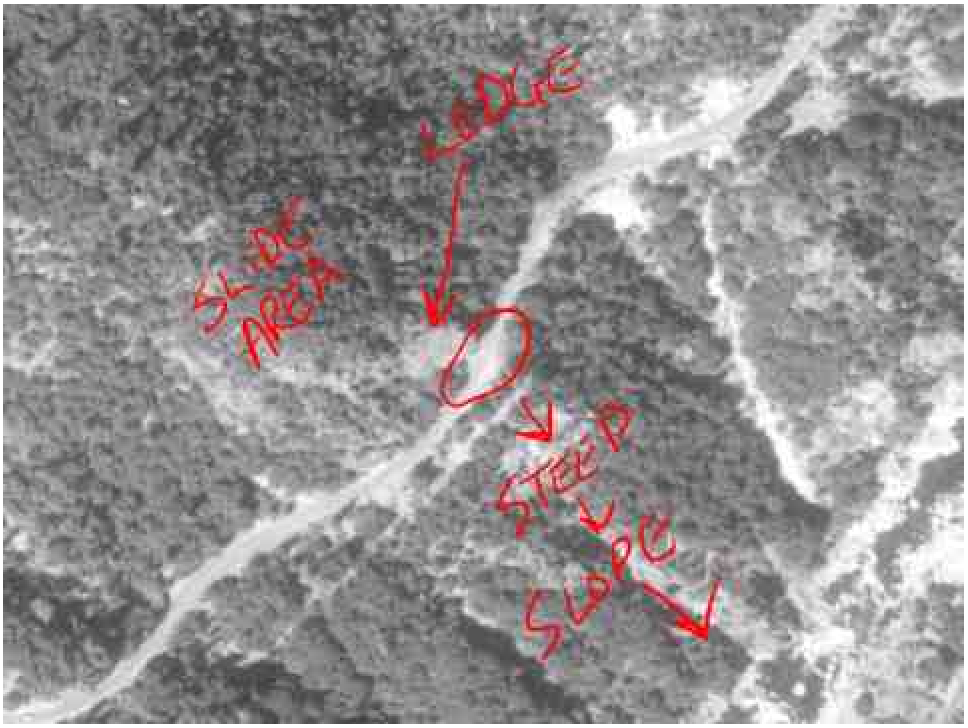
200+ Ton Rock!!!

Incident Sketch: sketch 3

Clearance on East Side

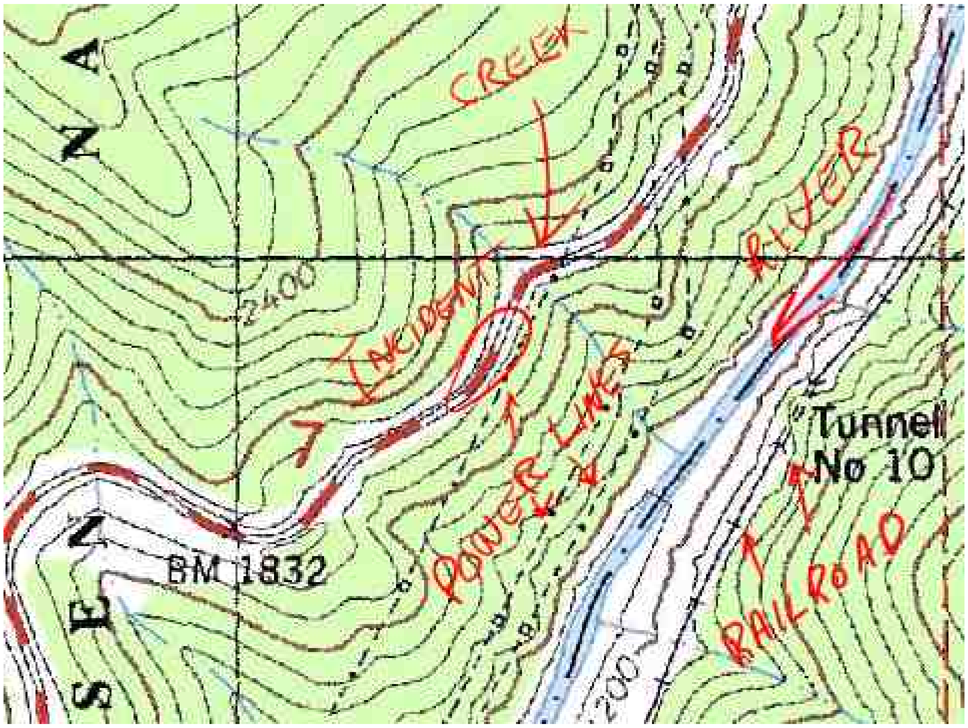
Incident Sketch: sketch 4

Aerial Photo



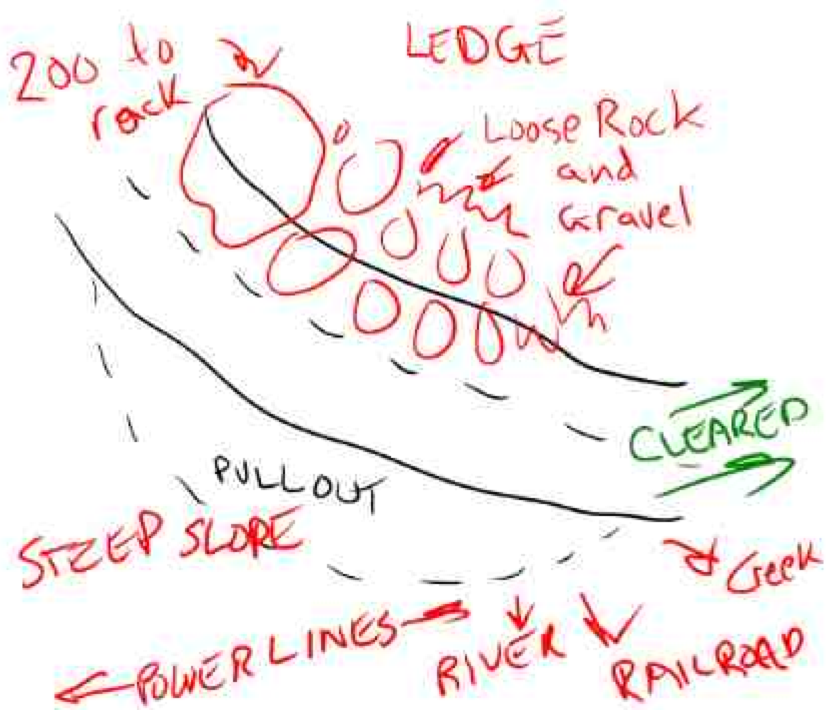
Incident Sketch: sketch 5

Topo Map



Incident Sketch: sketch 6

Incident Sketch



15. APPENDIX VI – PRELIMINARY SATELLITE PHONE REPORT

Use of Satellite Phones in Remote Areas by First Responders for Data Transmission

Part of the Redding Responder Project

Prepared for

The California Department of Transportation

by

The Western Transportation Institute
Montana State University

Douglas E. Galarus
Principal Investigator

William J. Jameson, PhD
Department of Electrical and Computer Engineering (Retired)
Montana State University

15.1. Introduction

Under contract with the California Department of Transportation (CALTRANS), the Western Transportation Institute (WTI) at Montana State University is conducting the Redding Responder project to investigate and demonstrate options and applications for data connectivity for first responders in CALTRANS District 2. While the study will incorporate services such as cellular, where available, emphasis has been placed on remote rural areas, in irregular terrain, that are otherwise not served by traditional RF systems or land-based wireless data providers. These areas not only suffer from a lack of data communications, but also from poor to non-existent voice communications. Satellite phones are being investigated in this project primarily for data connectivity, but also can serve as backups for other voice systems when those systems are out of contact.

Satellite phones are generally accepted as suitable for use in such remote rural areas and their use is becoming more prevalent with search and rescue teams, law enforcement and other responders who operate in such areas. However, there appears to be relatively little published information regarding the use of these phones, particularly for data communications in remote rural areas. A 2002 report by the Frost and Sullivan consulting firm compared services provided by the two major providers of satellite phone service, Globalstar and Iridium. The report indicates that Globalstar provides better service for both voice and data calls. In particular, data transmission rates are significantly higher (7.2 kb/s vs. 2.4 kb/s). But, despite the indication that tests were conducted in both urban and rural locations, there is little detail provided regarding adverse affects on service caused by geography and vegetation. The following quote from the Frost and Sullivan report summarizes their findings in these situations:

> *"Overall, it can be said that signal blockage is signal blockage, no matter which system. If there was sufficient clear sky, both systems would be operable and the main differentiator was audio quality. Under all types of conditions, Globalstar showed time and time again a significant and measurable superiority over the Iridium system in this aspect."*

WTI conducted several informal tests in rural and remote rural locations to become accustomed to using the phones and to determine if signal blockage might be a significant problem for this project. After conducting several voice and data tests and measuring signal strength as indicated by the phone, it was determined that signal blockage could definitely be a problem. Periodic degradation of service and even momentary total loss of service were observed. As a result, WTI decided to pursue more extensive testing in one of the areas where blockage was observed.

For voice communication, dropped calls can be an annoyance, but may be a tolerable annoyance if they have a relatively low frequency. If the call can be reestablished and maintained quickly, then the conversation can pick up where it was left off. For data communications, however, dropped calls can be a serious impediment to effective use. For instance, if an email is being sent and the call is dropped halfway through, then the connection must be reestablished and the data transmission must start again at the beginning. If this happens repeatedly, the end user will be unlikely to use the system.

A second set of tests (Phase 2) was performed to determine the circumstances, in terms of signal strength (on a scale of 0-4), in which a call would be disconnected. This is crucial when the phone is used for data transmissions. A third set of tests (Phase 3) was conducted to compare satellite phone, cell phone and Montana Highway Patrol's mobile data system coverage in the Gallatin Canyon between Bozeman and West Yellowstone, Montana. This canyon has many of the geographic features of the remote rural locations in the Redding, California area. A fourth set of tests (Phase 4) was conducted to further determine the affect of terrain and vegetation on satellite phone signal strength. These tests were conducted at two sites in Hyalite Canyon, to the south of Bozeman. A fifth set of tests (Phase 5) was conducted while traveling along Interstate 90 between Bozeman and Missoula.

The goal of these tests was to characterize "signal blockage" and "sufficient clear sky", and produce guidelines and technology to assist end-users in maximizing the effectiveness of these phones.

15.2. Phase 1 – Initial Remote Rural Tests

Initial observations were made from a site on the West Fork of Rock Creek in the Custer National Forest 12 miles west of Red Lodge, Montana, and near the Absaroka-Beartooth Wilderness. This area can be characterized as ranging from moderate terrain and foliage near Red Lodge to dense foliage and rugged terrain at the site. The road leading to the site is at times surrounded by trees within 10 feet of the road and heavily obstructed views of the sky and at other times clear to moderately clear, with relatively unobstructed views of the sky. Several of the tallest peaks in Montana are in this area, with elevations above 12,000 feet. In particular, Silver Run Peak measures 12,500 ft in elevation and is located to the southwest of the site.

It is suspected that vegetation and geography both play roles obstructing the line of site to Globalstar satellites. These factors, in combination with the nature and operation of the Globalstar satellite constellation, are considered to be the primary variables of concern regarding signal strength and loss of signal. Weather may also have an impact, but has not been investigated at this point. Formal and informal tests were conducted in the middle of the day during summer months, so weather was relatively stable with partly cloudy to clear skies and no precipitation or rain.

The Globalstar constellation can be described as follows:

- There are 48 total satellites, 6 per orbit plane.
- There are 8 orbit planes, each with a declination of 52 degrees.
- The satellites orbit at approximately 1410 km above the earth and with a period of approximately 90 minutes (780 km for Iridium).
- The satellite nominal footprint is 5850 km (4700 km for Iridium).

Globalstar phones communicate with these satellites using CDMA technology in a manner similar to that of cell phones communicating with cell towers. Handoffs from satellite to satellite provide the handset with continual coverage, where possible. For instance, when a satellite providing the current connection nears the horizon, the signal should be handed off to another satellite. Under ideal circumstances, the handset communicates with multiple satellites and this handoff occurs without disruption of service to the handset. However, we believe situations can occur in rugged areas when a satellite passes out of sight over a mountain and no other satellite is immediately visible for handoff. We believe that at least in part, this explains some of the dropped calls and lost signals we observed during initial use of the phones. In fact, this phenomenon seems quite likely in narrow canyons. A given satellite's visibility to a fixed location, even in flat areas, lasts only a matter of minutes. And, the orbit planes are separated by a great enough distance to make this explanation viable. Dense vegetation could cause similar problems. We have computed the reduced (effective) footprint (due to the space interference of the surrounding mountains) at the Rock Creek site to be, at a minimum, 3761 km or 64% of the nominal footprint and, at a maximum, 4828 km or 83% of the nominal footprint. See Figure 150: Satellite Footprints. The computation takes into consideration both the angles to the top of the mountains on either side of the canyon and the orbit angles (52^o or -52^o) of the satellite path relative to the direction of the canyon.

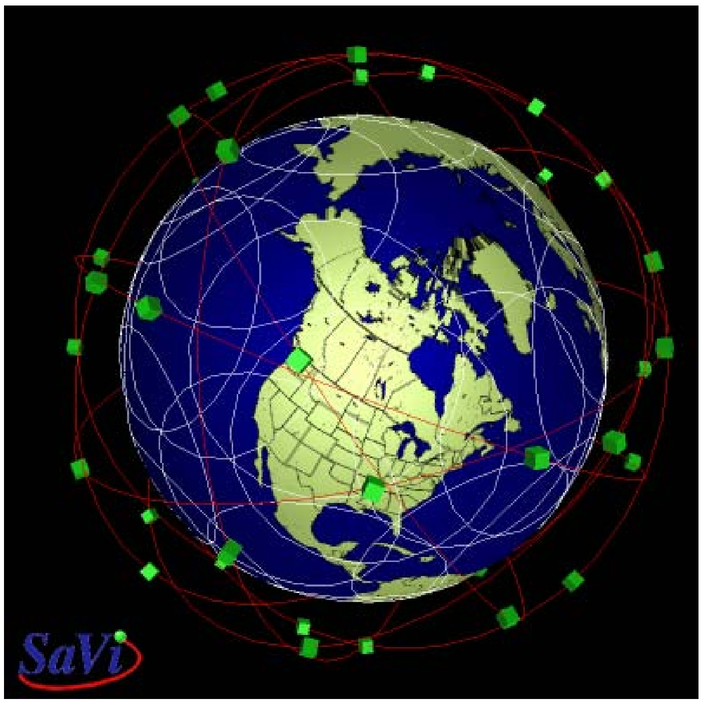
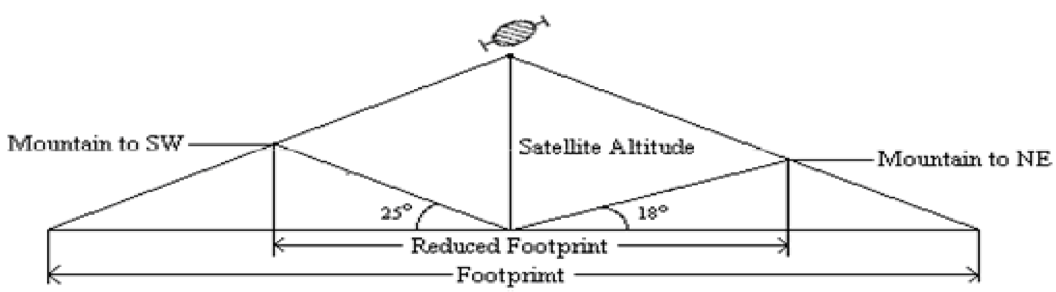


Figure 149: Globalstar Constellation



Reduced Footprint – Max – 4828 km (68%)

Reduced Footprint – Min – 3761 km (84%)

Figure 150: Satellite Footprints

15.2.1. Methodology

The region between the Red Lodge and the test site were investigated by observing and recording signal strengths while traveling to the site, while at the site, and traveling from the site back to Red Lodge. This area and path are summarized in the following two figures.

Figure 151: Phase 1 General Testing Area

Figure 152: Phase 1 Test Path

The majority of observations made on the road were made while the vehicle was moving. Observations made at the site were made from within the parked vehicle. A pickup truck was used for transport, and an Orbit One Communications mobile kit was used to provide power and housing for the phone. An external, magnetic mount antenna, provided as part of the mobile kit, was mounted in the middle of the truck cab roof. All testing was done using this configuration.

Satellite phone signal strengths were recorded along much of the dirt portion of the road leading to the site and along the majority of the road including the paved portion all the way into Red Lodge on the return trip. The vehicle was in motion much of this time, and the external antenna was used throughout the testing period.

The location of the site is Latitude = 45.17093^{o} N, Longitude = 109.4774^{o} W. As shown in Figure 153: Panoramic Image of Phase 1 Test Site, it is located in a heavily wooded area with rugged terrain.

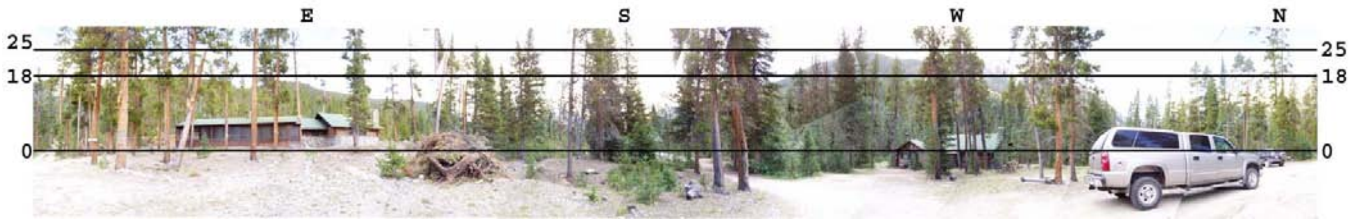


Figure 153: Panoramic Image of Phase 1 Test Site

As shown in the image, Silver Run Peak obstructs the sky up to approximately a 25 degree angle of elevation to the west-southwest. To the east-northeast, mountains obstruct the sky to approximately an 18 degree angle of elevation. Trees further obstruct the sky to even greater angles and appear to obstruct approximately 20-30% of the sky at an angle of elevation slightly greater than 25 degrees.

Note that the Globalstar user links operate in the L-Band (between 1610- and 1626.5 MHz) up-link and in the S-Band (between 2483.5 and 2500 MHz) downlink. A primary coverage issue relates to the frequency bands in which the handheld user units operate. The highest frequency, 2500 MHz, yields a wavelength of 4.721", which, in turn, yields a ¼ wavelength of 1.18". The lowest frequency, 1610 MHz yields a wavelength of 7.321" and a ¼ wavelength of 1.833". There are a large number of conifers that have needles in the range of 1.18" to 1.83". Moreover, conifer needles have been observed to absorb RF energy as though they were virtually ¼ wavelength antennae. Hence, in heavily wooded areas in which a vehicle does not have open exposure to the sky, there may be a problem with absorbed RF energy.

The roadside leading to the site is heavily wooded in proximity of the site and rises in elevation while still going deeper into the canyon. The roadside closer to Red Lodge is less wooded and the surrounding canyon is not near as steep.

Signal strength readings were observed visually and recorded on a PDA with an integrated GPS. Custom software developed at WTI allowed recordings to be made up to several seconds apart and automatically geo-coded. Signal strengths were recorded primarily when changes were observed.

A digital camera was used to take the panoramic image. A transit and compass were used to measure directions and angles of elevations, which are shown approximately in the image.

Figure 154: Silver Run Peak, as Seen from the Phase 1 Test Site

Several data calls were also attempted from the site location. A Tablet PC, connected to the satellite phone via serial cable, was used to make these data calls. An email, including a small (150K) digital image, was transmitted. Several websites were also visited, including a site that estimates connection speed.

15.2.2. Observations

Monitoring while en-route to the site was initiated at 10:20 AM on Tuesday, August 10th on FR 71, approximately 3.5 miles to the East of the site at Latitude 45.17116 N, Longitude 109.4249 W, and was carried on until stopping slightly before and then at the site. A signal strength of 4, the highest possible, was observed while traveling through a wooded area leading much of the way to the site. At approximately 10:36:30 AM and a quarter mile to the East of the site (Latitude = 45.171652 N, Longitude = 109.471753 W), signal strength momentarily dropped to 0 and proceeded to fluctuate between 1 and 4 for the next two minutes. This area was also heavily wooded and included a slight turn in the road.

Monitoring at the site was initiated at 10:41:40 AM, with observed signal strength of 4. After approximately one minute, signal strength dropped to 0 for an instant and returned immediately to 4. It remained at 4 for approximately 17 more minutes and dropped again to 0 at 10:59:30 AM. Over the next two minutes, until approximately 11:04:40 AM, signal strength bounced between 0 and 4. It then maintained a steady 4 until 11:08:30 AM, approximately 4 minutes, at which time it dropped to 0 for an instant and went back to 4 for another 3 minutes, until 11:11:40 AM. From 11:11:40 until 11:12:50, the signal bounced between 4 and 0 and returned to a steady 4 at that until approximately 11:17:20, about 4 minutes, 30 seconds. Until 11:17:50, it fluctuated between 0 and 4, and returned to 4. From 11:17:50 until 11:22:40, the signal fluctuated between 2 and 4, but didn't drop completely during that time. From 11:22:40 to 11:24:50, the signal fluctuated between 4 and 0. From 11:24:50 and 11:28:20, the signal fluctuated between 4 and 2 without losing signal during that period. The signal was lost for an instant at 11:28:20, and regained full strength for approximately 5 minutes, and then began fluctuating again.

The longest period observed with an uninterrupted signal was 15 minutes, while there were periods of several minutes in duration in which signal was fluctuating and dropping to zero. Aside from the initial 15 minute period, periods in which signal strength was maintained at 4 were generally about 5 minutes in duration.

Observations were also recorded from the site all the way back to Red Lodge, covering some areas that were not covered by earlier observations. In general, there were issues noticed in the steeper canyon and more heavily-wooded areas. From approximately halfway back to Red Lodge, all the way to Red Lodge, a solid signal was observed with no signal loss. This area was characterized as being within a shallow canyon and being generally open, with sparse vegetation next to the road.

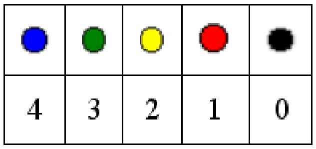


Figure 155: Legend - Satellite Phone Signal Strength

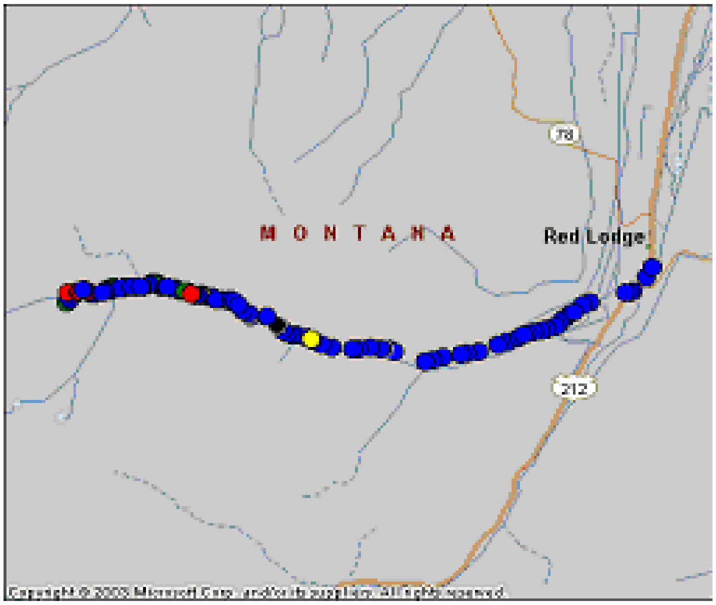


Figure 156: Observations from Phase 1 Test Site to Red Lodge

15.2.3. Data Connection Observations

Several observations were made at the site regarding data connectivity:

Table 25: Data Observations at Test Site

Date	Time	Observation
8/10/2004	12:43 PM	Dialup connection established.
8/10/2004	12:44 PM	Email composed containing 150K email message. Attempt to send ended in an error caused by a dropped connection.
8/10/2004	12:46 PM	Dialup connection reestablished.
8/10/2004	12:47 PM	Email resend attempted.
8/10/2004	12:51 PM	Email resend completed successfully.
8/10/2004	12:52 PM	Attempt to connect to www.msn.com via Internet Explorer.
8/10/2004	12:53 PM	Connection dropped before www.msn.com home page could render entirely.
8/10/2004	12:58 PM	Dialup connection reestablished.
8/10/2004	12:59 PM	Connection to www.msn.com home page succeeds.
8/10/2004	1:00 PM	Attempt to connect to CNET bandwidth
8/10/2004	1:03 PM	Connection dropped before CNET could be opened.
8/10/2004	1:05 PM	Dialup connection reestablished.
8/10/2004	1:09 PM	Connection dropped before CNET could be opened.
8/10/2004	1:10 PM	Dialup connection reestablished.
8/10/2004	1:10 PM	Connection dropped before CNET could be opened.
8/10/2004	1:11 PM	Dialup connection reestablished.
8/10/2004	1:12 PM	Connection to CNET established.
8/10/2004	1:14 PM	Bandwidth measured at 2.4 Kbps
8/10/2004	1:16 PM	Dialup connection cannot be established. Phone indicates “Looking for Service” for approximately 2-3 minutes.
8/10/2004	1:20 PM	Dialup connection reestablished.
8/10/2004	1:21 PM	Connection to CNET established.
8/10/2004	1:24 PM	Bandwidth measured at 2.7 Kbps

15.3. Phase 2 – Disconnect Tests

15.3.1. Methodology

An antenna cap device was developed to reduce the field strength levels at the magnetic mounted mobile Globalstar antenna. Field strength tests were conducted in an area of the WTI parking lot having minimal primary obstruction from nearby buildings and surrounding mountains. The angle of elevation to the obstructions was no more than 9-10 degrees.

Testing was conducted on the morning of August 31st, 2004. Skies were clear and there was no wind.

Signal strength was observed using the signal strength indicator on the satellite phone display. This display is similar to that of a cell phone, with signal strength clearly indicated by “bars” in the upper right of the display. These bars could be easily read to distinguish varying signal strengths during the test.

Calls were initiated from the satellite phone to a cell phone that was also at the test site. Calls were accepted on the cell phone and the call status and duration was observed on the satellite phone while testing various obstruction scenarios. All testing was done with voice calls.

15.3.2. Observations

Observation 1
The antenna cap device was placed over the antenna and signal strength dropped to zero. After seven seconds of zero signal strength, the voice call was dropped.

Observation 2
The antenna cap device was placed over the antenna and signal strength dropped to zero. After eight seconds of zero signal strength, the voice call was dropped.

Observation 3
The antenna cap device was held over the antenna for four seconds and then removed. Signal strength remained at zero for four more seconds, and the call was dropped. In total, signal strength remained at zero for eight seconds before the call was dropped.

Observation 4
The antenna cap device was held over the antenna for one, two, three, four, five, six, seven and eight seconds. After each timed obstruction, the antenna cap device was removed and the phone was monitored for loss of a call. In all cases except for an eight-second obstruction, the call was maintained. The call was dropped following the eight-second obstruction.

Observation 5
The antenna cap device was held over the antenna for eight seconds and the signal came back but was lost after about four seconds.

Observation 6
The antenna cap device was held over the antenna for seven seconds and the call was lost. This was repeated for seven seconds and the call was lost again.

Observation 7
The antenna cap device was held over the antenna for six seconds and the call was not lost. The process was repeated and the call again was not lost. The process was repeated a third time and the call was finally lost.

Observation 8
The antenna cap device was held over the antenna for five seconds. This process was iterated seven times and the call was not lost during any of these iterations.

Observation 9
The antenna cap device was held over the antenna for seven seconds. This process was iterated three times and the call was only dropped on the third iteration.

15.3.3. Conclusions

Calls are not dropped immediately when signal strength drops to zero. In general, if signal strength drops to zero for less than seven seconds, the call remains connected. In all cases in which signal strength dropped to zero for eight seconds or more, the calls were dropped. Thus, in areas where signal strength is observed to drop to zero for eight seconds or more, there is a high likelihood that calls will be dropped.

15.4. Phase 2 – Control

15.4.1. Methodology

To determine validity of the disconnect tests, a control test was conducted in the same location and in which the satellite phone antenna was not artificially obstructed. Signal strength was monitored and recorded on a computer connected to the satellite phone via an RS-232 cable.

Testing was conducted for approximately 47.5 minutes and starting at 10:18 AM. The following panoramic image depicts the test location. Again note that there is relatively little obstruction and virtually no obstruction other than several trees and street lamps at angles above 9 degrees.

Figure 157: Panoramic Image of WTI Parking Lot Test Phase 2 Site

15.4.2. Observations

As shown in Figure 157, the WTI Parking Lot Site exhibited virtually no signal loss. 97.34 % of 2857 recorded observations measured 4, the maximum signal strength. When combined with the 2.24% of observations that measured 3, and the 0.25% of observations that measured 2, there were a total of 99.82% of observations measured at a signal strength level of 2 or higher. Furthermore, none of the 5 observations measuring 0 occurred consecutively.

Table 26: Control Observations at WTI Parking Lot Test Phase 2 Site

Signal Strength	Frequency	Percent
0	5	0.18
1	0	0
2	7	0.25
3	64	2.24
4	2781	97.34
Total	**2857**	**100**

15.4.3. Conclusions

Following from the results of the disconnect tests, it is highly unlikely that a call would have been dropped during this time period. And, it can be reasonably concluded that the disconnect tests were valid.

15.5. Phase 3 – System Comparisons in the Gallatin Canyon

Signal strength measurements were made for cell phone and satellite phone operation on a continuous stretch of US 191 between Bozeman and West Yellowstone, Montana, to compare their relative effectiveness and to compare both system coverage aspects with the propagation coverage maps of the Montana Highway Patrol's mobile data system. Note that, due to the irregular terrain in the canyon, the cost of providing complete mobile data coverage over the entire canyon would be prohibitive. Similarly, the cost of providing a similar mobile data system in the remote areas surrounding Redding would be significant. Following are maps of the test area and signal strength measurements for cell and satellite phone overage in the canyon and a propagation coverage map of the MHP mobile data system for comparison.

Figure 158: Approximate Location of Signal Strength Measurements

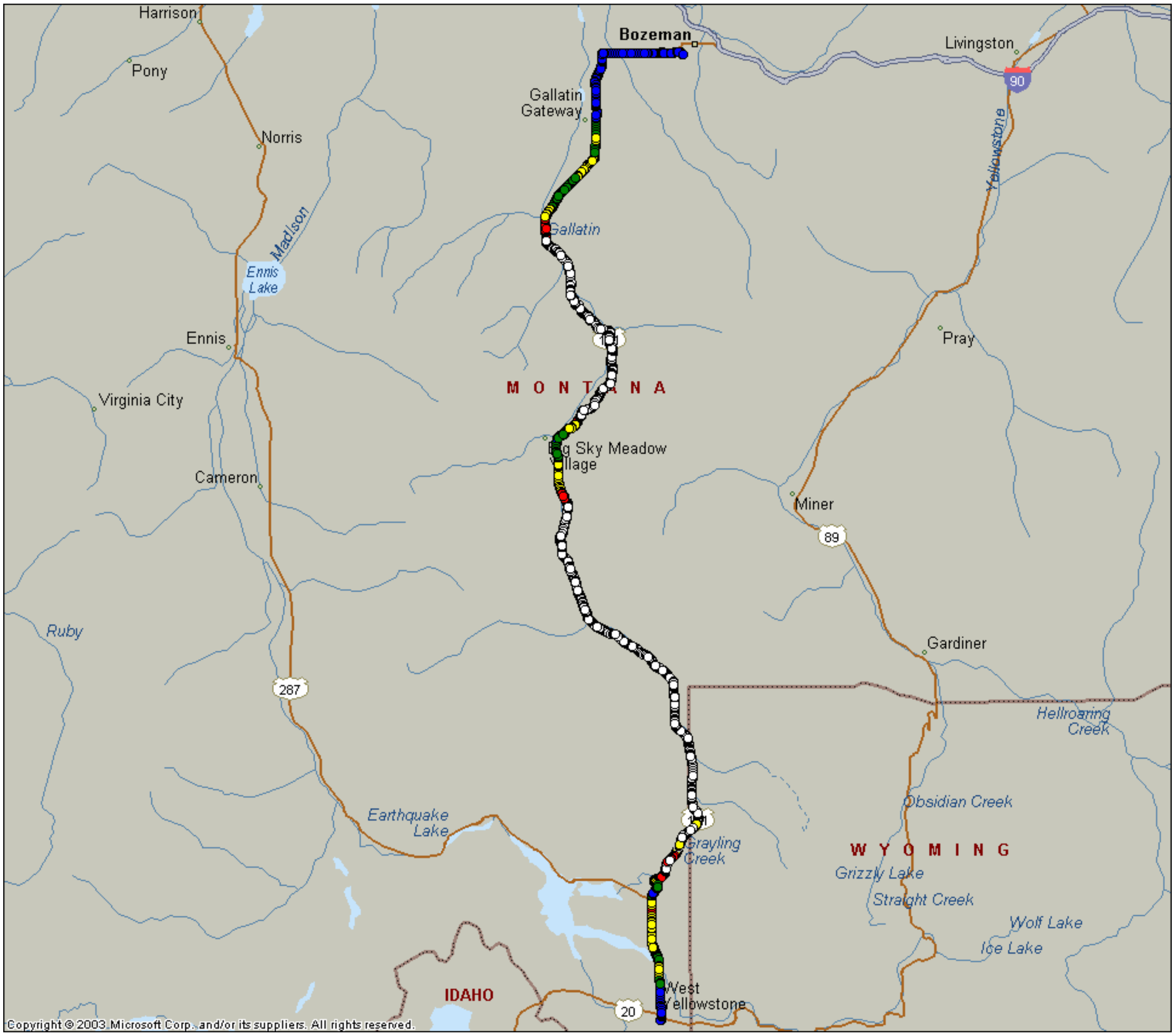


Figure 159: Cell Phone Signal Strength Measurements

Cell phone coverage, with the exception of the Big Sky area where a cell site is located, is essentially the same as the coverage of the MHP mobile data system (Figure 161: MHP Mobile Data System Coverage Map).

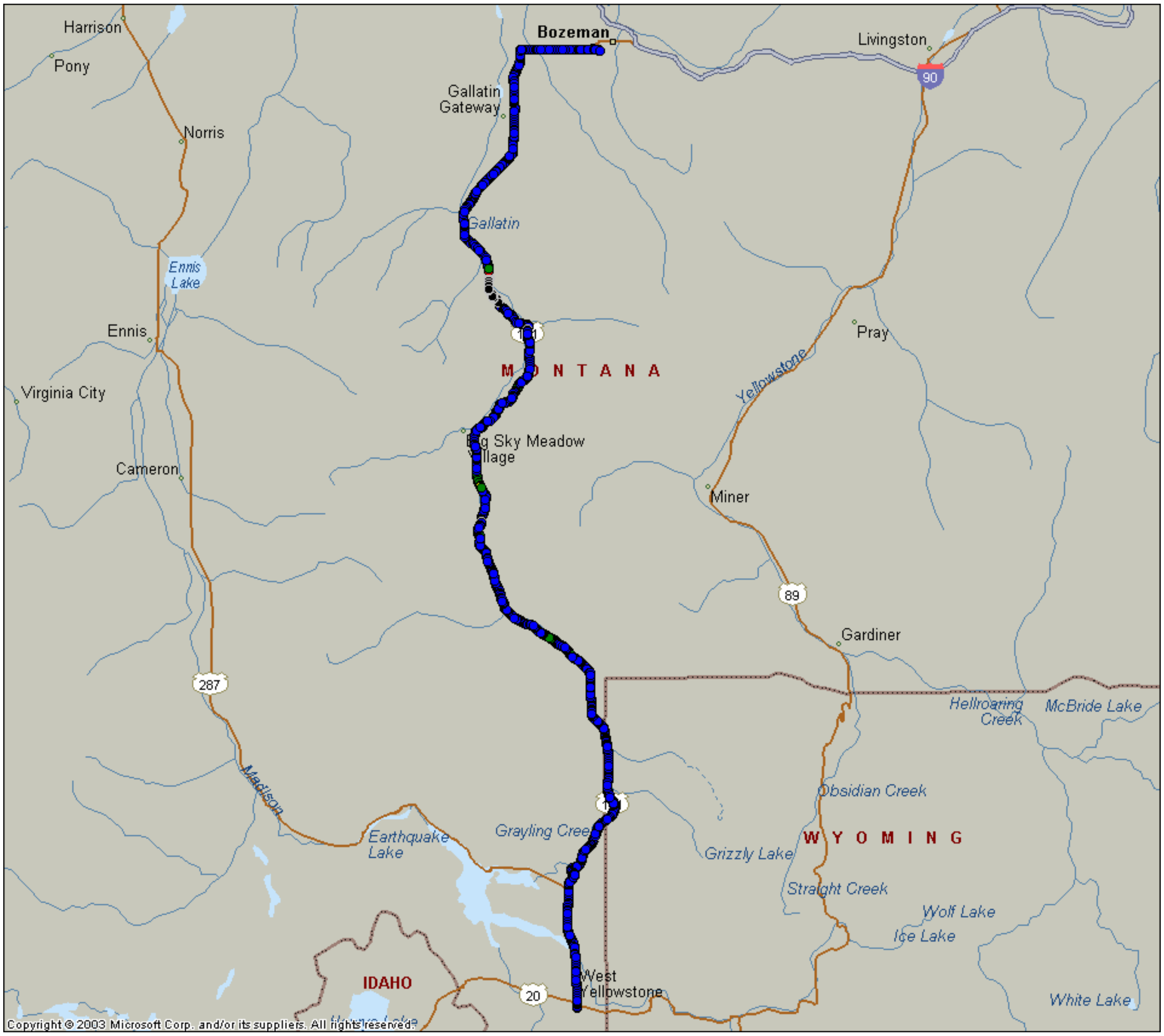


Figure 160: Satellite Phone Signal Strength Measurements

Note that the satellite phone field strength was three or better over virtually the entire test path. This indicates that a data transmission would rarely be interrupted.

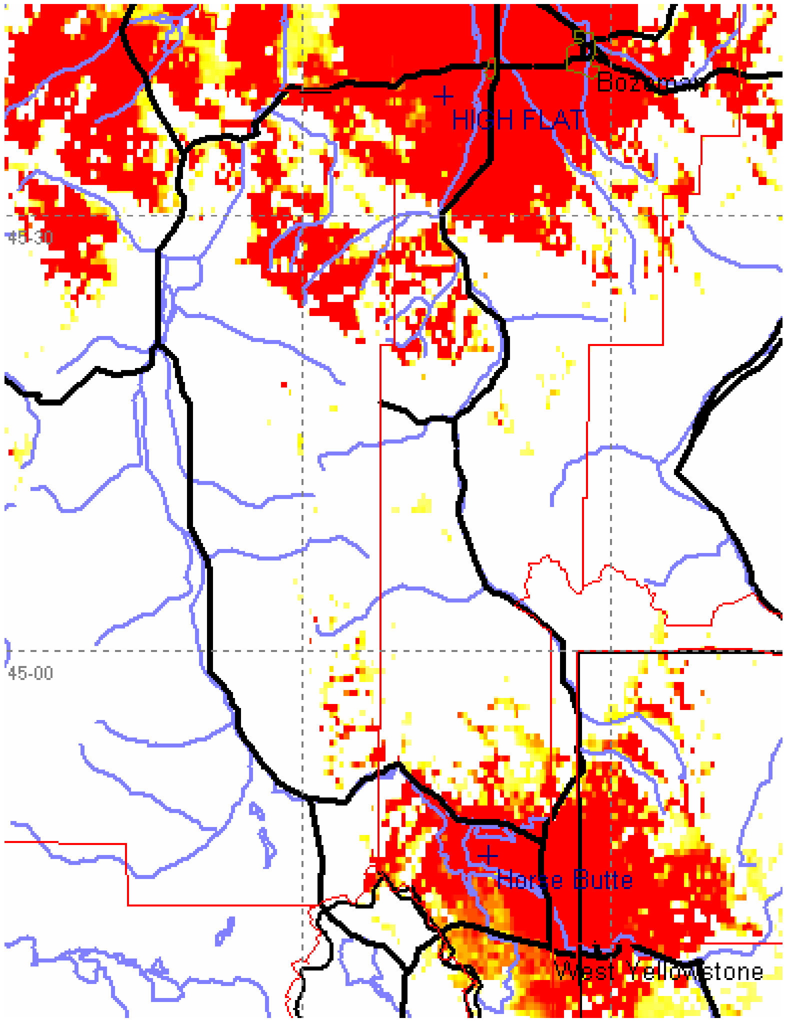


Figure 161: MHP Mobile Data System Coverage Map

In Figure 161, note that the red colored areas have excellent RF coverage for the MHP mobile data system, yellow colored areas have acceptable coverage and white colored areas have essentially no system coverage. (Since this is a digital radio system, this “cliff effect” is expected.)

15.5.1. Conclusions

RF data coverage is available only at the ends of the canyon. Cellular coverage is only available at the ends and in a small section in the middle of the canyon. Satellite coverage is available in virtually the entire canyon.

15.6. Phase 4 - Extended Site Tests

Site tests were conducted at two sites in Hyalite Canyon to the south of Bozeman, MT. The lower portion of Hyalite Canyon can be characterized as having moderate to steep terrain and dense vegetation very close to the road.

The first site was located in a portion of the canyon having obstruction angles of elevation measuring 30 degrees or more to the south and nearly 30 degrees to the north. The east and west sides of the canyon have visibility above 10 to 15 degrees. (See Figure 162: Hyalite Test Site .)

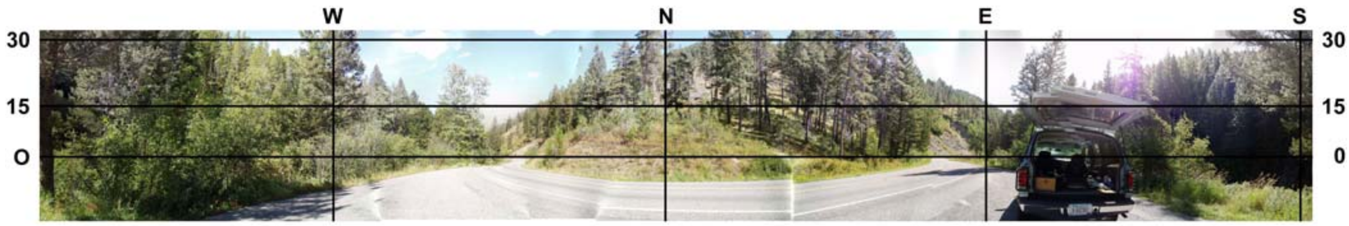


Figure 162: Hyalite Test Site A Panoramic Image

In approximately 40 minutes of stationary testing, signal loss was observed and in one case, signal loss lasted 6.5 minutes. The following table indicates durations of signal loss:

Table 27: Duration of Signal Outages at Hyalite Test Site A

Duration (seconds)	Frequency
1	26
2	5
3	2
4	1
7	1
13	1
15	1
18	1
20	1
36	1
331	1

The 6.5 minute (331 second) outage is certainly major. In cases where signal strength is lost for a matter of minutes, it may appear highly unlikely that signal strength will return long enough take successfully complete a data transmission, let alone complete a phone conversation. However, a glimmer of hope is found when looking at the duration of non-outage intervals.

Table 28: Duration of Non-Outage Intervals at Hyalite Test Site A

Duration (seconds)	Frequency
1	2
5	1
7	1
161	1
514	1
546	1
695	1

In the 40 minute time frame, there were windows of opportunity for successful, uninterrupted data or voice transmission measuring approximately 11.5 minutes, 9 minutes, 8.5 minutes and 2.5 minutes.

The second Hyalite test site was located in a less obstructed area, with obstruction measuring 16 degrees or greater only between South and South-West. Between West and North, obstruction is generally less than 11 degrees. From North to East, obstruction ranges between 11 and 16 degrees. Testing was conducted for a little over 30 minutes.

Figure 163: Hyalite Test Site B

Table 29: Signal Strength Frequency at Hyalite Test Site B

Signal Strength	Frequency	Percent
0	31	1.61%
1	0	0%
2	1	0.05%
3	12	0.62%
4	1878	97.71%
Total	**1922**	**100%**

Over 98% of the signal strength readings measured greater than 0 and in no case was signal strength dropped for more than 5 consecutive seconds. So, signal strength did not decrease sufficiently to drop a call during this time period.

There are several key differences between the two Hyalite test sites. First, site A is surrounded by higher mountain sides, obstructing the sky to greater angles of elevation than at site B. Second, site A is located in primarily an east-west canyon, while site B has greater visibility to the north and south. Since the orbits of the GlobalStar satellites tend to follow a paths biased more to the north and south than to the east and west, it is anticipated that east-west canyons would exhibit more problems than north-south canyons.

15.6.1. Conclusions

Terrain and vegetation can affect signal strength and disrupt calls. However, even under adverse conditions, windows of opportunity exist in which data communications can be conducted. The impact on signal strength can vary dramatically with changes in obstruction angles of elevation and orientation.

15.7. Phase 5 – Rural Interstate Highway Test

Satellite and cell signal strengths were tested over 200 miles of generally rural interstate highway between Bozeman, MT and Missoula, MT on Interstate 90. This area is diverse and can be characterized as having plains, plateaus, valleys and mountain passes. In general, the area does not contain deep, winding canyons, so satellite service was anticipated to be good. The area is well-served by cellular, but dead-spots certainly do exist. Testing was conducted both from Bozeman to Missoula and on the return trip from Missoula to Bozeman. Generally, with several short exceptions including the start and end of each trip, readings were recording while moving. Weather ranged from partly cloudy to heavy rain.

Table 30: Satellite Phone Signal Strength Frequency between Bozeman to Missoula

Signal Strength	Bozeman to Missoula		Missoula to Bozeman		Combined	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	53	0.40%	14	0.12%	67	0.27%
1	0	0.00%	0	0.00%	0	0.00%
2	4	0.03%	1	0.01%	5	0.02%
3	11	0.08%	3	0.02%	14	0.06%
4	13027	99.48%	12066	99.85%	25093	99.66%
Total	**13095**	**100.00%**	**12084**	**100.00%**	**25179**	**100.00%**

Table 31: Cell Phone Signal Strength Frequency from Bozeman to Missoula

Signal Strength	Bozeman to Missoula		Missoula to Bozeman		Combined	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	23	0.18%	30	0.25%	53	0.21%
1	12	0.09%	15	0.12%	27	0.11%
2	4	0.03%	15	0.12%	19	0.08%
3	24	0.18%	36	0.30%	60	0.24%
4	41	0.31%	39	0.32%	80	0.32%
5	40	0.31%	37	0.31%	77	0.31%
6	96	0.73%	77	0.64%	173	0.69%
7	116	0.89%	65	0.54%	181	0.72%
8	104	0.79%	112	0.93%	216	0.86%
9	201	1.53%	198	1.64%	399	1.58%
10	130	0.99%	120	0.99%	250	0.99%
11	305	2.33%	265	2.19%	570	2.26%
12	167	1.28%	173	1.43%	340	1.35%
13	333	2.54%	307	2.54%	640	2.54%
14	297	2.27%	340	2.81%	637	2.53%
15	179	1.37%	175	1.45%	354	1.41%
16	359	2.74%	320	2.65%	679	2.70%
17	408	3.12%	389	3.22%	797	3.17%
18	217	1.66%	201	1.66%	418	1.66%
19	556	4.25%	614	5.08%	1170	4.65%
20	372	2.84%	236	1.95%	608	2.41%
21	609	4.65%	547	4.53%	1156	4.59%
22	682	5.21%	562	4.65%	1244	4.94%
23	353	2.70%	287	2.38%	640	2.54%
24	621	4.74%	621	5.14%	1242	4.93%
25	328	2.50%	366	3.03%	694	2.76%
26	615	4.70%	620	5.13%	1235	4.90%
27	571	4.36%	756	6.26%	1327	5.27%
28	303	2.31%	341	2.82%	644	2.56%
29	780	5.96%	627	5.19%	1407	5.59%
30	329	2.51%	248	2.05%	577	2.29%
31	3294	25.15%	2634	21.80%	5928	23.54%
No signal	626	4.78%	711	5.88%	1337	5.31%
Total	**13095**	**100.00%**	**12084**	**100.00%**	**25179**	**100.00%**

15.7.1. Conclusions

Satellite service is available over this entire route. Cell service is available over much of the route. Where cell service is unavailable, satellite could certainly be used as an alternative.

15.8. Conclusions

While we do not have enough information to conclusively determine the cause of all the dropped calls and signal abnormalities, we are certain that terrain and vegetation both play a major role. This is particularly important when the phone is used as a modem for data connectivity. As demonstrated, data connections will be disrupted under such conditions.

More specifically, data and voice calls may be disconnected if signal strength drops to zero for a period of 7-8 seconds or more. Due to the nature and movement of the Globalstar constellation, signal strength in a given location may fluctuate. This is particularly true when mountains, buildings, foliage, etc. block the sky. The amount and orientation of obstruction plays a role in signal strength fluctuation and call disconnection. We note that, in none of our tests, was a call disconnected if the signal strength dropped to zero for five seconds or less.

We believe that through further analysis and study, it will be possible to mitigate the potential problems caused by terrain and vegetation in one of the following ways:

1) Create “rules of thumb” that characterize the circumstances under which the satellite phone can and can’t be used.
2) Identify problem situations and mitigation by automated monitoring of satellite phone signal strength.
3) Automate redial/reconnect for disconnected data connections.
4) Optimize, through compression and other means, data send via data connections.

Satellite phones show great promise in providing voice and data connectivity in remote rural locations that are otherwise not served by data or voice communications. This is particularly true when coupled with a cellular phone that provides greater bandwidth at a lower cost. Knowing the limitations and having methods to mitigate potential problems will help to more effectively use this tool.

15.9. Addendum: Phase 6 –Data Transmission Test

Data transmissions were tested in the WTI parking, by sending several email messages with attachments from a Tablet PC connected to the Satellite Phone to an external email account. The antenna was placed on the opened back door of an SUV, approximately 7 feet off the ground. The SUV had a cargo carrier, which was about 18 inches tall and sat approximately 6 feet ahead (to the south) of the antenna.

Six email transmissions, including attachments, were tested for success or failure and for transmission time. The results are summarized in the following table:

Table 32: Data Transmission Test from WTI Parking Lot

Email Attachment Size (KB)	Success / Failure	Approx. Transmission Time (sec)	Approx. Data Rate (Kbps)
209	Success	300	5.71
376	Fail	-	-
376	Success	360	8.62
376	Fail	-	-
376	Success	420	7.39
376	Success	360	8.62

As shown in the table, there was a two-thirds success rate for attempted data transmissions. For successful data transmissions, the average data rate was 7.66 Kbps, and messages generally took between 5 and 7 minutes.

15.9.1. Conclusions

Obstruction due to the cargo carrier and possibility of poor performance of the rear door of the SUV as a ground plane could contribute to less than perfect data transmission performance. Other factors affecting performance could be network load and server availability. Considering prior experience in the WTI parking lot where the antenna was unobstructed, it is likely that one or a combination of several of these factors reduced performance.

The observed data rates were promising, and approached the Globalstar advertised rate of “up to 9.6 Kbps.” Automated redials could have been used to mitigate the failed transmissions.

16. APPENDIX VII – SITE SATELLITE COVERAGE ANALYSIS

16.1. Horizon Profiles and Statistics for Sites

16.1.1. Site: Gibson

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	41.02261	**Average:**	11.0 deg	**Blocked Sky %**	22.7%
Longitude:	-122.39877	**Std Dev:**	4.2 deg	**Blocked Sat. Sky %**	5.5%
Elevation (m):	495.50	**Min:**	2.9 deg	**Blocked Sig. %**	2.1%
		Max:	17.2 deg		

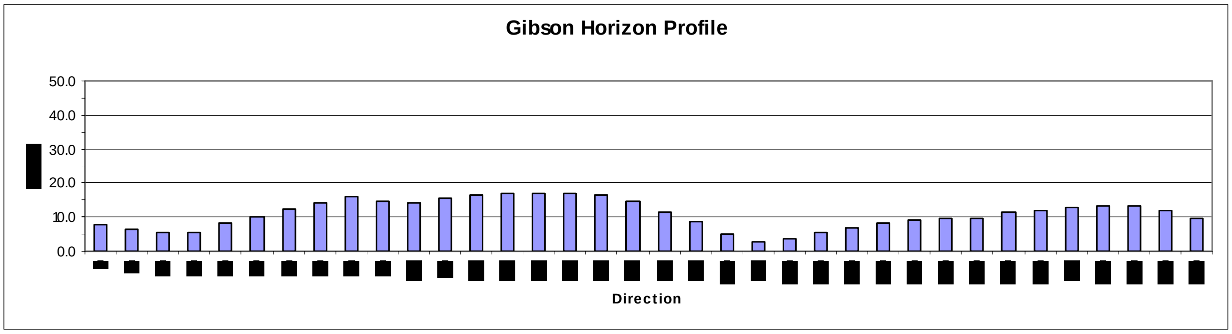


Figure 164: Gibson Horizon Profile

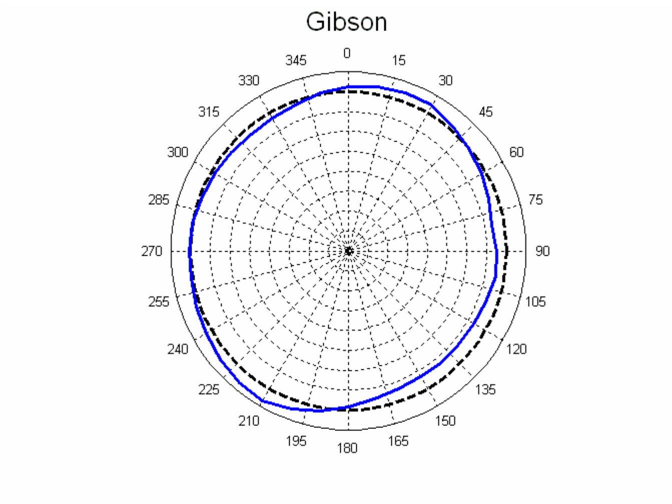


Figure 165: Gibson Visible Sky

16.1.2. Site: Incident (SR-70)

Location		Horizon Profile Statistics		Visible Sky Statistics	
Latitude:	39.77616	**Average:**	21.9 deg	**Blocked Sky %**	40.8%
Longitude:	-121.45572	**Std Dev:**	12.8 deg	**Blocked Sat. Sky %**	26.8%
Elevation (m):	554.86	**Min:**	1.8 deg	**Blocked Sig. %**	15.2%
		Max:	45.1 deg		

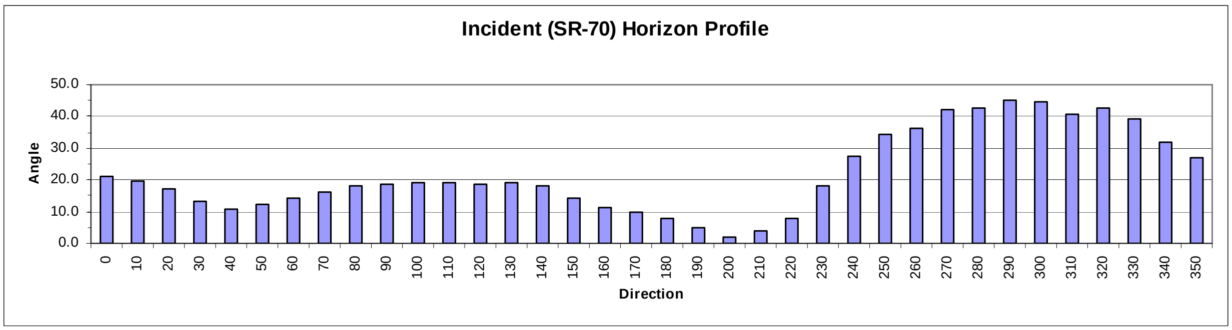


Figure 166: Incident (SR-70) Horizon Profile

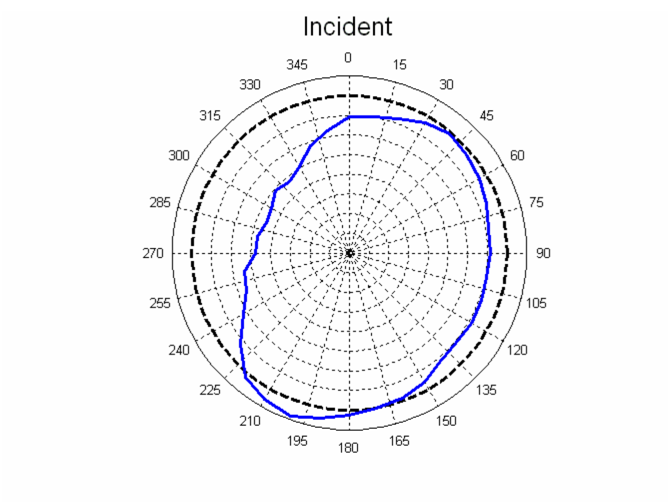


Figure 167: Incident (SR-70) Visible Sky

16.1.3. Site: Incident (SR-70) with No Surrounding Elevation

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.77616	**Average:**	0 deg	**Blocked Sky %**	0.0%
Longitude:	-121.45572	**Std Dev:**	0 deg	**Blocked Sat. Sky %**	0.0%
Elevation (m):	554.86	**Min:**	0 deg	**Blocked Sig. %**	0.0%
		Max:	0 deg		

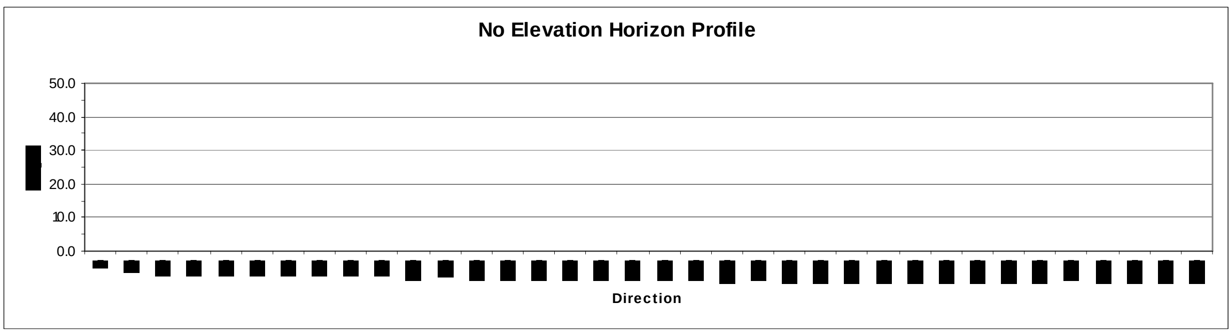


Figure 168: No Elevation Horizon Profile

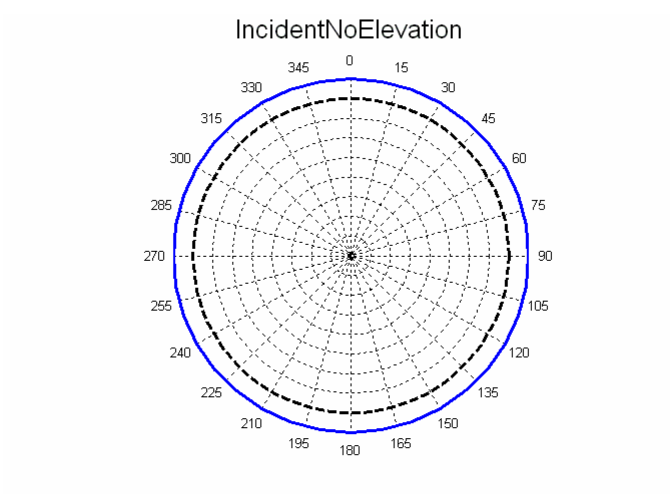


Figure 169: No Elevation Visible Sky

16.1.4. Site: Incident (SR-70) with Surrounding 15 Degree Bowl

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.77616	**Average:**	15 deg	**Blocked Sky %**	30.6%
Longitude:	-121.45572	**Std Dev:**	0 deg	**Blocked Sat. Sky %**	12.1%
Elevation (m):	554.86	**Min:**	15 deg	**Blocked Sig. %**	4.6%
		Max:	15 deg		

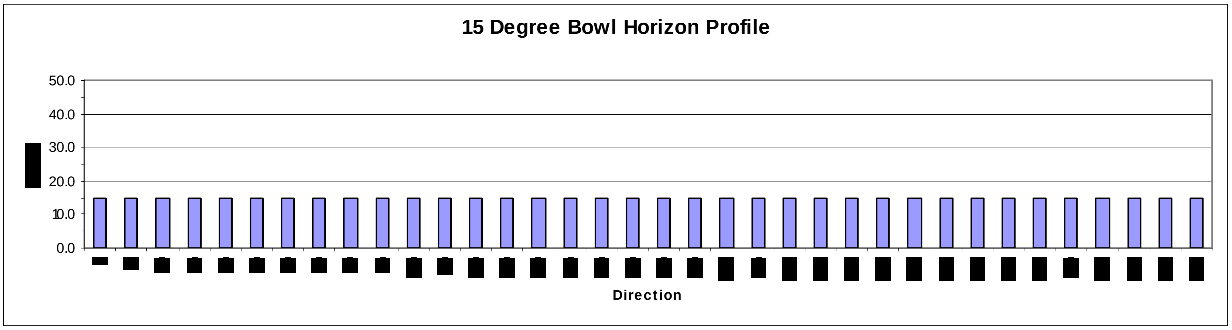


Figure 170: 15 Degree Bowl Horizon Profile

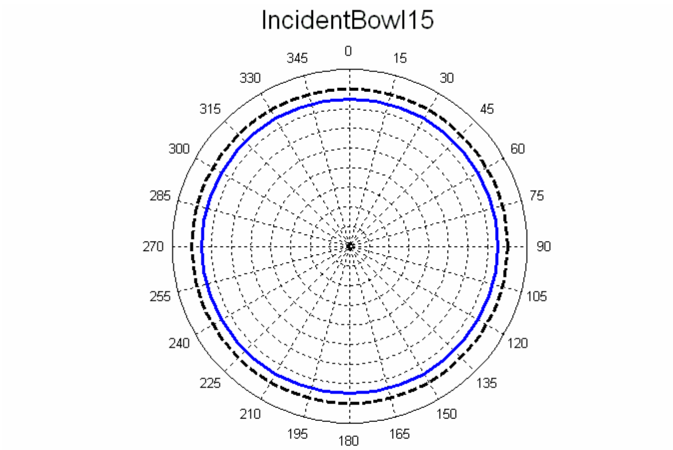


Figure 171: 15 Degree Bowl Visible Sky

16.1.5. Site: Incident (SR-70) with Surrounding 30 Degree Bowl

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.77616	**Average:**	30 deg	**Blocked Sky %**	55.6%
Longitude:	-121.45572	**Std Dev:**	0 deg	**Blocked Sat. Sky %**	43.8%
Elevation (m):	554.86	**Min:**	30 deg	**Blocked Sig. %**	23.3%
		Max:	30 deg		

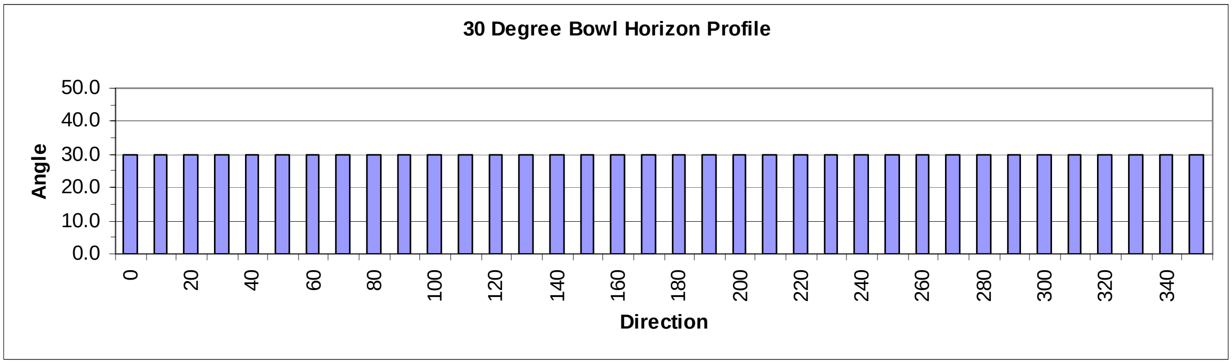


Figure 172: 30 Degree Bowl Horizon Profile

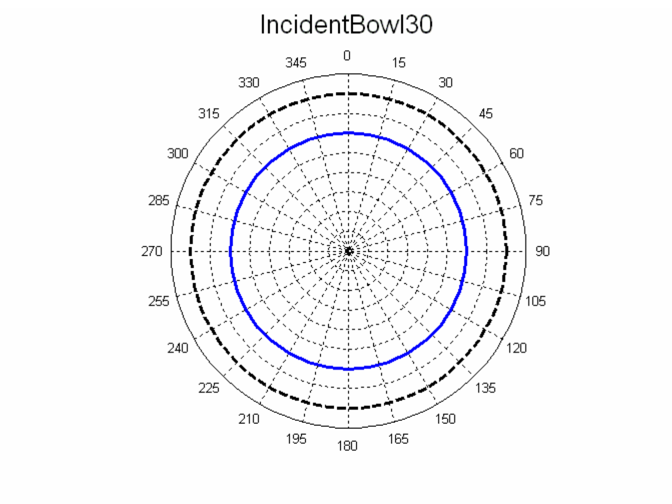


Figure 173: 30 Degree Bowl Visible Sky

16.1.6. Site: Incident (SR-70) with Surrounding 45 Degree Bowl

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.77616	**Average:**	45 deg	**Blocked Sky %**	75.0%
Longitude:	-121.45572	**Std Dev:**	0 deg	**Blocked Sat. Sky %**	68.4%
Elevation (m):	554.86	**Min:**	45 deg	**Blocked Sig. %**	47.8%
		Max:	45 deg		

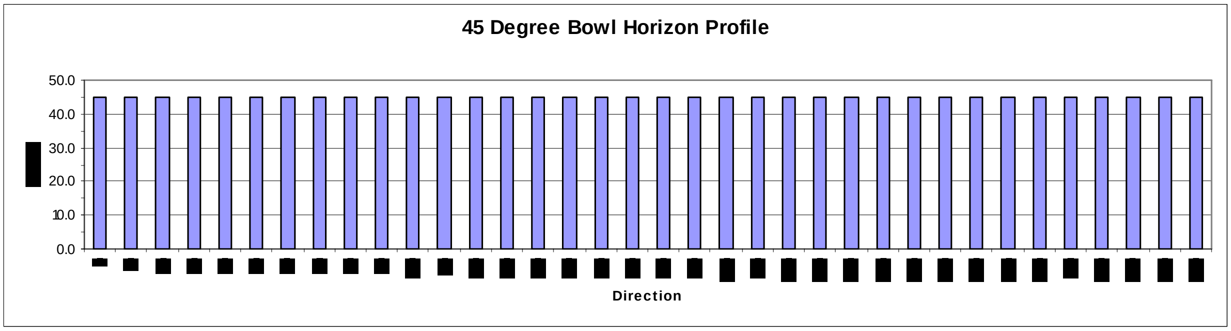


Figure 174: 45 Degree Bowl Horizon Profile

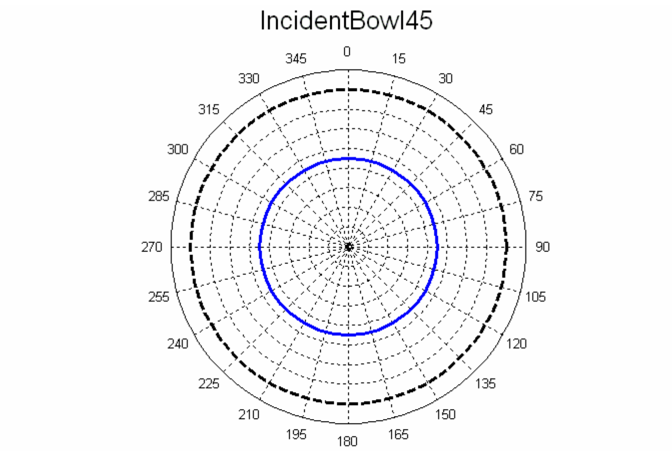


Figure 175: 45 Degree Bowl Visible Sky

16.1.7. Site: Incident (SR-70) with Surrounding Vegetation

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.77616	**Average:**	26.1 deg	**Blocked Sky %**	47.8%
Longitude:	-121.45572	**Std Dev:**	12.2 deg	**Blocked Sat. Sky %**	34.1%
Elevation (m):	554.86	**Min:**	7.6 deg	**Blocked Sig. %**	19.9%
		Max:	45.1 deg		

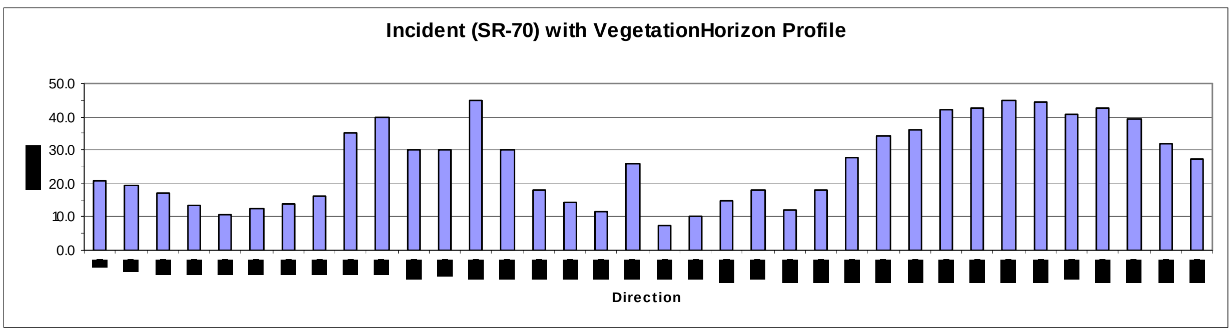


Figure 176: Incident (SR-70) with Vegetation Horizon Profile

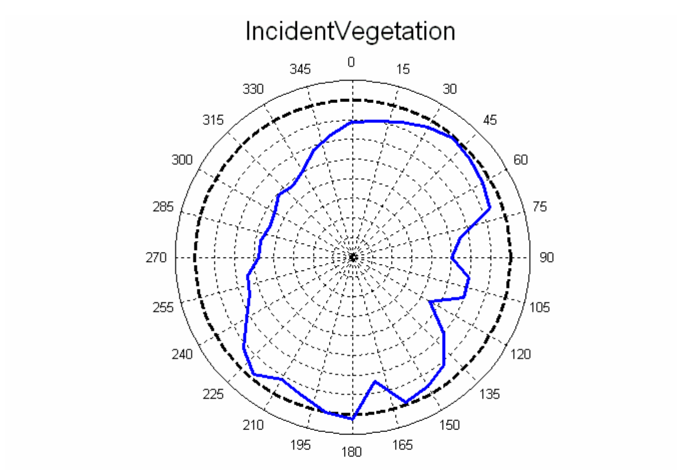


Figure 177: Incident Vegetation (SR-70 with Vegetation Visible Sky

16.1.8. Site: 2

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.80453	**Average:**	18.1 deg	**Blocked Sky %**	35.7%
Longitude:	-121.43974	**Std Dev:**	5.8 deg	**Blocked Sat. Sky %**	18.9%
Elevation (m):	422.32	**Min:**	7.3 deg	**Blocked Sig. %**	8.5%
		Max:	28.8 deg		

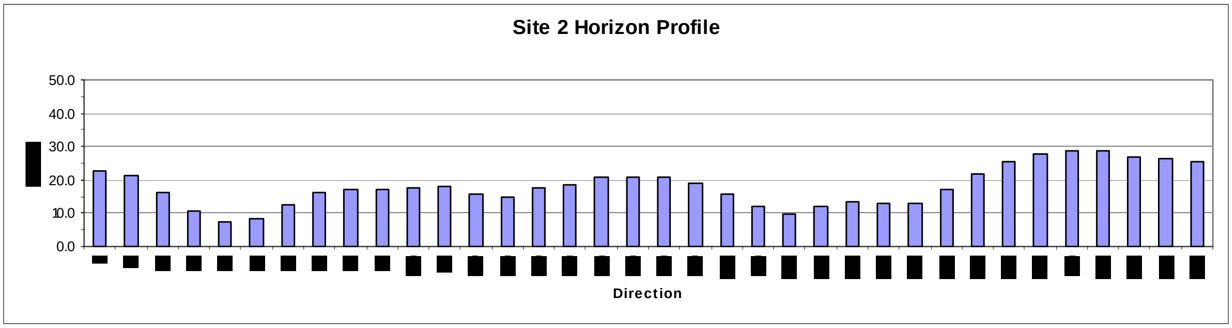


Figure 178: Site 2 Horizon Profile

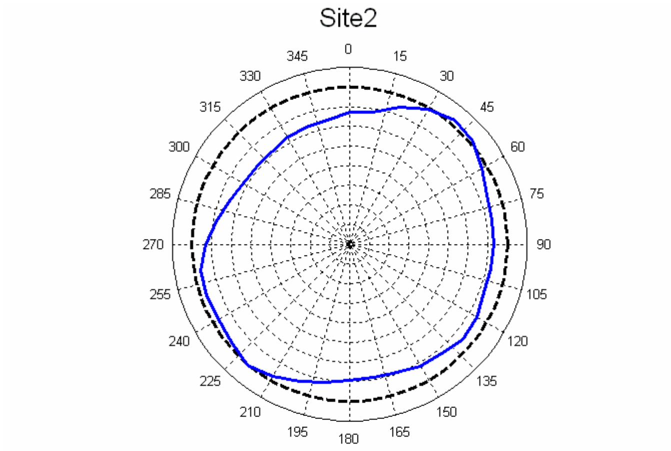


Figure 179: Site 2 Visible Sky

16.1.9. Site: 3

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.95749	**Average:**	22.5 deg	**Blocked Sky %**	43.2%
Longitude:	-121.29116	**Std Dev:**	6.7 deg	**Blocked Sat. Sky %**	28.3%
Elevation (m):	624.14	**Min:**	8.9 deg	**Blocked Sig. %**	13.8%
		Max:	31.4 deg		

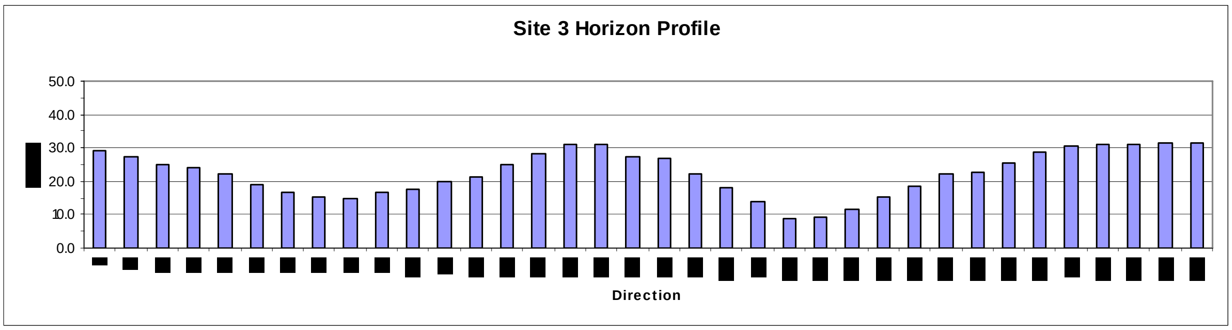


Figure 180: Site 3 Horizon Profile

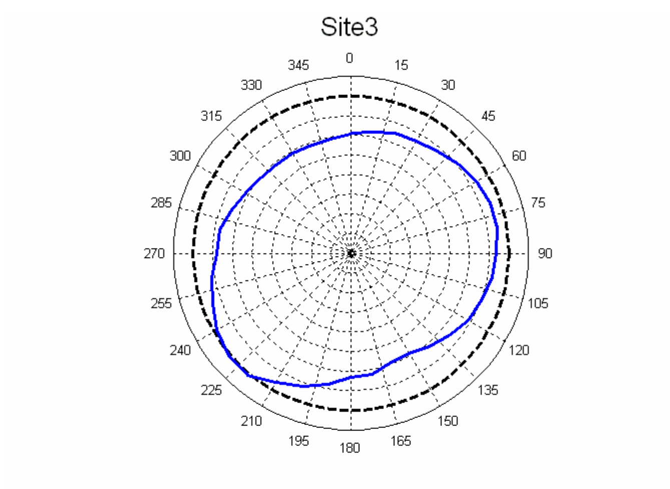


Figure 181: Site 3 Visible Sky

16.1.10. Site: 4

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.85434	**Average:**	26.1 deg	**Blocked Sky %**	48.5%
Longitude:	-121.39110	**Std Dev:**	9.6 deg	**Blocked Sat. Sky %**	34.9%
Elevation (m):	461.57	**Min:**	8.7 deg	**Blocked Sig. %**	19.1%
		Max:	41.3 deg		

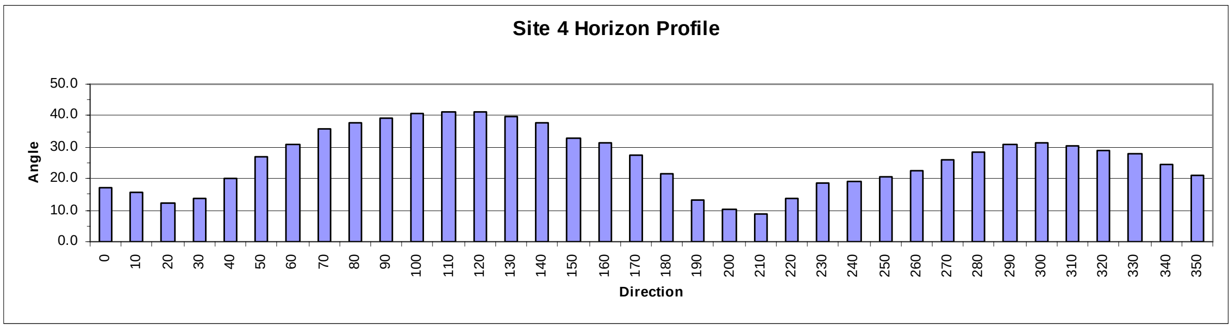


Figure 182: Site 4 Horizon Profile

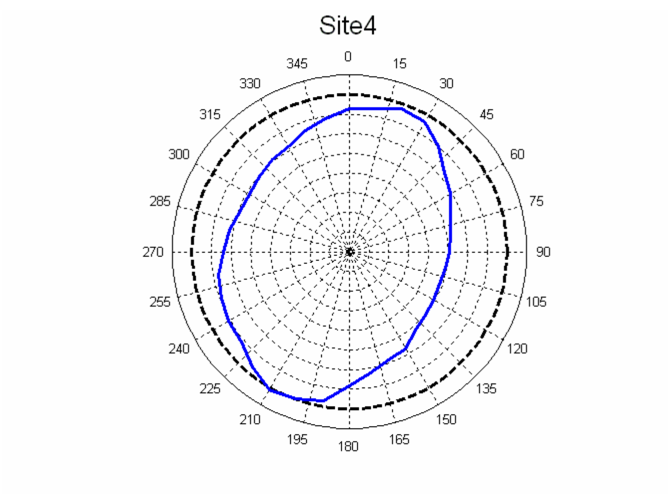


Figure 183: Site 4 Visible Sky

16.1.11. Site: 5

Location		Horizon Profile Statistics		Visible Sky Statistics	
Latitude:	39.90676	**Average:**	26.0 deg	**Blocked Sky %**	48.5%
Longitude:	-121.34105	**Std Dev:**	8.9 deg	**Blocked Sat. Sky %**	34.8%
Elevation (m):	533.76	**Min:**	9.8 deg	**Blocked Sig. %**	18.8%
		Max:	36.8 deg		

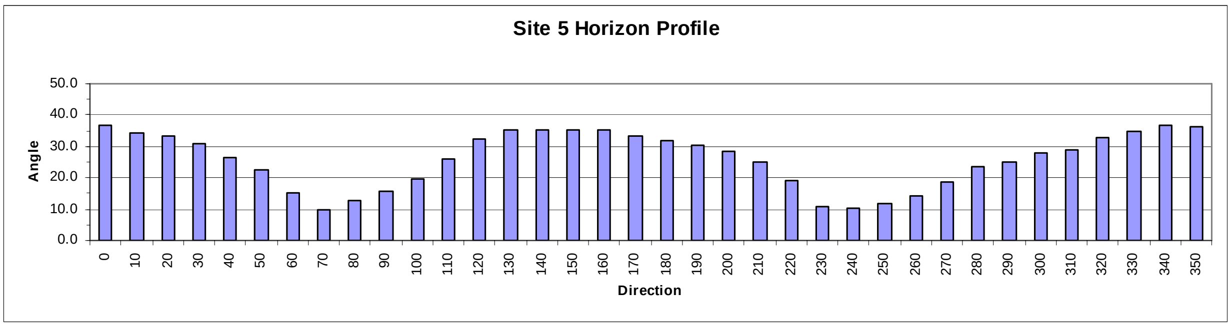


Figure 184: Site 5 Horizon Profile

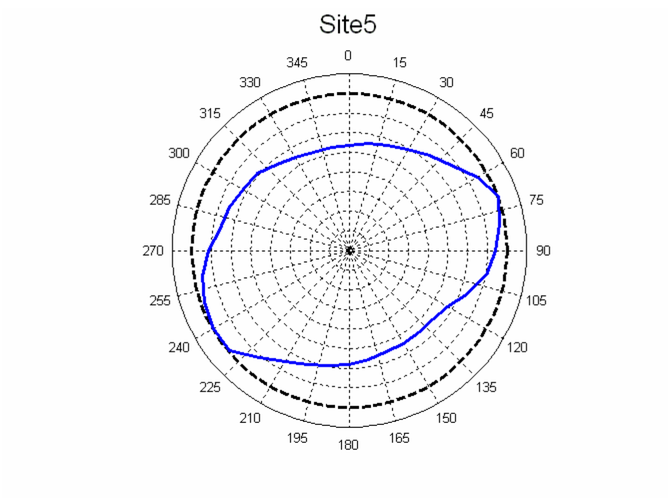


Figure 185: Site 5 Visible Sky

16.1.12. Site: 6

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.94519	**Average:**	23.2 deg	**Blocked Sky %**	44.3%
Longitude:	-121.30733	**Std Dev:**	7.2 deg	**Blocked Sat. Sky %**	29.5%
Elevation (m):	619.13	**Min:**	9.8 deg	**Blocked Sig. %**	14.7%
		Max:	33.8 deg		

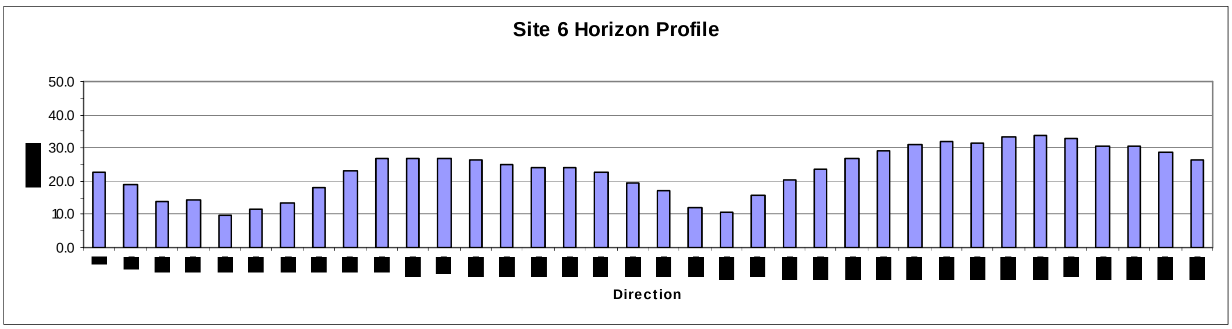


Figure 186: Site 6 Horizon Profile

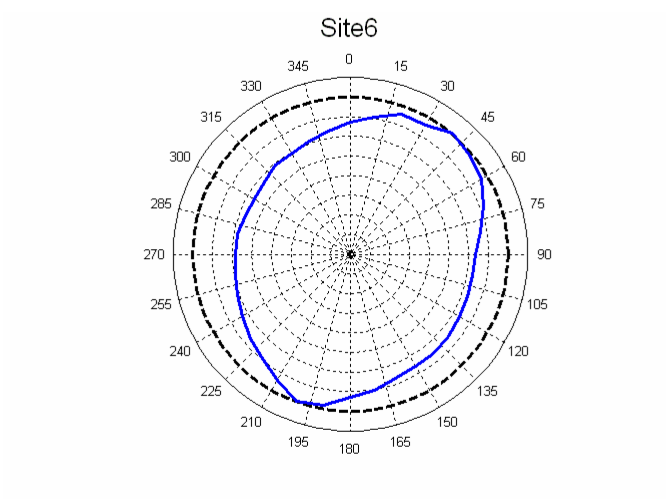


Figure 187: Site 6 Visible Sky

16.1.13. Site: 7

Location		Horizon Profile Statistics		Visible Sky Statistics	
Latitude:	39.97464	**Average:**	27.9 deg	**Blocked Sky %**	51.7%
Longitude:	-121.27799	**Std Dev:**	7.7 deg	**Blocked Sat. Sky %**	38.8%
Elevation (m):	662.25	**Min:**	12.6 deg	**Blocked Sig. %**	21.1%
		Max:	40.1 deg		

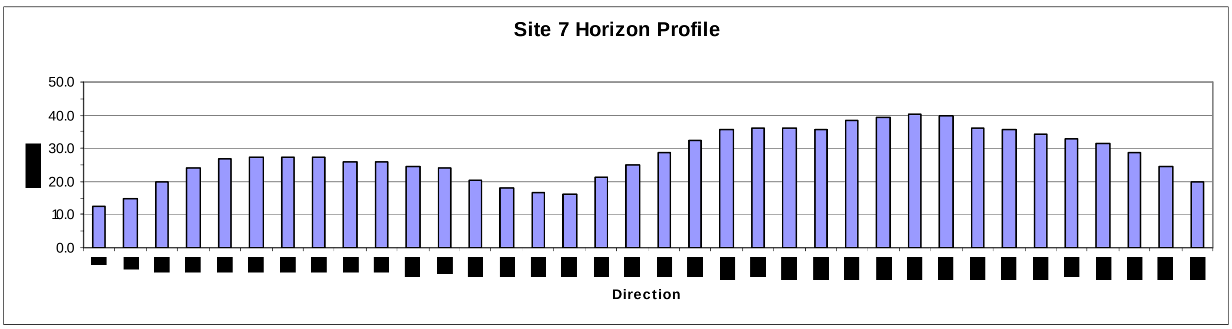


Figure 188: Site 7 Horizon Profile

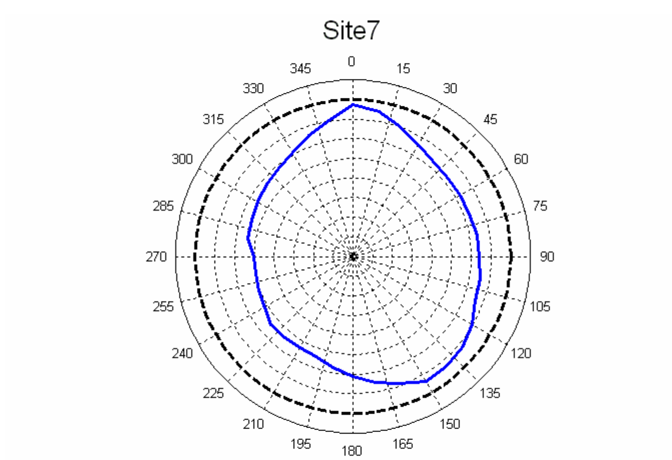


Figure 189: Site 7 Visible Sky

16.1.14. Site: 8

Location		**Horizon Profile Statistics**		**Visible Sky Statistics**	
Latitude:	39.99533	**Average:**	27.6 deg	**Blocked Sky %**	50.9%
Longitude:	-121.27485	**Std Dev:**	9.0 deg	**Blocked Sat. Sky %**	38.1%
Elevation (m):	693.37	**Min:**	7.8 deg	**Blocked Sig. %**	21.0%
		Max:	40.7 deg		

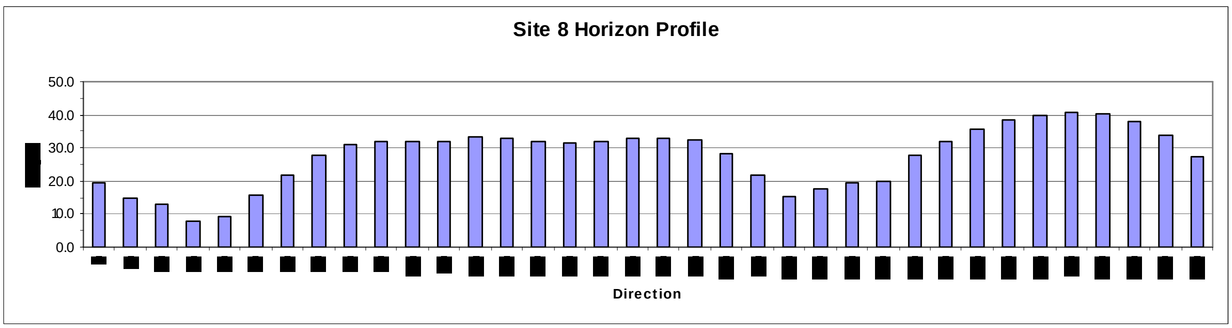


Figure 190: Site 8 Horizon Profile

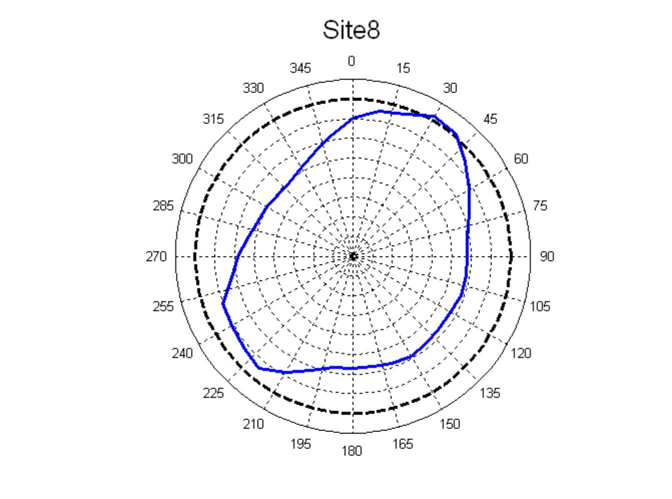


Figure 191: Site 8 Visible Sky

16.2. Simulation Statistics

16.2.1. 40 Satellite Walker Configuration

Site	Signal Mean	Signal Min	Signal Max	Signal Std Dev	Signal Percent = 0	Signal Percent 0<x<=0.5	Signal Percent 0.5<x<=1.	Signal Percent 1.0<x<=1.	Signal Percent 1.5<x<=2
Gibson 40 Sats	0.99	0.37	1.81	0.35	0.00	0.05	0.49	0.37	0.10
Incident 40 Sats	0.73	0.00	1.82	0.45	0.04	0.33	0.38	0.17	0.08
Incident 40 Sats No Elevation	1.03	0.39	1.82	0.34	0.00	0.02	0.48	0.38	0.11
Incident 40 Sats Bowl 15	0.94	0.31	1.82	0.37	0.00	0.13	0.44	0.35	0.08
Incident 40 Sats Bowl 30	0.64	0.00	1.82	0.52	0.23	0.30	0.18	0.21	0.08
Incident 40 Sats Bowl 45	0.31	0.00	1.82	0.53	0.70	0.00	0.19	0.04	0.08
Incident Vegetation 40 Sats	0.66	0.00	1.82	0.48	0.10	0.36	0.30	0.15	0.08
Site 2 - 40 Sats	0.87	0.00	1.82	0.42	0.02	0.26	0.32	0.32	0.08
Site 3 - 40 Sats	0.83	0.00	1.82	0.44	0.02	0.33	0.27	0.30	0.08
Site 4 - 40 Sats	0.66	0.00	1.82	0.50	0.18	0.28	0.29	0.17	0.08
Site 5 - 40 Sats	0.81	0.00	1.82	0.45	0.02	0.35	0.26	0.29	0.08
Site 6 - 40 Sats	0.74	0.00	1.82	0.46	0.07	0.36	0.29	0.21	0.08
Site 7 - 40 Sats	0.65	0.00	1.82	0.51	0.21	0.27	0.27	0.17	0.08
Site 8 - 40 Sats	0.63	0.00	1.82	0.51	0.18	0.34	0.20	0.19	0.08

Site	Sats Mean	Sats Min	Sats Max	Sats Std Dev	Sats Percent = 0	Sats Percent = 1	Sats Percent = 2	Sats Percent = 3	Sats Percent = 4	Sats Percent = 5
Gibson 40 Sats	2.40	1	4	0.77	0.00	0.08	0.55	0.28	0.10	0.00
Incident 40 Sats	1.57	0	2	0.57	0.04	0.35	0.61	0.00	0.00	0.00
Incident 40 Sats No Elevation	2.70	1	4	0.79	0.00	0.02	0.44	0.35	0.19	0.00
Incident 40 Sats Bowl 15	2.18	1	4	0.71	0.00	0.13	0.61	0.21	0.05	0.00
Incident 40 Sats Bowl 30	1.12	0	2	0.75	0.23	0.43	0.34	0.00	0.00	0.00
Incident 40 Sats Bowl 45	0.42	0	2	0.69	0.70	0.19	0.11	0.00	0.00	0.00
Incident Vegetation 40 Sats	1.31	0	2	0.65	0.10	0.48	0.42	0.00	0.00	0.00
Site 2 - 40 Sats	1.91	0	4	0.72	0.02	0.23	0.59	0.14	0.02	0.00
Site 3 - 40 Sats	1.77	0	4	0.72	0.02	0.33	0.52	0.13	0.01	0.00
Site 4 - 40 Sats	1.24	0	2	0.74	0.18	0.39	0.43	0.00	0.00	0.00
Site 5 - 40 Sats	1.76	0	4	0.79	0.02	0.40	0.41	0.16	0.02	0.00
Site 6 - 40 Sats	1.45	0	2	0.62	0.07	0.41	0.52	0.00	0.00	0.00
Site 7 - 40 Sats	1.17	0	2	0.75	0.21	0.41	0.38	0.00	0.00	0.00
Site 8 - 40 Sats	1.14	0	2	0.70	0.18	0.49	0.32	0.00	0.00	0.00

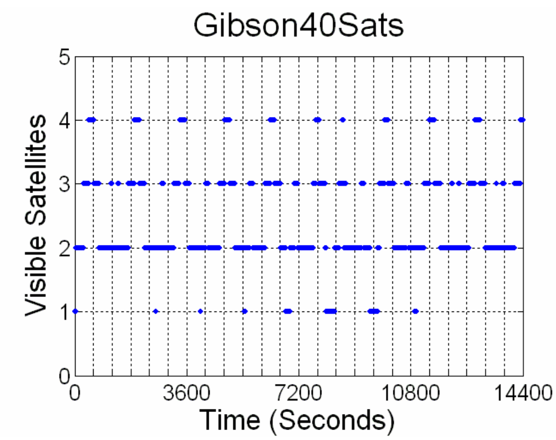
16.2.2. 48 Satellite Configuration

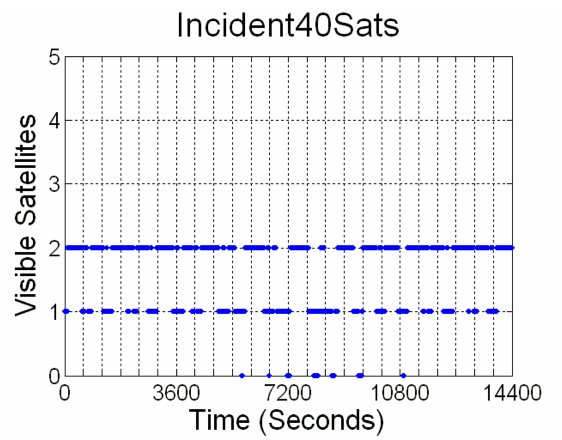
Site	Signal Mean	Signal Min	Signal Max	Signal Std Dev	Signal Percent = 0	Signal Percent 0<x<=0.5	Signal Percent 0.5<x<=1.	Signal Percent 1.0<x<=1.	Signal Percent 1.5<x<=2
Gibson 48 Sats	1.19	0.43	1.91	0.27	0.00	0.00	0.24	0.62	0.14
Incident 48 Sats	0.88	0.00	1.83	0.43	0.05	0.12	0.49	0.23	0.10
Incident 48 Sats No Elevation	1.24	0.71	1.83	0.22	0.00	0.00	0.12	0.75	0.13
Incident 48 Sats Bowl 15	1.13	0.44	1.83	0.27	0.00	0.01	0.33	0.56	0.10
Incident 48 Sats Bowl 30	0.77	0.00	1.83	0.51	0.13	0.34	0.16	0.26	0.10
Incident 48 Sats Bowl 45	0.38	0.00	1.83	0.59	0.67	0.00	0.17	0.06	0.10
Incident Vegetation 48 Sats	0.79	0.00	1.83	0.49	0.12	0.20	0.36	0.21	0.10
Site 2 - 48 Sats	1.04	0.27	1.83	0.31	0.00	0.02	0.49	0.38	0.11
Site 3 - 48 Sats	1.00	0.00	1.84	0.37	0.02	0.07	0.46	0.35	0.11
Site 4 - 48 Sats	0.80	0.00	1.83	0.50	0.12	0.23	0.28	0.26	0.11
Site 5 - 48 Sats	0.97	0.00	1.84	0.41	0.01	0.11	0.39	0.37	0.11
Site 6 - 48 Sats	0.89	0.00	1.84	0.44	0.04	0.23	0.36	0.27	0.11
Site 7 - 48 Sats	0.78	0.00	1.84	0.50	0.11	0.30	0.24	0.24	0.11
Site 8 - 48 Sats	0.76	0.00	1.84	0.52	0.16	0.22	0.28	0.22	0.11

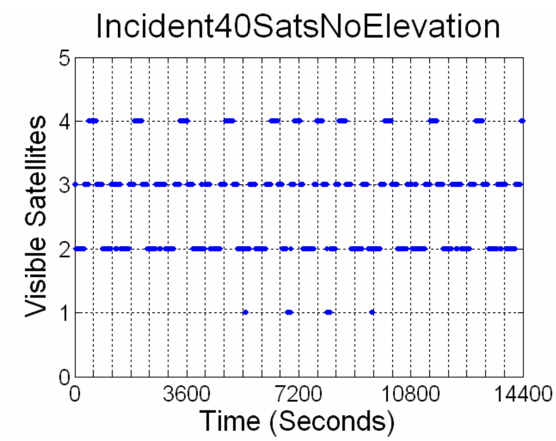
Site	Sats Mean	Sats Min	Sats Max	Sats Std Dev	Sats Percent = 0	Sats Percent = 1	Sats Percent = 2	Sats Percent = 3	Sats Percent = 4	Sats Percent = 5
Gibson 48 Sats	2.88	1	4	0.85	0.00	0.01	0.41	0.28	0.31	0.00
Incident 48 Sats	1.88	0	3	0.71	0.05	0.18	0.62	0.16	0.00	0.00
Incident 48 Sats No Elevation	3.24	2	5	0.84	0.00	0.00	0.25	0.27	0.46	0.01
Incident 48 Sats Bowl 15	2.62	1	4	0.76	0.00	0.01	0.53	0.30	0.17	0.00
Incident 48 Sats Bowl 30	1.34	0	2	0.70	0.13	0.39	0.48	0.00	0.00	0.00
Incident 48 Sats Bowl 45	0.50	0	2	0.76	0.67	0.17	0.16	0.00	0.00	0.00
Incident Vegetation 48 Sats	1.57	0	3	0.83	0.12	0.28	0.49	0.10	0.00	0.00
Site 2 - 48 Sats	2.30	1	4	0.57	0.00	0.02	0.69	0.25	0.04	0.00
Site 3 - 48 Sats	2.13	0	4	0.65	0.02	0.07	0.72	0.16	0.03	0.00
Site 4 - 48 Sats	1.49	0	3	0.77	0.12	0.32	0.51	0.05	0.00	0.00
Site 5 - 48 Sats	2.11	0	4	0.73	0.01	0.12	0.66	0.15	0.05	0.00
Site 6 - 48 Sats	1.74	0	3	0.66	0.04	0.26	0.62	0.08	0.00	0.00
Site 7 - 48 Sats	1.40	0	3	0.68	0.11	0.39	0.50	0.00	0.00	0.00
Site 8 - 48 Sats	1.36	0	3	0.75	0.16	0.31	0.52	0.00	0.00	0.00

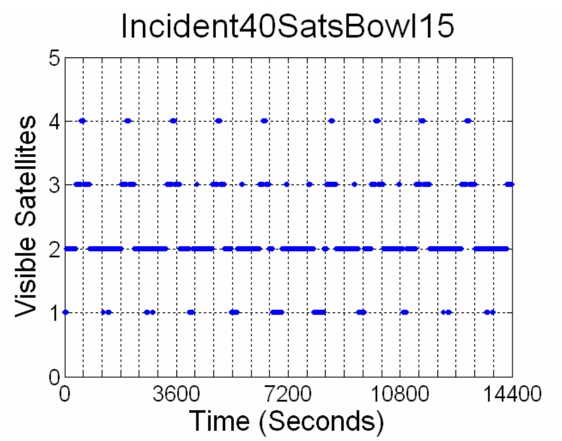
16.3. Simulated Visible Satellite Counts

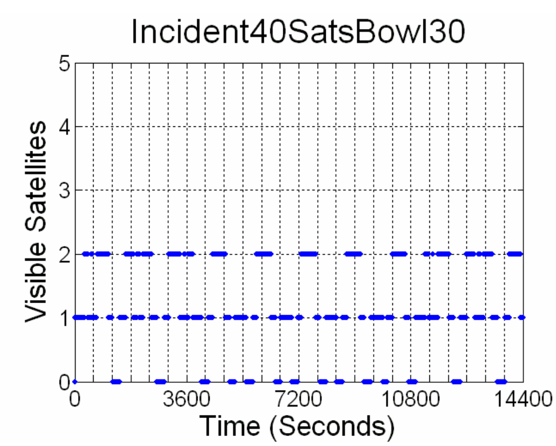
16.3.1. 40 Satellite Walker Configuration

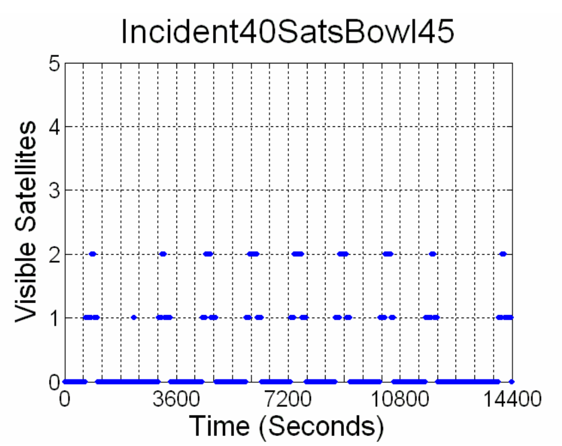


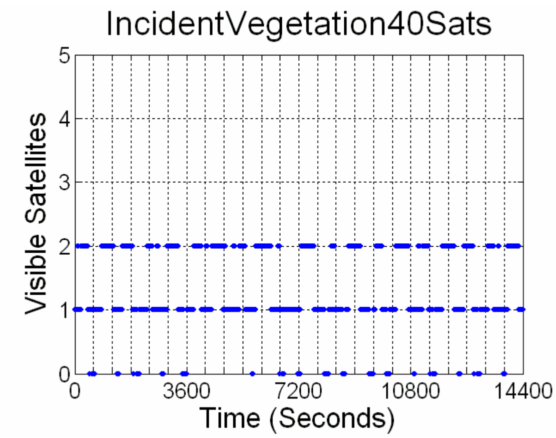


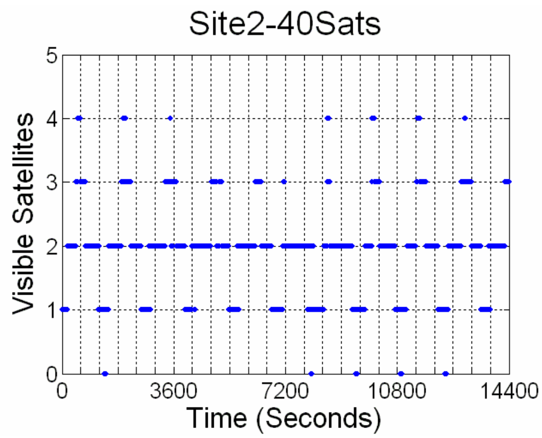


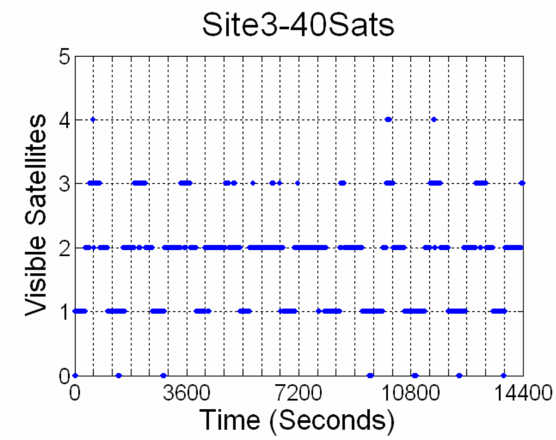


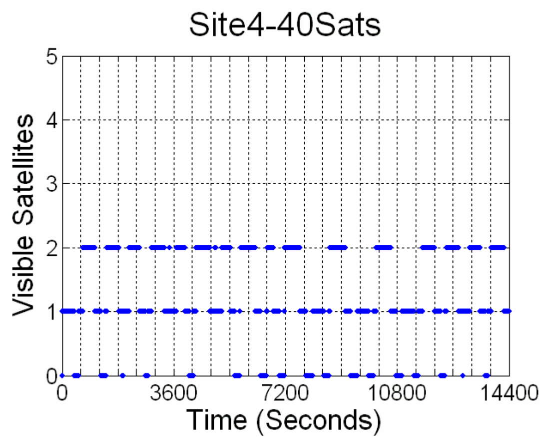


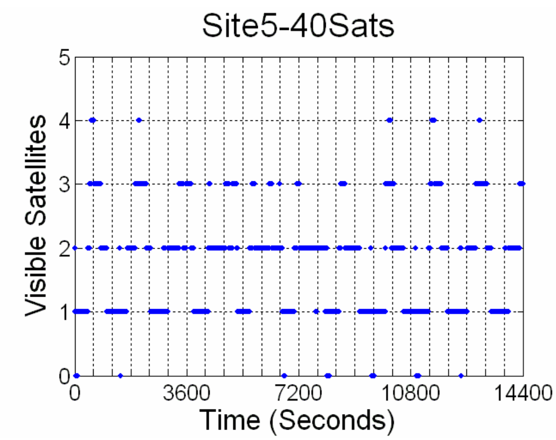


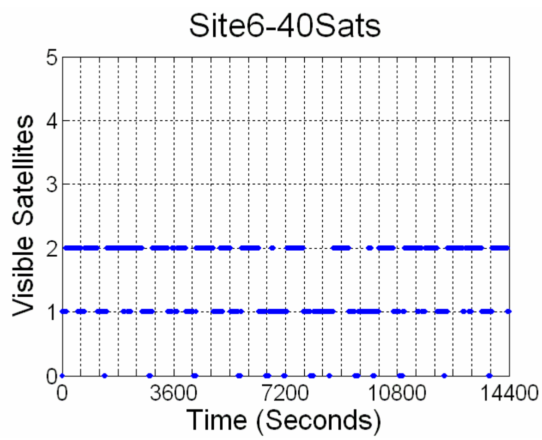

IncidentVegetation40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400

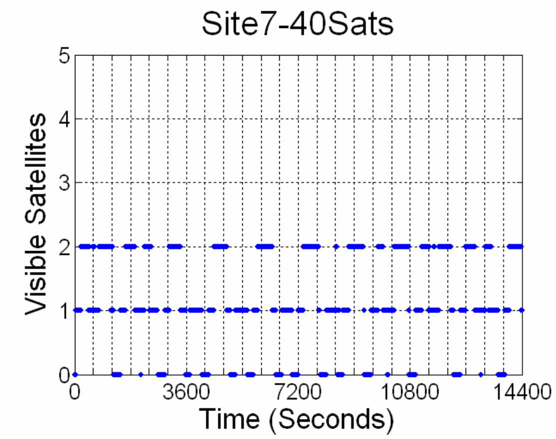

Site2-40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400

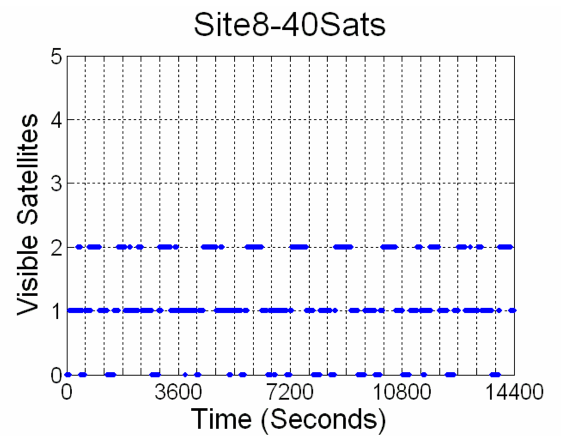

Site3-40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400


Site4-40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400

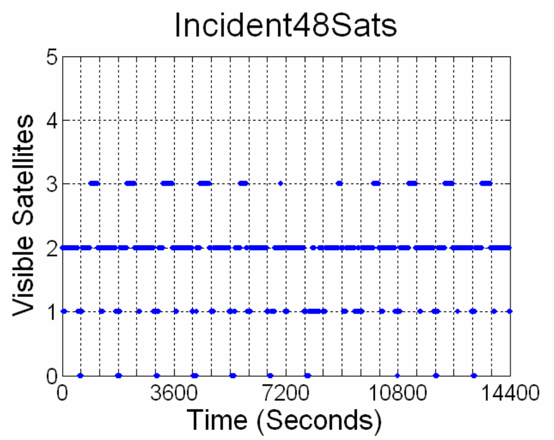

Site5-40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400

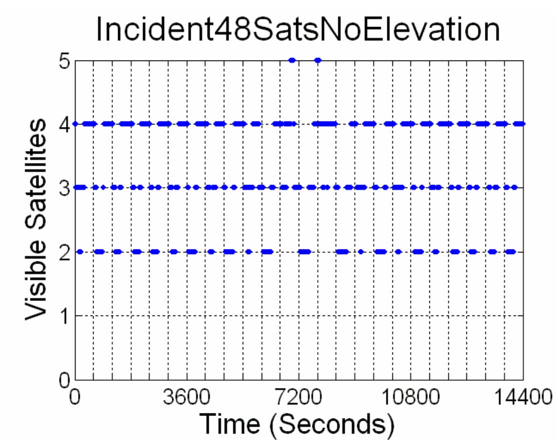

Site6-40Sats
Visible Satellites
0 1 2 3 4 5
Time (Seconds)
0 3600 7200 10800 14400

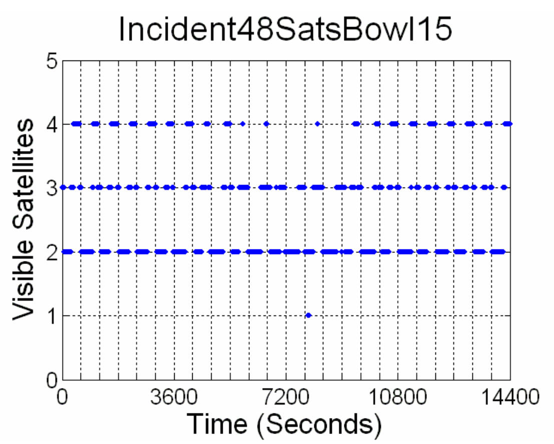

Site7-40Sats
Visible Satellites
0
1
2
3
4
5
0
3600
7200
10800
14400
Time (Seconds)

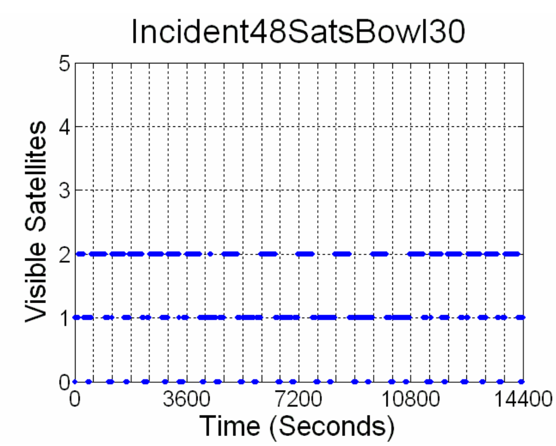

Site8-40Sats
Visible Satellites
0
1
2
3
4
5
0
3600
7200
10800
14400
Time (Seconds)

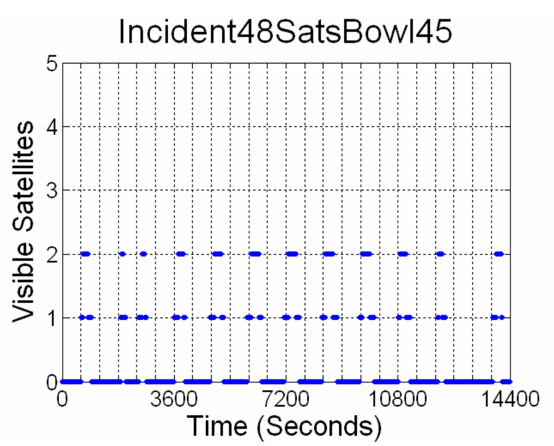
16.3.2. 48 Satellite Configuration

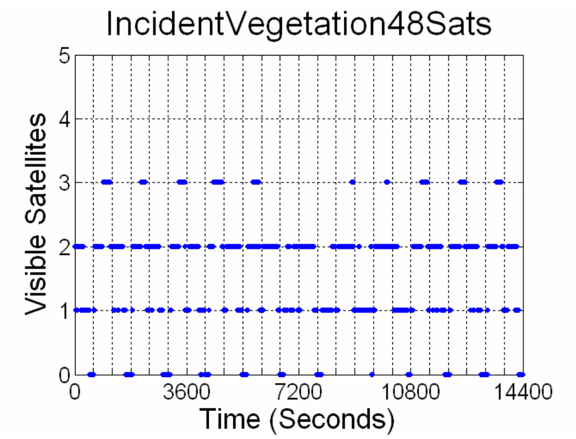


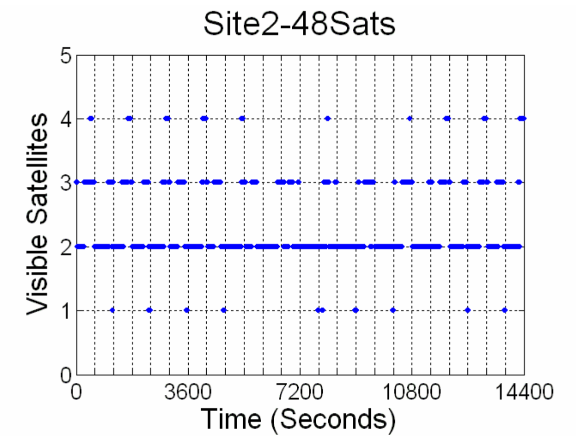


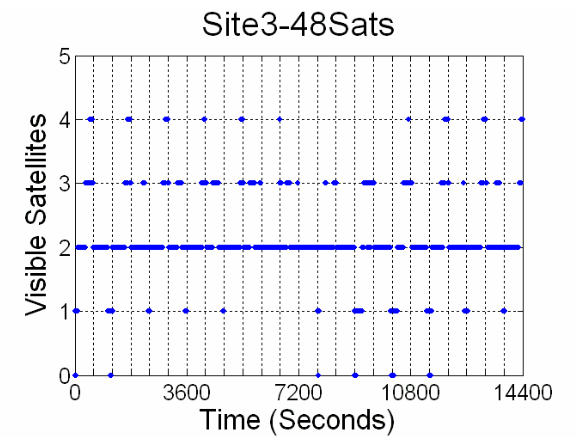


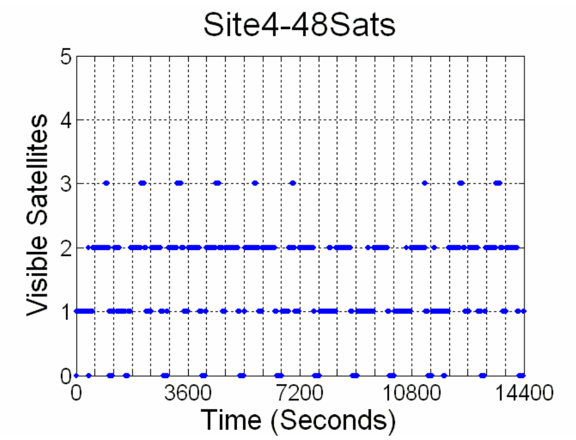




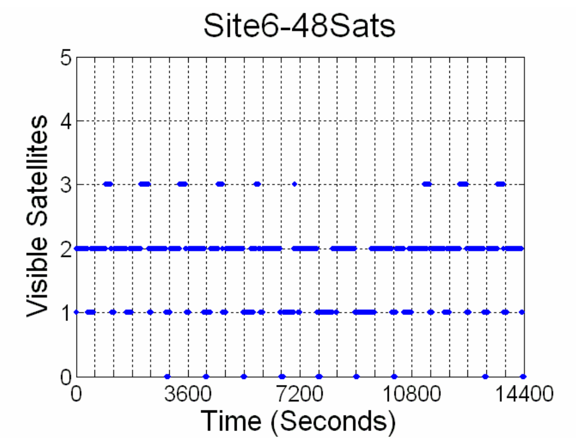

IncidentVegetation48Sats
Visible Satellites
Time (Seconds)
0
3600
7200
10800
14400

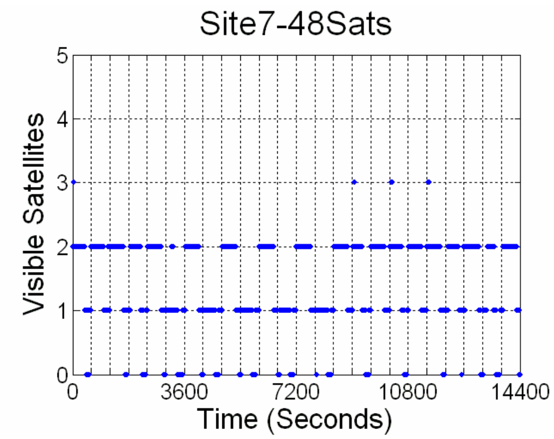

Site2-48Sats
Visible Satellites
Time (Seconds)

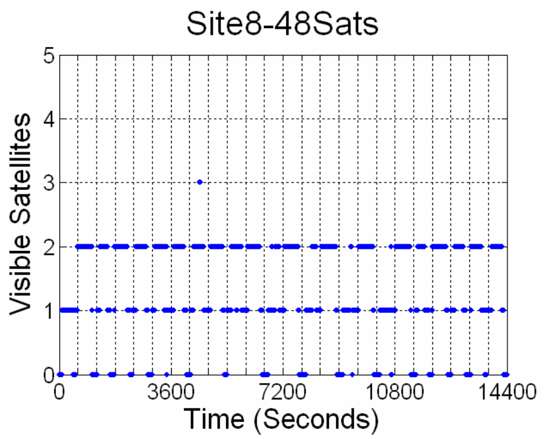

Site3-48Sats
Visible Satellites
Time (Seconds)


Site4-48Sats
Visible Satellites
Time (Seconds)


Site5-48Sats
Visible Satellites
Time (Seconds)

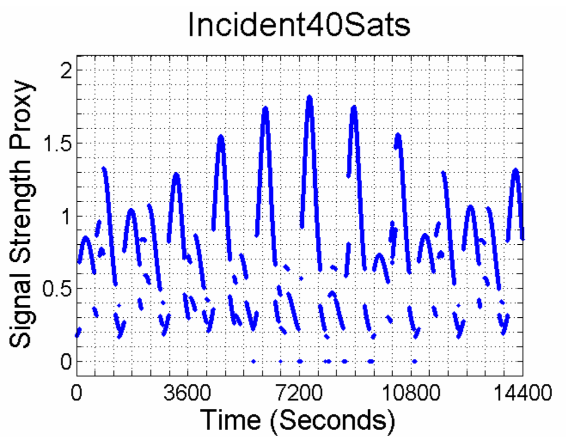

Site6-48Sats
Visible Satellites
Time (Seconds)

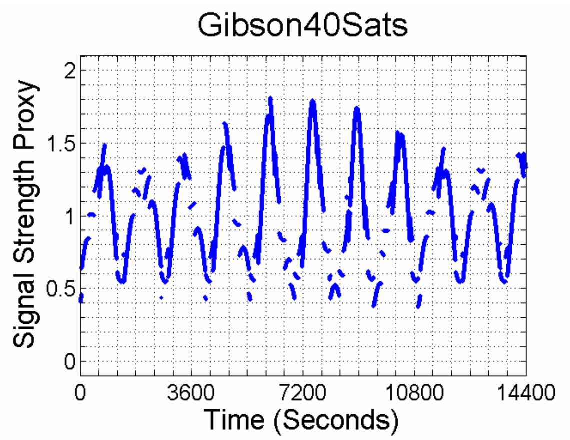

Site7-48Sats
Visible Satellites
Time (Seconds)
0
3600
7200
10800
14400
0
1
2
3
4
5

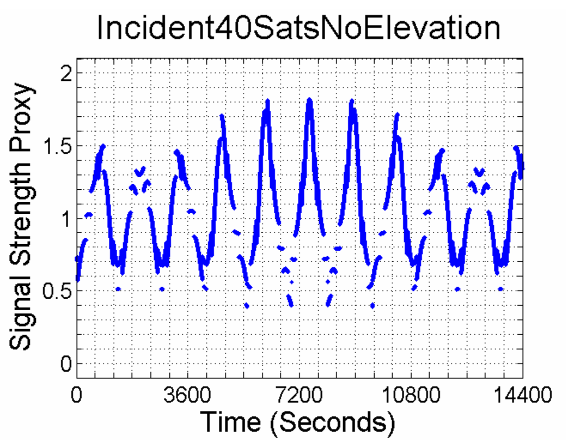

Site8-48Sats
Visible Satellites
Time (Seconds)
0
3600
7200
10800
14400
0
1
2
3
4
5

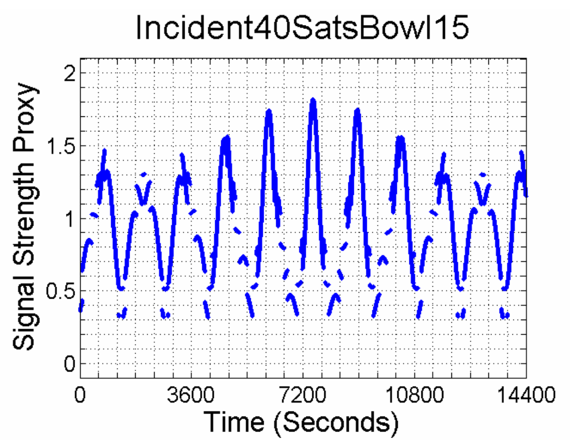
16.4. Simulated Signal Strength Proxies

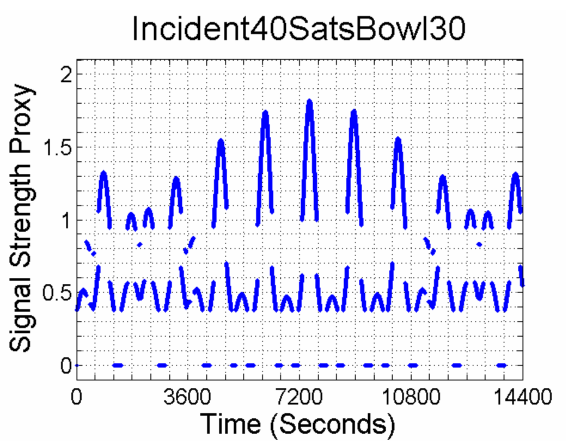
16.4.1. 40 Satellite Walker Configuration

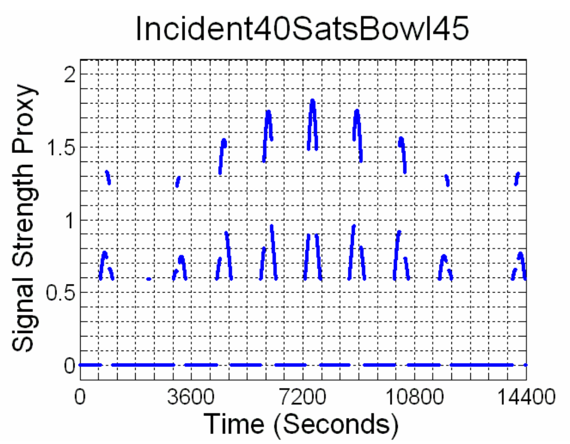


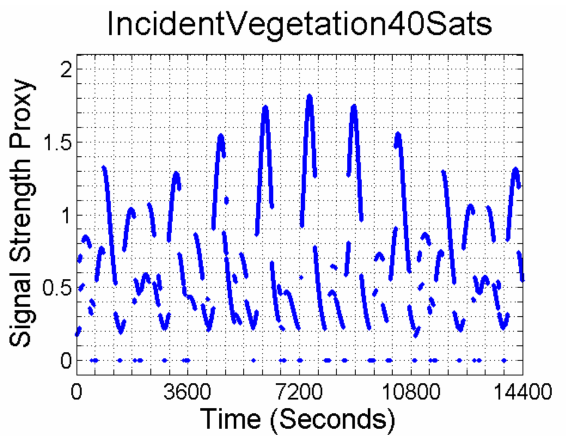


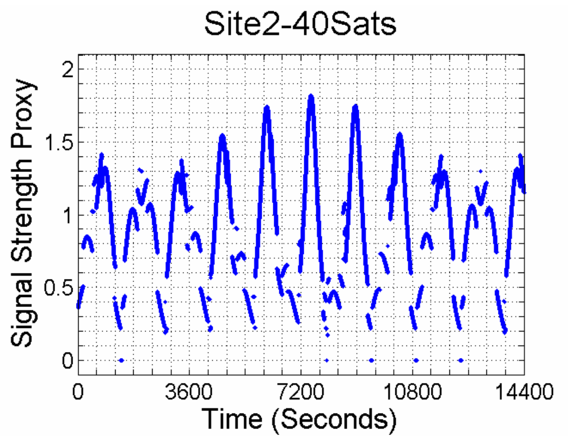


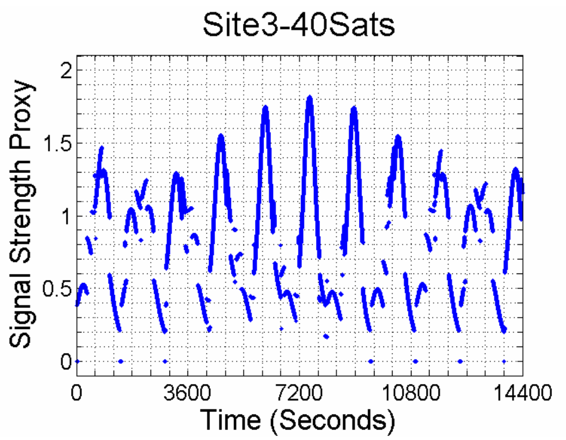


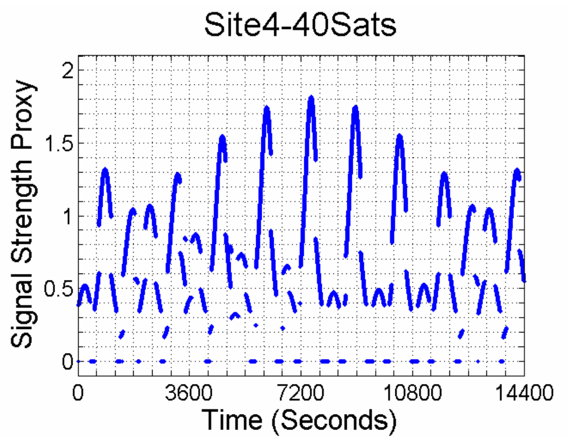


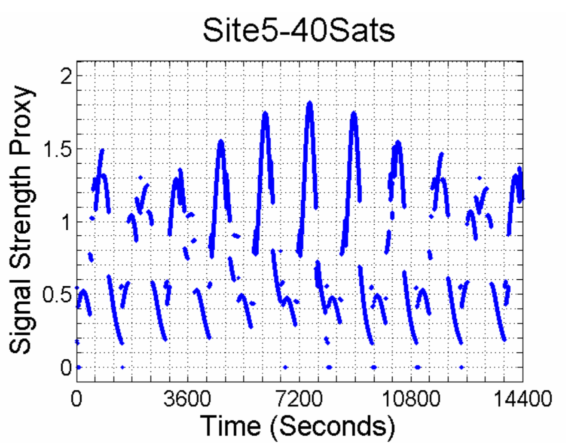


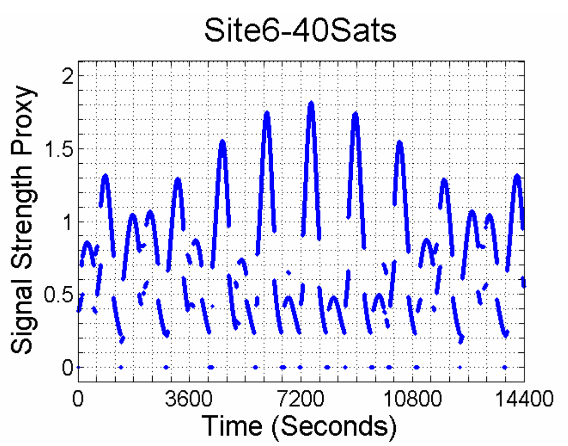

IncidentVegetation40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400

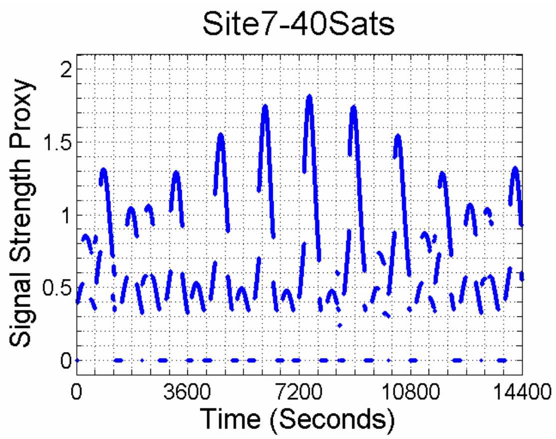

Site2-40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400

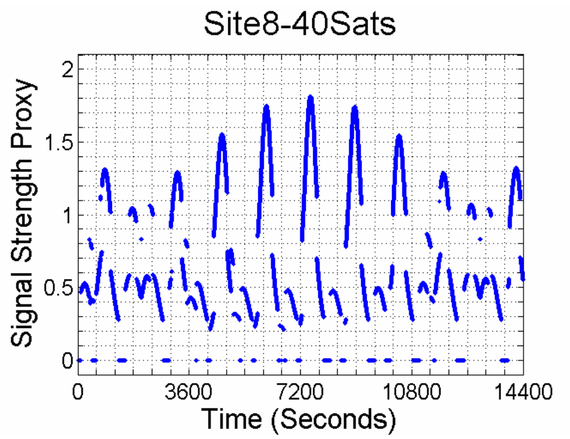

Site3-40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400


Site4-40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400

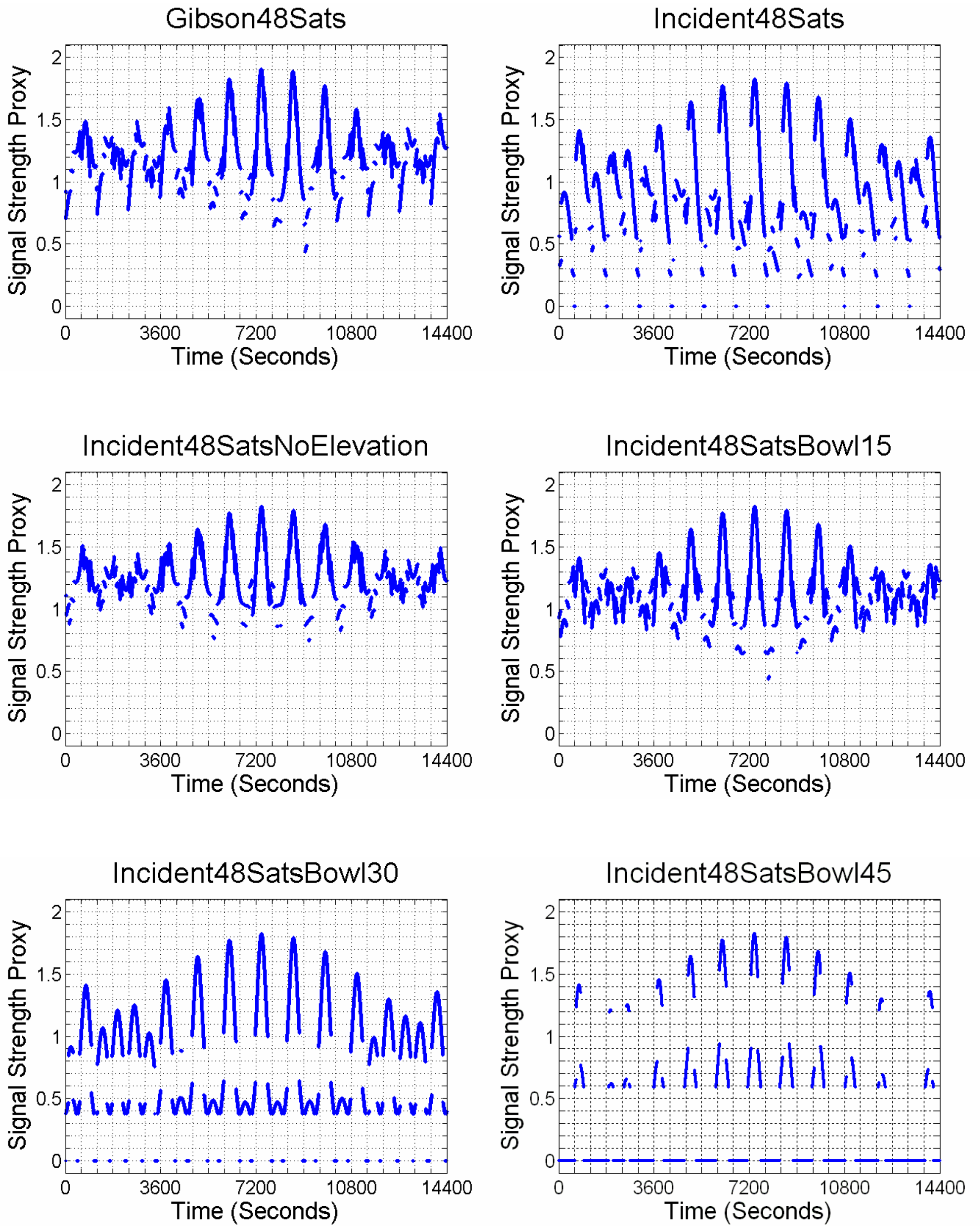

Site5-40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400

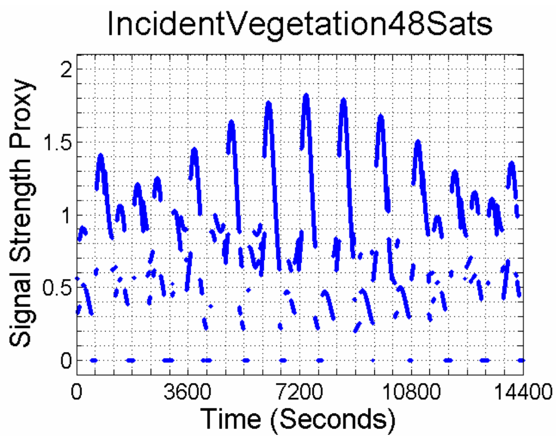

Site6-40Sats
Signal Strength Proxy
Time (Seconds)
0
0.5
1
1.5
2
0
3600
7200
10800
14400

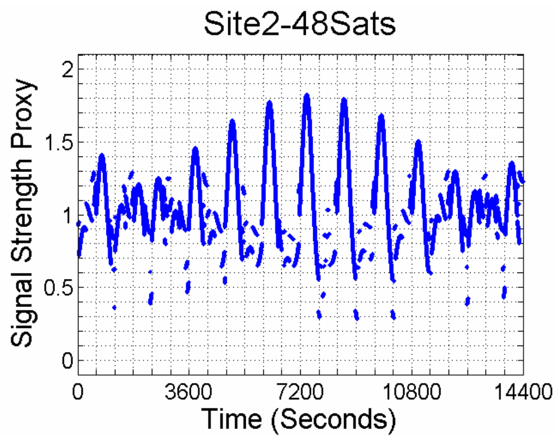

Site7-40Sats
Signal Strength Proxy
Time (Seconds)
0
3600
7200
10800
14400
0
0.5
1
1.5
2

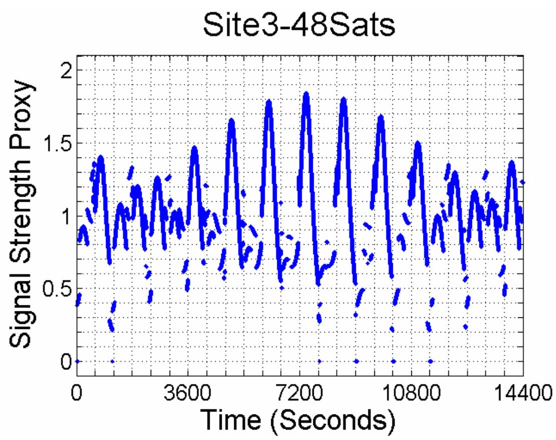

Site8-40Sats
Signal Strength Proxy
Time (Seconds)
0
3600
7200
10800
14400
0
0.5
1
1.5
2

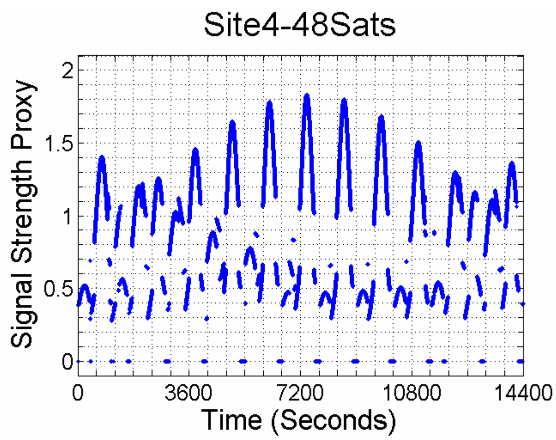
16.4.2. 48 Satellite Configuration

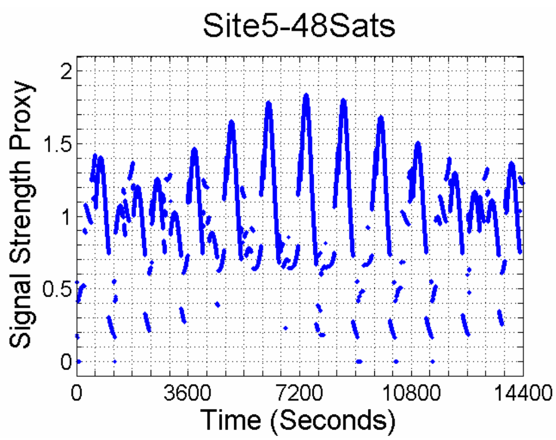


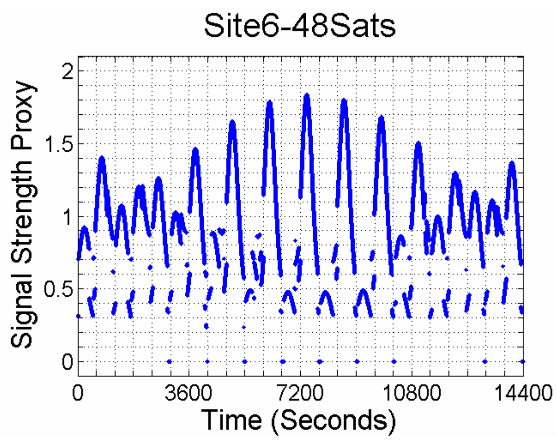

IncidentVegetation48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)

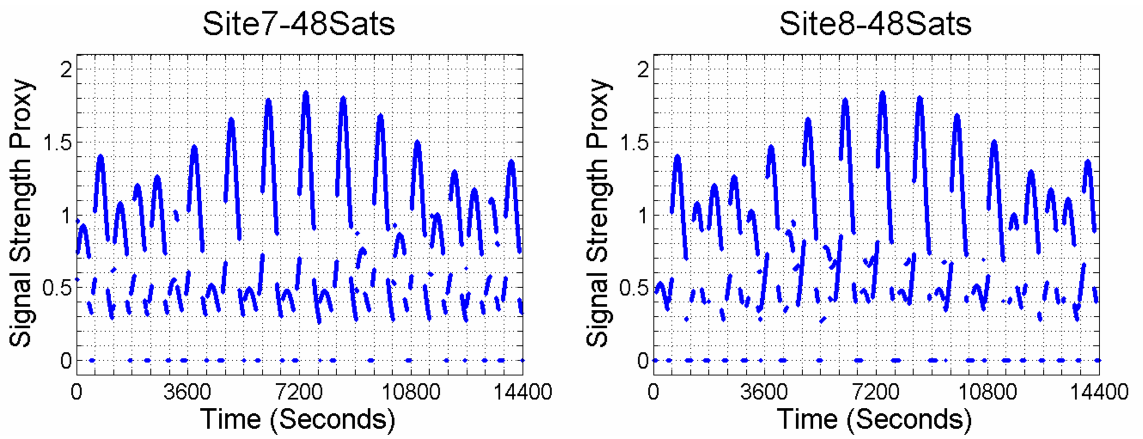

Site2-48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)


Site3-48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)


Site4-48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)

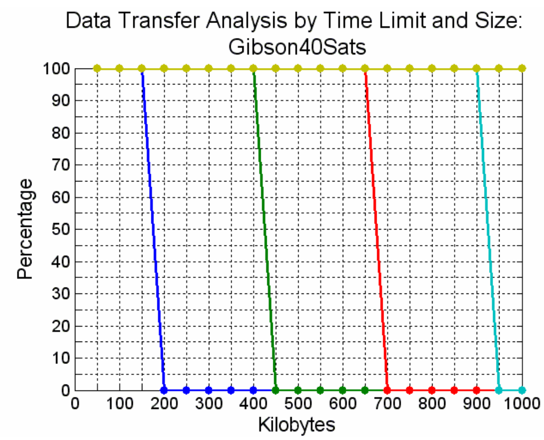

Site5-48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)

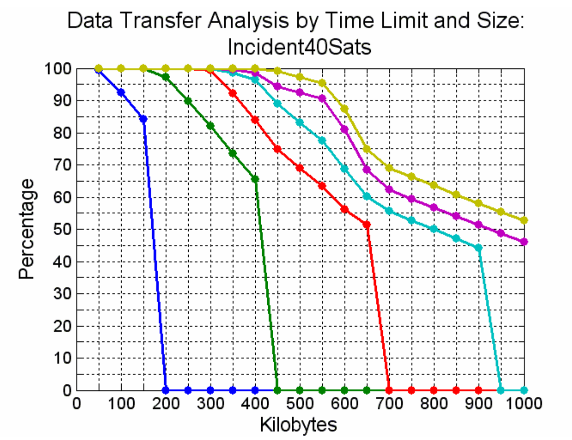

Site6-48Sats
Signal Strength Proxy
0
0.5
1
1.5
2
0
3600
7200
10800
14400
Time (Seconds)

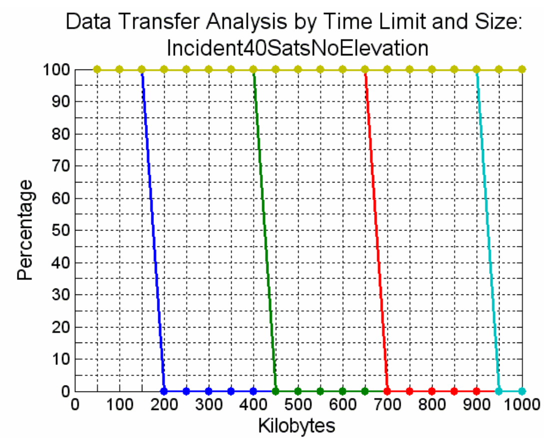

Site7-48Sats
Signal Strength Proxy
Time (Seconds)
0
3600
7200
10800
14400
0
0.5
1
1.5
2
Site8-48Sats
Signal Strength Proxy
Time (Seconds)

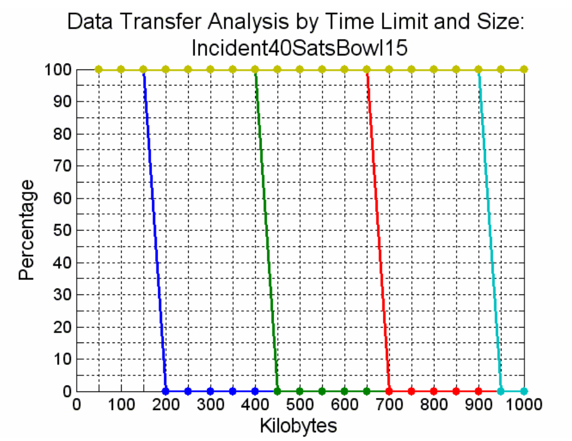
16.5. Simulated Transmission Analysis

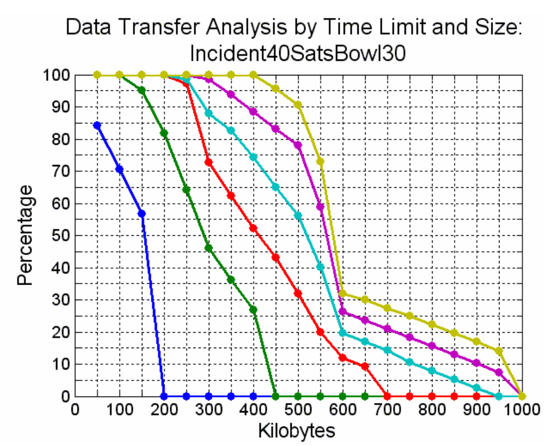
16.5.1. 40 Satellite Walker Configuration

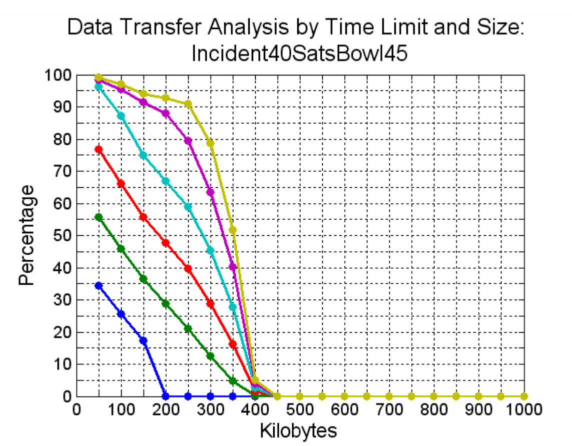


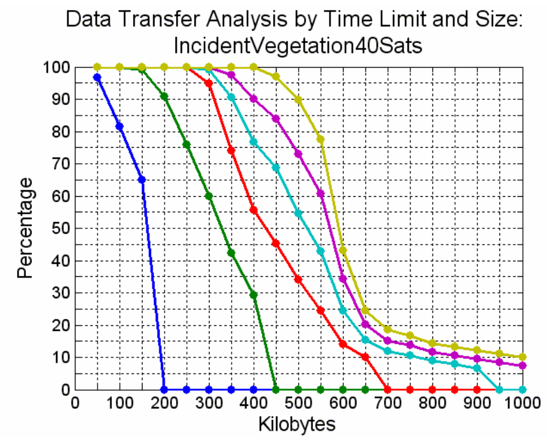


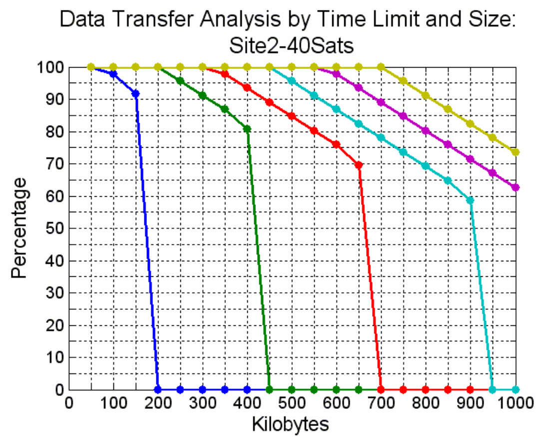


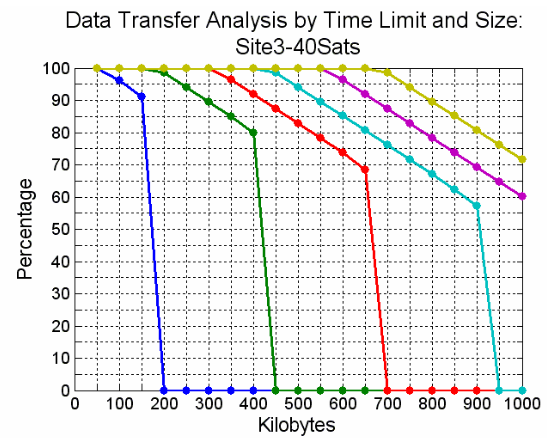


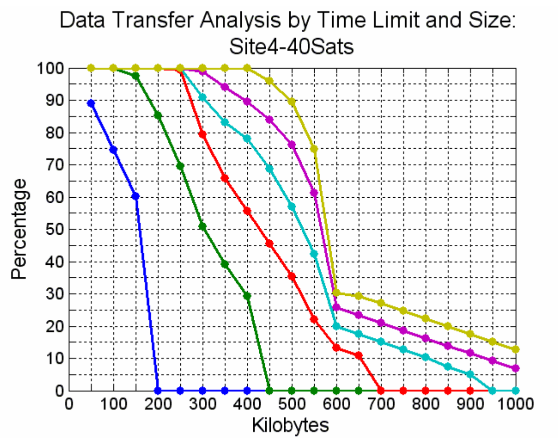


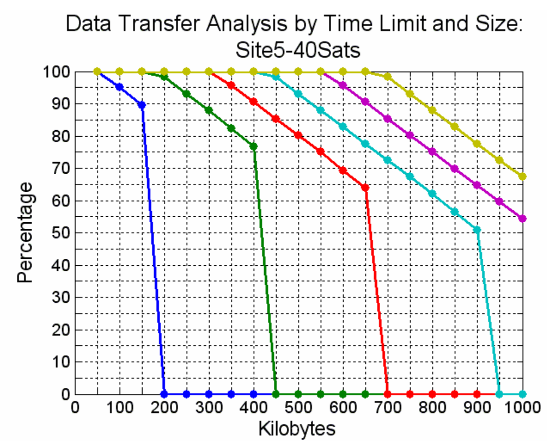


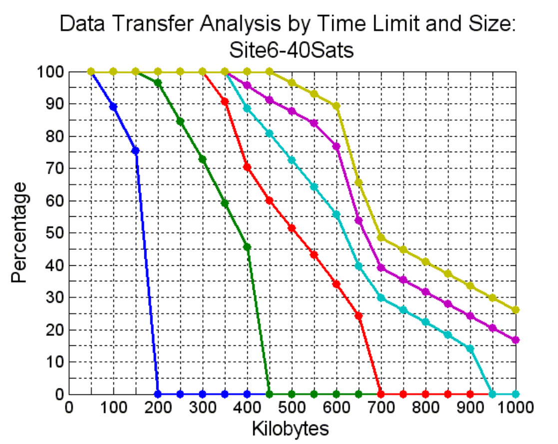

Data Transfer Analysis by Time Limit and Size:
IncidentVegetation40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

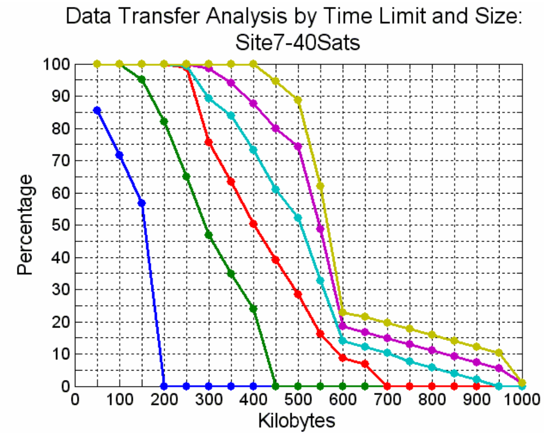

Data Transfer Analysis by Time Limit and Size:
Site2-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

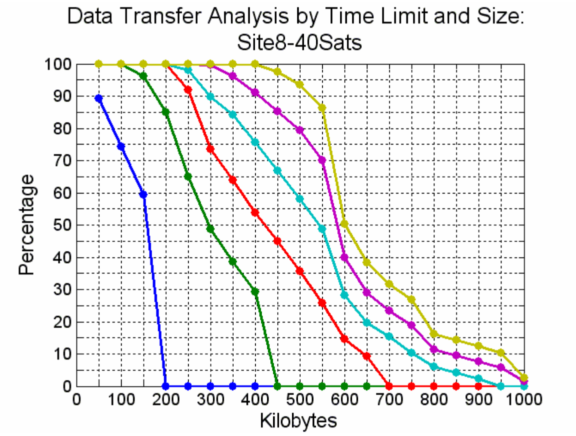

Data Transfer Analysis by Time Limit and Size:
Site3-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100


Data Transfer Analysis by Time Limit and Size:
Site4-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

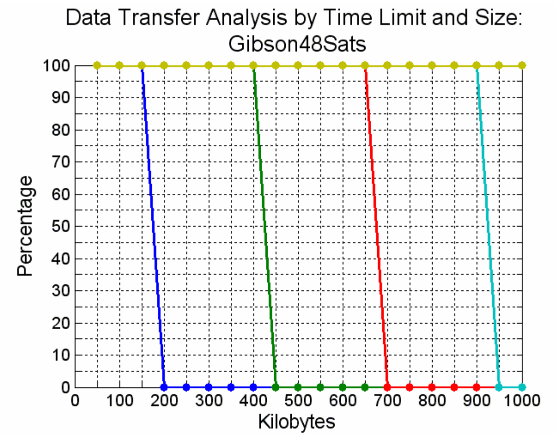

Data Transfer Analysis by Time Limit and Size:
Site5-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

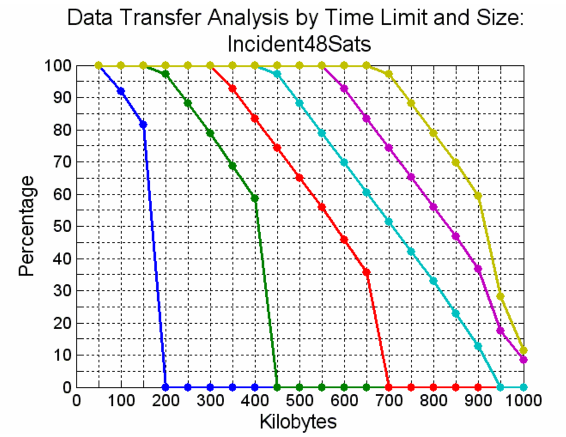

Data Transfer Analysis by Time Limit and Size:
Site6-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

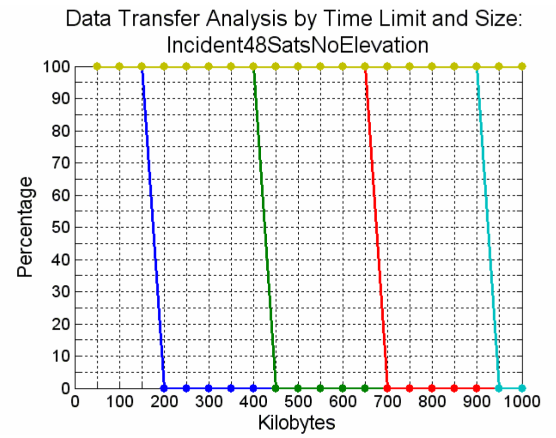

Data Transfer Analysis by Time Limit and Size:
Site7-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

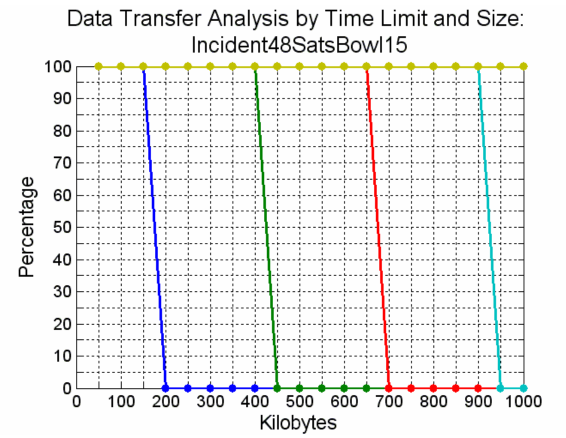

Data Transfer Analysis by Time Limit and Size:
Site8-40Sats
Percentage
Kilobytes
0 100 200 300 400 500 600 700 800 900 1000
0 10 20 30 40 50 60 70 80 90 100

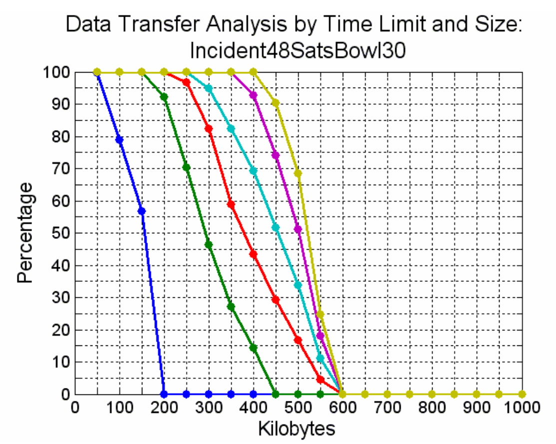
16.5.2. 48 Satellite Configuration

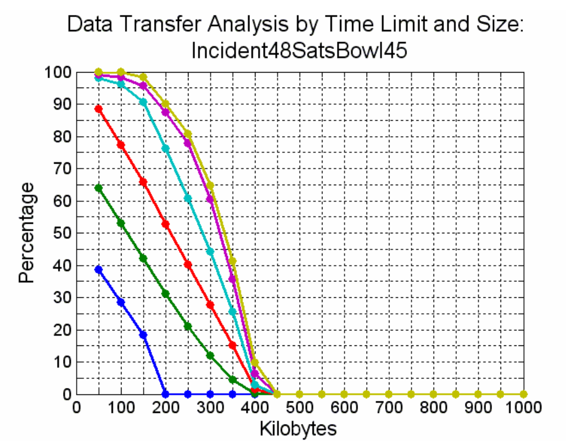


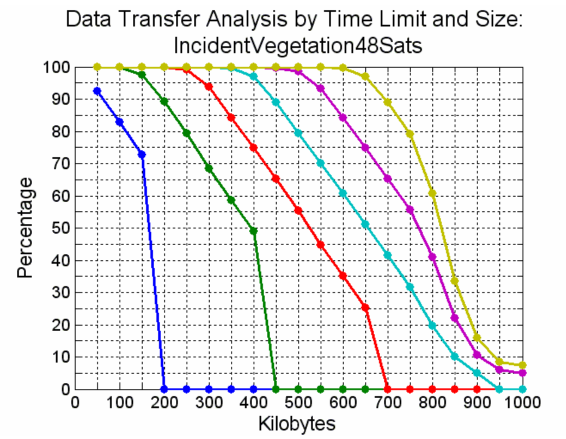


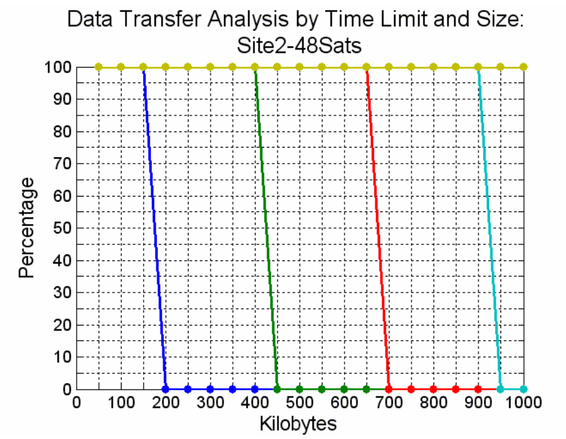


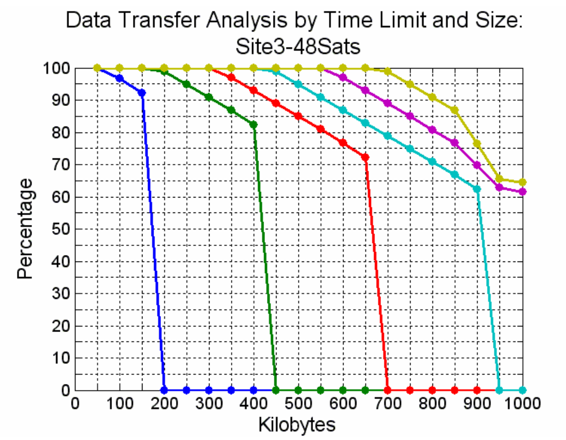


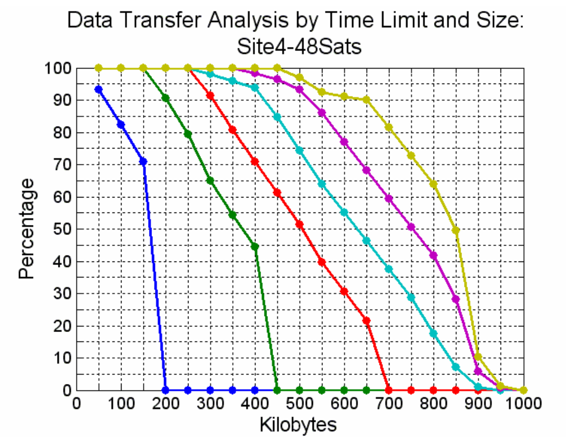


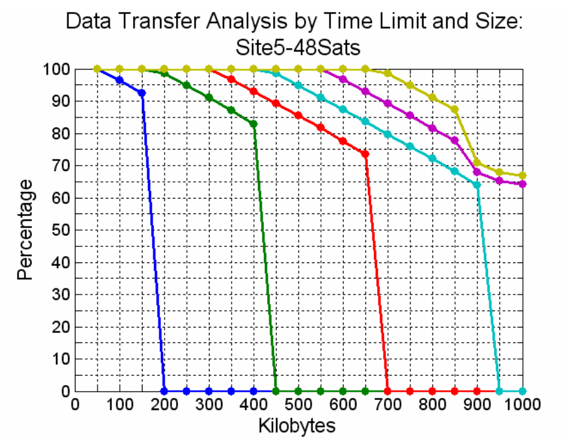


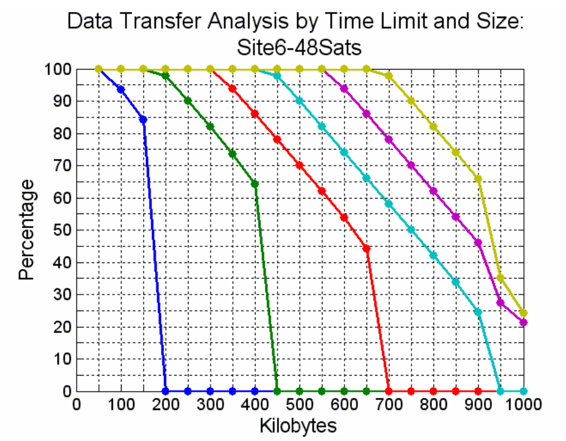

Data Transfer Analysis by Time Limit and Size:
IncidentVegetation48Sats
Percentage
Kilobytes

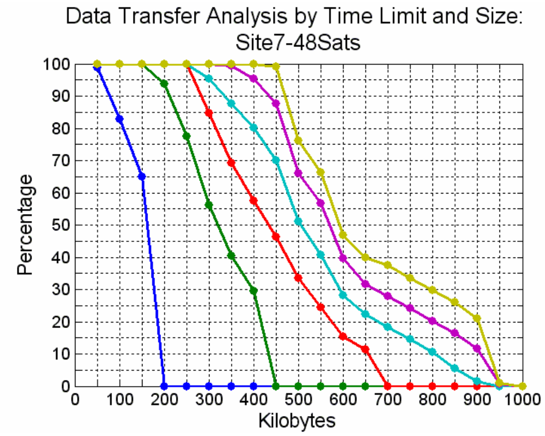

Data Transfer Analysis by Time Limit and Size:
Site2-48Sats
Percentage
Kilobytes

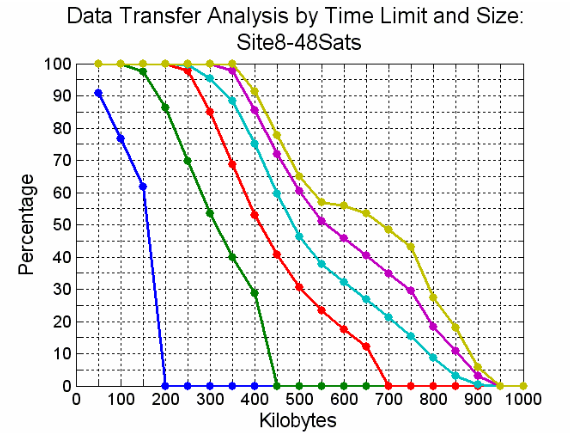

Data Transfer Analysis by Time Limit and Size:
Site3-48Sats
Percentage
Kilobytes


Data Transfer Analysis by Time Limit and Size:
Site4-48Sats
Percentage
Kilobytes


Data Transfer Analysis by Time Limit and Size:
Site5-48Sats
Percentage
Kilobytes


Data Transfer Analysis by Time Limit and Size:
Site6-48Sats
Percentage
Kilobytes


Data Transfer Analysis by Time Limit and Size:
Site7-48Sats
Percentage
Kilobytes
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900
1000


Data Transfer Analysis by Time Limit and Size:
Site8-48Sats
Percentage
Kilobytes
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
900
1000