STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV 10/98)

ADA Notice

For individuals with sensory disabilities, this document is available in alternate formats. For information call (916) 654-6410 or TDD (916) 654-3880 or write Records and Forms Management, 1120 N Street, MS-89, Sacramento, CA 95814.

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA16-1846		

4. TITLE AND SUBTITLE Development and Testing of Responder Phase III	5. REPORT DATE June 28, 2017
	6. PERFORMING ORGANIZATION CODE AHMCT Research Center, UC Davis
7. AUTHOR Stephen Donecker, Travis Swanston, Kin Yen, Bahram Ravani, and Ty A. Lasky	8. PERFORMING ORGANIZATION REPORT NO. UCD-ARR-15-09-30-05
9. PERFORMING ORGANIZATION NAME AND ADDRESS AHMCT Research Center UCD Dept. of Mechanical & Aerospace Engineering Davis, California 95616-5294	10. WORK UNIT NUMBER
	11. CONTRACT OR GRANT NUMBER IA65A0416, Task 1846
12. SPONSORING AGENCY AND ADDRESS California Department of Transportation P.O. Box 942873, MS #83 Sacramento, CA 94273-0001	13. TYPE OF REPORT AND PERIOD COVERED Final Report June 2013 – September 2015
	14. SPONSORING AGENCY CODE Caltrans

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report documents the research project "Development and Testing of Responder Phase III." Under previous research, a Responder system has been developed to provide relevant and timely information to first responders, allow responders to provide information on the scene and incident to others in the organization, and support reliable and always available communications. The primary goal of the current project was to migrate the Responder system to the latest computing and communications technologies, including smartphone and tablet systems. The project includes review of previous phase efforts, updating of requirements, review of commercial systems, design and development of Phase III Responder system, and testing and reporting. The research product will provide Caltrans with a more field-ready system to support first responders in rural environments.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
First response, Highway maintenance, emergency response, first responder, incident management	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	118	

DISCLAIMER

Advanced Highway Maintenance and Construction Technology Research Center

Department of Mechanical and Aerospace Engineering
University of California at Davis

Development and Testing of Responder Phase III

Stephen Donecker, Travis Swanston, Kin Yen, Bahram Ravani &
Ty A. Lasky (Principal Investigator)

Report Number: CA16-1846
AHMCT Research Report: UCD-ARR-15-09-30-05
Final Report of Contract: IA65A0416, Task 1846

June 28, 2017

California Department of Transportation

Division of Research, Innovation and System Information

ABSTRACT

This report documents the research project "Development and Testing of Responder Phase III." Under previous research, a Responder system has been developed to provide relevant and timely information to first responders, allow responders to provide information on the scene and incident to others in the organization, and support reliable and always available communications. The primary goal of the current project was to migrate the Responder system to the latest computing and communications technologies, including smartphone and tablet systems. The project includes review of previous phase efforts, updating of requirements, review of commercial systems, design and development of Phase III Responder system, and testing and reporting. The research product will provide Caltrans with a more field-ready system to support first responders in rural environments.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
3D	Three-dimensional
AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
API	Application Programming Interface
ATMS	Advanced Transportation Management System
BGAN	Broadband Global Area Network
CAD	Computer-Aided Design
Caltrans	California Department of Transportation
CCTV	Closed-Circuit TV
CDEC	California Data Exchange Center
CHP	California Highway Patrol
CMS	Changeable Message Sign
CNRFC	California Nevada River Forecast Center
COTS	Commercial Off–The-Shelf
CWWP	Commercial Wholesale Web Portal
DHIPP	Digital Highway Inventory Photography Program
DMS	Dynamic Message Sign
DOE	Division of Equipment
DOT	Department of Transportation
DRISI	Caltrans Division of Research, Innovation and System Information
EMS	Emergency Medical Services
GDAL	Geospatial Data Abstraction Library
GPS	Global Positioning System
HMI	Human Machine Interface
HTTP	Hypertext Transfer Protocol
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IR	Infrared
IRIS	Intelligent Roadway Information System
ISM	Industrial, Scientific, and Medical
ITS	Intelligent Transportation Systems
JSON	JavaScript Object Notation
LTE	Long-Term Evolution
LRS	Linear Reference System
MADIS	Meteorological Assimilation Data Ingest System
MSU	Montana State University
NED	National Elevation Dataset
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OES	Office of Emergency Services
OS	Operating System
OSM	OpenStreetMap
OSS	One-Stop-Shop
PDF	Portable Document Format
PIO	Public Information Office
QOS	Quality of Service
R&D	Research & Development
RF	Radio Frequency
RWIS	Road Weather Information System

Acronym	Definition
SR	State Route
SWR	Standing Wave Ratio
TAG	Technical Advisory Group
TCP/IP	Transmission Control Protocol / Internet Protocol
TMC	Transportation Management Center
UCD	University of California – Davis
USGS	United States Geological Survey
VDS	Vehicle Detector Station
Wi-Fi	Wireless Fidelity
WTI	Western Transportation Institute
XML	Extensible Markup Language

ACKNOWLEDGMENTS

The authors thank the California Department of Transportation (Caltrans) for their support, in particular Ian Turnbull, Chief, Office of Intelligent Transportation Systems (ITS) Engineering and Support, and Melissa Clark, Asfand Siddiqui, and Gurprit Hansra with the Division of Research, Innovation and System Information. The authors also thank Carlos Aguilar, Joe Baltazar, Geno Cervantes, Javier Del Rio, Keith Farnsworth, Philip Graham, Michael Gunn, Francisco Gutteres, Steve Hardie, Ed Hardimann, Ed Lamkin, Kevin Marshall, Ferdinand Milanes, Mitchell Ngo, Sidra Pauly, Jeremiah Pearce, James Province, John Schmidt, Chris Seale, Bill Stein, and Larry Wooster of Caltrans for their guidance and support. For assistance with the Caltrans data feeds, the authors thank Sean Campbell and Keith Koeppen. The authors also thank Doug Galarus and his researchers at the Western Transportation Institute for their pioneering work in earlier phases of Responder development. The authors thank Tomás Guerra of OZ Engineering LLC, and Israel Lopez and James Whalen of the Nevada Department of Transportation (DOT) for assistance with the Nevada data feeds. For their assistance with the Oregon data feeds, the authors thank Robert Fedele, Kyle Hedspeth, and Galen McGill of the Oregon DOT. The authors also thank Caltrans District 6 for the gracious loan of their maintenance supervisor vehicle. The authors also thank the Caltrans district maintenance personnel in Districts 2, 3, 4, and 9 for their valuable system testing and feedback. The authors acknowledge the dedicated efforts of the AHMCT team who have made this work possible.

CHAPTER 1:
INTRODUCTION

Incident response is a critical function for the California Department of Transportation (Caltrans). It is important to provide relevant and timely information to responders, including for example weather. In addition, it is important for first responders to be able to provide relevant information from the scene and the incident to others in the organization who are involved in the process. Reliable and always available communication is a key component for incident response. Under the Responder Phase II research project [7], a system was developed by the Western Transportation Institute (WTI) of Montana State university (MSU) at Bozeman to meet these needs for Caltrans.

The goal of the current Responder Phase III research project was to migrate the existing Responder system to the latest computing and communications technologies, including smartphone and tablet systems. As part of this Phase III research project, the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center at the University of California – Davis (UCD) designed and developed this next-generation Responder system. The project included review of previous phase efforts, updating of requirements, review of commercial systems, design and development of Phase III Responder system, and testing and reporting. The research product will provide Caltrans with a field-ready system ready for full deployment to support first responders in rural environments.

Research Approach

This work builds on AHMCT's experience with winter maintenance operations, our strength in sensing and system integration, and our established Mechatronic hardware and software knowledge base [2,4-6,9-13].

The research methodology included:

- Update prototype system concept and requirements
- Literature and product review
- Prototype system development
- Prototype system testing and evaluation

Overview of Research Results and Benefits

The key deliverables of this project include:

- Updated prototype system high-level design
- Updated requirements
- System software and hardware design and code
- User guide
- Field test of Responder system

CHAPTER 2:
RESPONDER SYSTEM CONCEPT

Caltrans maintenance staff is first responder to incidents on the state roadways. They must collect information, determine the appropriate response, and access and manage resources at-scene. These events must be done in concurrence with providing transportation management services to respond to and recover from the incident. Caltrans currently does not have an efficient means to collect at-scene incident information and the capacity to share this information with transportation management centers and other emergency responders. In most Caltrans districts, emergency responders rely on voice communications to exchange information. In addition, many districts lack the ability to distribute incident support information to responders via data networks. Such information could better prepare responders for incident support, provide assistance for incident management, and guide responders in making safe and sound decisions. Caltrans needs a communication tool for first responders to allow photos, drawings, weather information, and maps to be shared between responders and a transportation management center (TMC) during an incident via Wireless Fidelity (Wi-Fi), cellular, satellite, or other forms of communications.

As a key element of this project, AHMCT has developed the third-generation of the Responder system. This is a communication tool that integrates hardware, software, and communications to provide incident responders with an easy to use means to accurately collect and communicate at-scene information with their managers and the TMC. The system is particularly useful to those in rural areas with sparse communication coverage. The incident responder will use a smart device such as a tablet or cell phone. The Responder system provides access to critical information such as weather, fire, and TMC field element status to responders. It manages communications via multiple channels, selecting the best channel based on availability, bandwidth, and cost. Responder includes a store-and-forward architecture to address situations where communications is temporarily unavailable. The Responder system does not rely on any centralized server, as it must function in situations with complete communications degradation.

Unique features of the system include the ability for users to capture, annotate, and transmit images. Using Global Positioning System (GPS) readings, the system automatically downloads local weather data, retrieves maps and aerial photos, and pinpoints the responder's location on the maps. By simply clicking on the "SEND" button, an email message is automatically composed and sent to the TMC operator or other emergency/first responder parties. The system connects to the most efficient and available service (Wi-Fi, cellular, satellite, or other communication) on its own; photos and sketches are compressed to minimize transmission time. With an emphasis on ease of use, the system allows responders to concentrate on work at the scene without burdening them with data input and reporting. The high-level Responder concept and architecture is shown in Figure 2.1.

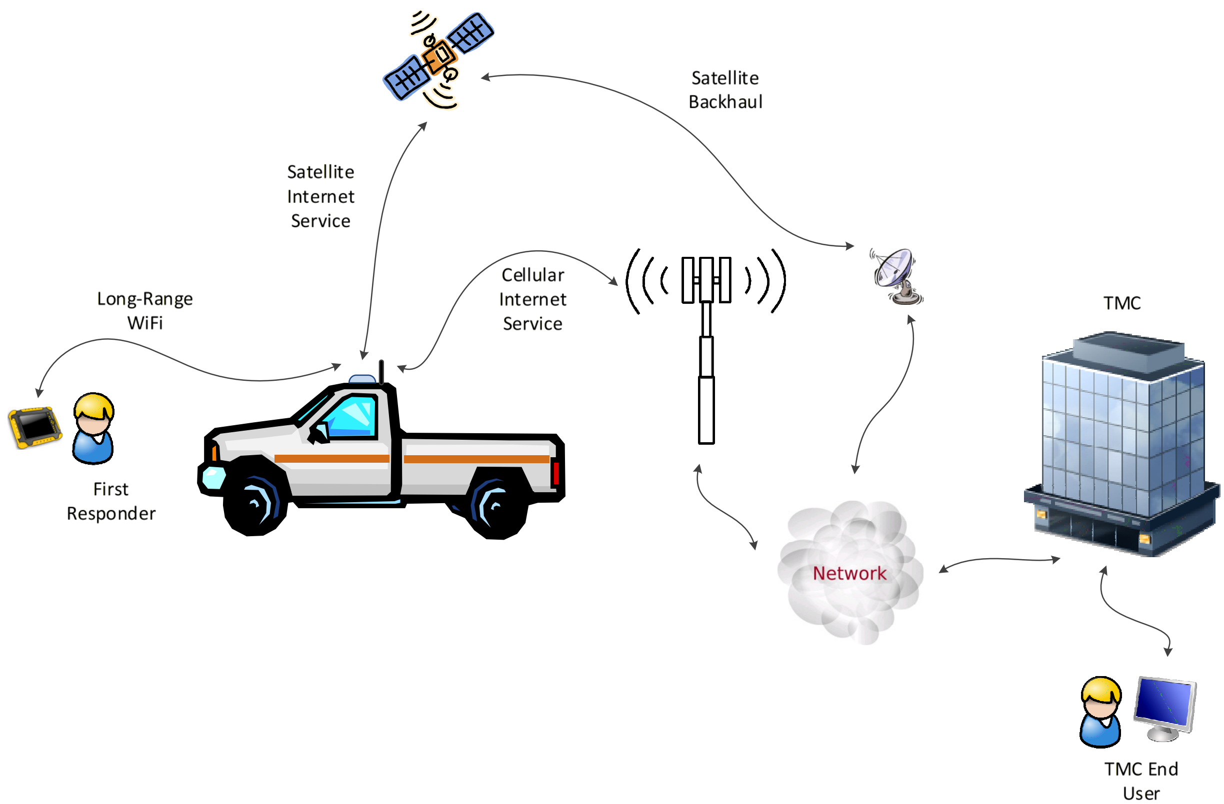


Figure 2.1: Responder concept

The Responder system allows first responders to collect and share at-scene information quickly and efficiently. It is especially valuable in:

- Major incidents such as landslides, floods and earthquakes, where the damage could be extensive
- Remote rural areas where communication is often limited to voice, and coverage is sparse
- When the first responder is new or inexperienced in responding to certain situations

The use of this system will save resources by:

- Having the ability to evaluate what is happening at the scene from a maintenance yard/location or TMC without extended delay
- Sending the correct employees and equipment to the incident in a timely manner based on the initial information that can be seen in the photo(s) and/or report(s) submitted by Caltrans staff at the incident scene
- Being able to provide real-time information to other staff, such as the Public Information Office (PIO), who may have to answer to outside agencies regarding what is happening at the incident.

CHAPTER 3:
RESPONDER REQUIREMENTS

The requirements for the current phase of Responder research and development (R&D) are derived from those presented in [3]. These requirements were developed through extensive project workshops, user feedback, and review. The requirements as presented in this chapter drove all system architecture, design, and implementation decisions.

Unless otherwise note, requirements marked as partially (yellow) or not met (red) are included in a plan provided to DRISI by AHMCT for future implementation.

Table 3.1: Responder Phase III Requirements

	Key (status as of 5/31/17)
Green	Requirement met
Yellow	Requirement partially met
Red	Requirement not met

Green	1. **A system shall be implemented to collect incident information.**
Green	1.1. The system shall collect and store incident metadata.
Green	1.2. The system shall collect the incident location.
Green	1.2.1. The system shall record the precise location of the incident using latitude and longitude.
Green	1.2.2. The system shall record post mile location of the incident.
Green	1.3. The system shall collect the incident occurrence time.
Green	1.4. The system shall collect a description of the incident.
Green	1.4.1. The system shall record the type of incident.
Green	1.4.1.1. The system shall record analysis of spill impacts for Hazmat incidents.[1]
Green	1.4.1.2. The system shall record severity of incidents.

[1] This can be recorded in the description field.

	1.4.2. The system shall record traffic control, closures, and directions of traffic in a form.
	1.4.3. The system shall record equipment needed for incident clearance.
	1.4.4. The system shall record incident measurements.
	1.5. The system shall collect incident photographs.
	1.6. The system shall collect incident sketches.
	1.7. The system shall facilitate sketches.
	1.7.1. The system shall facilitate sketches to annotate incident photographs.
	1.7.2. The system shall facilitate sketches to annotate maps.
	1.7.3. The system shall facilitate sketches to annotate aerial photos.
	1.7.4. The system shall facilitate free-form sketches.
	1.8. The system shall store incident information as a collection, not disparate pieces.
	1.9. The system shall allow incident information to be edited.
	1.10. The system shall allow incident information to be deleted.
	1.11. The system shall store incident information in a format compatible with database import utilities.
	1.12. The system shall automatically identify incidents.
	1.12.1. The system shall identify incidents by date, time, organization, name of responder, county, and/or road.
	1.12.2. The system shall facilitate searching and organizing incidents by date, organization, name of responder, county, and/or road.
	1.13. 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 (Emergency Medical Services), fire and other agencies.**
	2.1. The system shall be usable by one primary field contact person for communication with dispatch.
	2.2. The system shall transmit incident information to an operator selectable or editable list of contacts and groups.
	2.3. The system shall be usable by other agencies.
	2.3.1. The system shall be configurable for use by other agencies.
	3. **The system shall be deployed within Caltrans' vehicles in the field.**
	3.1. 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.
	3.1.1. The system shall be portable.
	3.2. The system shall be storable in a "box" behind the driver's seat.
	3.3. The system shall be storable in a "box" in the bed of a truck.
	3.4. The system shall use hardened equipment.
	3.4.1. The system shall be usable in temperatures between -20°F to 120°F.
	3.4.2. The system shall be storable in temperatures between -20°F to 150°F.
	3.4.3. The system shall release heat generated during operation.
	3.4.4. The system shall be usable in all weather conditions including rain, snow, bright sun, and wind.
	3.5. The system shall have a charging/docking station.
	3.5.1. The system shall have an ergonomic charging/docking station.
	3.5.2. The system shall facilitate easy retrieval and replacement of equipment.
	3.5.3. The system shall facilitate easily recharging batteries.
	3.5.4. The system shall have a charging/docking station that is resistant to liquid spills, dirt, and other debris.
	3.6. The system shall be operable directly off vehicle power.

	3.7. The system shall be stored within the vehicle in a manner such that it doesn't interfere with other work.
	3.8. The system shall allow for antennas to be permanently fixed.
	3.9. The system shall allow for antennas to be removable.
	3.10. 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.**
	4.1. The system shall be usable up to 200 feet from the vehicle.
	5. **The system shall be easy to use.**
	5.1. The system shall include a checklist for use and procedure at the scene.
	5.2. The system shall include a reference guide for basic operation.
	5.3. The system shall include a user manual including detailed trouble-shooting.
	5.4. The system shall provide a mechanism to capture photographs.
	5.5. The system shall facilitate preview of photographs.
	5.6. The system shall facilitate management of photographs.
	5.7. The system shall facilitate archival of photographs.
	5.7.1. The system shall facilitate deletion of photographs.
	5.8. The system shall require minimal navigation to complete operations.
	5.9. The system shall use functional names for interface elements.
	5.10. The system shall facilitate pre-stored configuration information and default values.
	5.10.1. The system shall store default contact information (email address) for incident information transmission.
	5.10.1.1. The system shall allow the user to override default contact information by selection or entry.
	5.11. The system shall be designed for ease of use so as not to require embedded help.

	5.12. The system shall be reliable.
	6. **The system shall automate the collection of incident information.**
	6.1. The system shall automatically geo-locate the responder.
	7. **The system shall minimize the amount of time required for use.**
	7.1. The system shall facilitate the collection and entry of incident information in less than 20 minutes.
	7.2. The system shall facilitate automated transmission of incident information.
	7.3. 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.**
	8.1. The system shall transmit incident information to an operator selectable or editable list of contacts and groups.
	8.2. The system shall preview messages prior to transmission.
	8.3. The system shall automatically scale and compress photos and sketches for transmission.
	8.3.1. The system shall default to minimal suitable quality for transmission.
	8.3.2. The system shall allow the user to override image quality.
	8.4. The system shall facilitate breaking messages into "chunks" in the event of transmission problems.
	8.5. The system shall transmit incident records as soon as possible.
	8.6. The system shall allow the transmission of all incident information including all sketches and photographs.
	8.7. The system shall allow the selection and transmission of incident information including selected sketches and photographs.
	8.8. The system shall allow the transmission of text-only incident information.
	8.9. The system shall mark information that has been successfully transmitted.

	8.9.1. The system shall use marked information to facilitate interpretation of multiple transmissions to a recipient.
	9. **The system shall receive information from outside sources.**
	9.1. The system shall display weather information based on the responder's location.[2]
	9.1.1. The system shall display weather forecasts based on the responder's position.
	9.1.2. The system shall display wind directions.
	9.1.3. The system shall display storm information.
	9.1.4. The system shall display wildland fire information.
	9.1.5. The system shall display RWIS (Road Weather Information System) data
	9.1.6. The system shall display Chain Control.
	9.1.7. The system shall display projected stream flows.
	9.1.8. The system shall display weather information from CDEC (California Data Exchange Center), MESOWEST, & MADIS (Meteorological Assimilation Data Ingest System).[3]
	9.1.9. The system shall display zone forecasts.
	9.1.10. The system shall display road camera (CCTV) displays.
	9.2. The system shall display road maps based on the responder's location.[4]
	9.2.1. The system shall include pre-loaded road maps.

[2] All information sources (feeds) are being acquired and parsed. All relevant information is being extracted and sent to the Responder database. The display of this information currently uses prototype screens that are not optimal for such display. These displays will be updated in AHMCT's planned pending work.

[3] All weather information is being obtained from other reliable sources, e.g. the National Weather Service. CDEC does not provide weather, to our knowledge. MESOWEST requires membership, including payment, to obtain its data. MADIS requires a user account. AHMCT applied for a MADIS account, but did not receive a reply. AHMCT sent MADIS several requests for status of the account application, and received no replies. As the needed weather information was being obtained from reliable sources, no further attempt was made related to MADIS.

[4] The system will include mapping tiles for all appropriate zoom levels. Exact zoom levels are TBD in discussion with TAG. For the road map, Responder uses the same map tiles used in Caltrans' IRIS (Intelligent Roadway Information System) traffic management system.

	9.3. The system shall display aerial photos based on the responder's location.[5]
	9.3.1. The system shall include pre-loaded aerial photos.
	9.3.2. The system shall include pre-loaded Caltrans' Digital Highway Inventory Photography Program (DHIPP) aerials photos.
	9.3.3. The system may indicate creation dates for aerial photos.[6]
	9.4. The system shall display topographic maps based on the responder's location.[7]
	9.4.1. The system shall include pre-loaded topographic maps.
	9.4.2. The system may indicate creation dates for topographic maps.
	9.5. The system shall display Caltrans' maps.[8]
	9.5.1. The system may indicate creation dates for Caltrans' maps.[9]
	9.6. The system shall display expected traffic volumes.
	9.7. The system shall display chemical information for Hazmat spills.[10]
	9.8. The system shall download data to responders while en route to and at the scene of an incident.
	9.9. The system shall not download unnecessary information such as graphics and links.
	9.10. The system shall use incident location information to identify and expedite downloads.
	9.11. The system shall display information within a user-selectable radius.

[5] The system will include aerial photo tiles for all appropriate zoom levels. Exact zoom levels are TBD in discussion with TAG. Aerial photos will be based on content provided by Caltrans DRISI.

[6] While this requirement uses "may" rather than "shall", AHMCT hopes to address it. However, it is not clear whether creation date is available from Caltrans DRISI for the included aerial photos.

[7] The system will include topographic map tiles for all appropriate zoom levels. Exact zoom levels are TBD in discussion with TAG. Topographic map tiles will be generated by AHMCT, per prior discussions with TAG.

[8] This requirement is unclear. The difference between "road maps" (requirement 9.2) and "Caltrans maps" (requirement 9.5) needs explanation.

[9] While this requirement uses "may" rather than "shall", AHMCT hopes to address it. However, it is not clear whether creation date is available for "Caltrans maps", particularly since this term is not currently clear.

[10] AHMCT recommends use of a separate app, "ERG 2016", as it provides advanced navigation, searching and viewing capabilities for the 2016 Emergency Response Guidebook. This app can be installed from Google Play Store. The app has been installed on the Responder tablet.

	9.12. The system shall minimize dependencies on Caltrans' server resources.
	10. **The system shall have data communications capability in all areas of District 2.**
	10.1. The system shall be operable in rural areas including mountainous areas.
	10.2. The system shall be operable in urban areas.
	10.3. The system shall attempt to automatically mitigate communication failures.
	10.3.1. The system shall retry sends or downloads in the case of failure.
	10.3.2. The system shall switch over to another communication device, if available, in the event of a failure.
	10.4. The system shall notify the user if communication fails.
	11. **The system shall display diagnostic information for system devices.**[11]
	11.1. The system shall display diagnostic information in clearly separate location from other information.

[11] AHMCT is implementing diagnostics and status in pending work.

CHAPTER 4:
HIGH-LEVEL SYSTEM DESIGN

The Responder system design was developed based on the concept presented in Chapter 2 and the detailed requirements of Chapter 3. This design is presented here.

Responder Physical Architecture

Figure 2.1 illustrates the Responder physical architecture. The Responder system is designed to be completely independent of any centralized server. Obviously, information from any particular data source, e.g. CMS status, requires communications with an associated server, e.g. the Caltrans Commercial Wholesale Web Portal (CWWP). However, Responder is independent of any particular server, as it will continue to support all functionality that does not depend on a particular unavailable server. This was a key requirement for Responder, and drove many of the architecture and detailed design decisions.

For the end user, i.e. the Caltrans first responder, the human machine interface (HMI) is all that they will have to know, or should know, about Responder. The remainder of the system should be transparent to them. The user interacts with the HMI app on either a smartphone or a tablet. This app is discussed in detail in a separate chapter.

The HMI communicates with the in-vehicle system using long-range Wi-Fi, with a range of at least 200 feet. In extreme situations, such as natural disasters, all known communication may be down. The in-vehicle system acts as a Wi-Fi router for any Responder users within range.

As noted previously and as clearly illustrated in the cellular survey results, rural (and in extreme cases urban), responders often operate in areas where cellular communications is intermittent, including large areas where no signal is available. To accommodate this constraint, the Responder system implements a store-and-forward architecture. Under normal conditions wherein cellular signal is available, the system transmits and receives as would any other cellular data-equipped system, e.g. a smartphone. Responder also includes satellite communications, which is used in cases where cellular signal is unavailable. However, when no communications is possible, the system then stores up any reports, messages, data, and monitors for cell or satellite signal availability. Upon detecting a communications signal with sufficient quality of service (QOS), the system forwards all stored messages. Selection of appropriate communications medium is done by an arbiter, as discussed in the next section.

The system communicates over the Internet to transmit information from the Caltrans responder to the TMC and other external entities, e.g. the California Highway Patrol (CHP). This information includes incident report (e.g. location, location description, infrastructure type, lane blockage, incident type, vehicle type, special considerations, incident description, and start/open timestamps), incident photos, and any user-annotated photos, maps, and aerial photos related to the incident. Information is also communicated to the responder on request. This information includes weather, zone forecasts, storm alerts, RWIS data, projected stream flows, wildland fires, Caltrans chain control, CHP incidents, road information, CCTV still images, and CMS messages. This information is available for all of California, and, for many information types, for 30 miles beyond the California border with Arizona, Nevada, and Oregon.

Responder Truck Architecture

The Responder truck software architecture is presented in Figure 4.1.

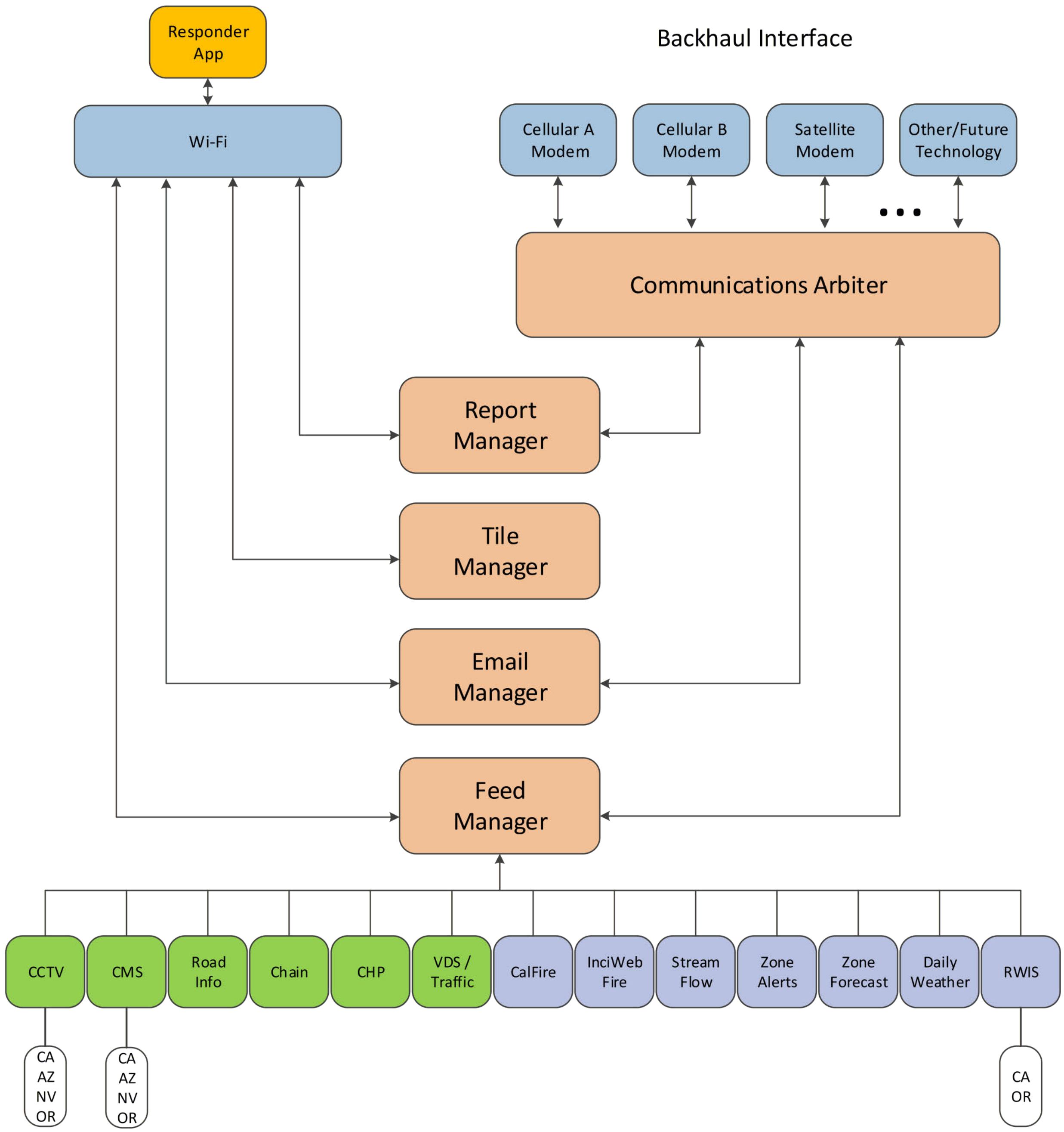


Figure 4.1: Responder in-vehicle software architecture

The interface between the in-vehicle system and the HMI is via long-range Wi-Fi. Multiple responders can be supported, allowing significant flexibility in how Caltrans decides to manage its incidents.

The first component of the in-vehicle architecture is the Communications Arbiter. The Communications Arbiter interfaces to multiple cellular modems, as well as a satellite modem. As implemented, Responder includes cellular communications modem for Verizon service, based on the results of the cellular signal survey discussed in Appendix C. For use in situations where no cellular communications is possible, Responder also includes satellite communications. The assorted communications options have a range of speed (cellular is higher, satellite is lower), cost (satellite is higher, cellular is lower), and data caps (satellite is typically lower, cellular is higher). The Communications Arbiter selects the optimal communications channel based on these factors. Other factors could also be incorporated into the arbitration algorithm. As implemented, the Communications Arbiter can support future communications systems as they become available and make sense for Caltrans. This could include, for example, data communications over 800 MHz radio. The Communications Arbiter interfaces between the communications systems and the report and feed managers, which communicate over the Internet.

The second component is the Report Manager. This component handles all reports provided by the user. It tracks reports by date and time, and assigns a unique identification (ID) to each report. A list of available reports is provided to the Responder HMI app, so that the user can bring up prior reports.

The Mail Manager is the third component of the architecture. It works with the Communications Arbiter to send reports to the TMC and external agencies in the form of an email. The mail manager keeps track of the mail transmission status and provides the administrator a configurable store-and-forward feature. The manager provides feedback to the HMI as necessary to update the application to the mail queue status (i.e. in process, successful, failed).

The Feed Manager is the fourth component of the in-vehicle architecture. A key portion of the HMI app is the feed request and response screen. This allows the user to request various information (discussed in the previous section) which can be critical in managing an incident. The Feed Manager accepts feed information requests from the user, and provides detailed response to the extent possible, by way of communications through the arbiter. It will not always be possible to give current, up-to-date information for every feed, for two reasons. First, there will be times where no communications is available between the Responder in-vehicle system and the Internet. Second, each feed relies on a specific server, and any server is subject to unavailability for multiple reasons. As such, the Feed Manager will provide most current information available, and will make clear, via a timestamp, the "freshness" or age of the information.

The Feed Manager will also pre-fetch information via the most available and lowest-cost method, when feasible. Upon system start-up, ideally in the maintenance yard, the Feed Manager can be instructed to begin querying relevant feed sources and pre-fetching information. This process continues where possible as the vehicle travels to the incident site. In this way, when the vehicle is at the incident site, which is likely more isolated than the maintenance yard and the route between, it will have as much information pre-loaded as is feasible. Thus, feed information can still be provided from the store of pre-fetched information in cases where either communications is completely degraded, or when a feed source is unavailable. This can also minimize communication costs, as higher-priced satellite communications are used less.

The fifth component of the in-vehicle architecture is the Tile Manager. This component stores all necessary tile images, and provides tiles to the HMI app to support the various forms of mapping. The tiles include the roadway map, aerial map, and topographic map. All tiles are pre-loaded to eliminate data transmission cost and server dependencies. The tiles provide a wide range of zoom levels based upon the stated needs of Caltrans responders. Tiles will be updated at some regular, to be determined, interval based on the rate of change of the information. It is currently anticipated that the tiles would not need to be updated more than once a year, likely less often, as the roadway and landscape does not change that frequently.

CHAPTER 5:
SYSTEM DETAILS

To facilitate incorporation of the Responder system into Caltrans core business practices, the design and implementation was based completely on COTS hardware. Some component integration is needed to assemble the electronics box. However, this integration is well within Caltrans Division of Equipment (DOE) capabilities, or of a competent 3rd-party contractor. Thus, it will be fairly easy for Caltrans to procure and install Responder systems in its vehicles. The system uses custom software developed by AHMCT. Software installation is straightforward. This chapter discusses the primary software and hardware components of the Responder system.

Software

The Responder software is divided into two main programs: the HMI app running on a smartphone or tablet, and the Responder system program. The user interacts directly with the HMI app, which communicates to the vehicle-based Responder system or the portable Responder system via long-range Wi-Fi. The Responder system program manages all aspects of Responder data, along with communications over the Internet using a variety of communications systems—it is best understood in reference to Figure 4.2. Unless otherwise indicated, Responder software is implemented in Java. The operating system (OS) for the in-vehicle system is Linux (Ubuntu 14.04.5). The HMI OS is Android.

Responder System Program

Report Manager

The Report Manager handles all reports provided by the user via the HMI app. It tracks reports by date and time, and assigns a unique ID to each report, and to subsequent report revisions. A list of available reports is provided to the Responder HMI app, via the main menu "Reports" option, so that the user can bring up prior reports. The Report Manager works with the Communications Arbiter to send reports to the TMC and external agencies in the form of an email with attachments. The Report Manager extracts all incident report details from the user's input, and updates the internal Responder database. The values of every field in the report are stored in a local database, along with pictures, snapshots, annotations, messages, and other pertinent information. All aspects of the Responder report are collected each time a report is saved either manually or automatically as various actions are completed. When the app user attempts to send the report as an email, the Report Manager communicates with the Communications Arbiter and attempts to send the message immediately. This message is a compiled form of the Responder report in human-readable text format, along with any selected pictures, screenshots, and annotations. The Report Manager stores the request to send this message and, if a communication channel is available, begins sending the message in a priority fashion. If at any point the message transfer is interrupted, the Report Manager provides status information to the user. It continues to attempt to send the message in any way possible, logging attempts and other metadata along the way. If no direct communications channels are available through the Communications Arbiter, the Report Manager uses built-in store-and-forward technology to hold the message until a communications channel becomes available.

Feed Manager

The Feed Manager accepts feed information requests from the app, and provides detailed response to the extent possible, by way of communications through the Communications Arbiter. It will not always be possible to give current, up-to-date information for every feed, for two reasons. First, there will be times where no communications is available between the Responder in-vehicle system and the Internet. Second, each feed relies on a specific server, and any server is subject to unavailability for multiple reasons. As such, the Feed Manager will provide the most current information available, and will make clear, via a timestamp, the age of the supplied information.

In concert with the Communications Arbiter, the Feed Manager pre-fetches information via the most available and lowest-cost method, when feasible. While seeking to use the least expensive communications channel possible, the Feed Manager processes all received feed information into the database even though the app user requested only a subset of this information. For example a user may be near a Caltrans district boundary and request data within a 10-mile radius, which demands requesting all district data from the two adjacent districts even though the end user only requested a small subset of this data. All data from both districts will be processed into the database. It is quite possible that a user that has requested data from an area of interest may change the radius of the requested area or may move location, and thus the app could use this pre-fetched data, improving responsiveness and reducing data transmission and cost. Upon system start-up, ideally in the maintenance yard, the Feed Manager can be requested to begin querying relevant feed sources and pre-fetching information over a large area of interest based upon the anticipated incident location. This process continues as the vehicle travels to the incident site. In this way, when the vehicle is at the incident site, which is likely more isolated than the maintenance yard and the route between, the Responder system will have as much information pre-loaded as is feasible. Thus, feed information can still be provided from the store of pre-fetched information in cases where either communications is completely degraded, or when a feed source is unavailable. This can also minimize communication costs, as higher-priced satellite communications are used less.

The feed acquisition and parsing portion of the Feed Manager was developed in Python[12], as this language is well-suited for the necessary Internet communications, and parsing of Extensible Markup Language (XML)[13] and JavaScript Object Notation (JSON)[14] formatted files. Most feeds are available in XML and/or JSON format. Some feeds are less structured, and the parsers must resort to cruder methods, often referred to as "scraping." These feed parsers will be in a sense more "brittle," subject to complete failure if the underlying web site format changes. Wherever possible, structured JSON or XML feeds were used. If a scraping approach feed parser were to break, revising it for a newer format should in general be straightforward. Python has built-in modules for Internet data requests, XML and JSON parsing, and many other modules quite useful for

[12] https://www.python.org
[13] https://en.wikipedia.org/wiki/XML
[14] http://json.org/

parsing, such as the regular expression module.[15] It also has modules specifically geared for screen scraping.

The Feed Manager coordinates requests from the app with feed information stored in the database, as provided by the feed parsers. The database includes timestamp information for each feed. Based on the assumed characteristics of each feed source (e.g. frequency of update), the request time, and the database timestamp, the Feed Manager chooses whether to provide the existing database information, or to update this information by a request to the relevant feed parser. In this manner, communications costs are reduced. In the case that a feed update is requested but fails for some reason, the Feed Manager will provide the most current information. The timestamp is always provided to the app.

The Feed Manager also handles geographic constraints on feed requests. The app allows the user to set the range (radius, in miles) for individual feeds. For example, display of CMS information for 20 miles from the user's location can be set as a default. This information is used to properly query the feed parser (e.g. only the districts intersected by that 20-mile radius circle), and to limit subsequent queries for feeds that include sub-feeds, such as the CalFire feed. This again reduces communications costs.

Tile Manager

The Tile Manager stores all necessary tile images, and serves them to the HMI app to support the various forms of mapping. The Tile Manager contains a set of tiles for the roadway map, the aerial map, and the topographic map. All tiles are pre-loaded onto the Responder system Tile Manager on system setup to eliminate data transmission costs and server dependencies. The tiles provide a wide range of zoom levels based upon the stated needs of Caltrans responders. Tiles can be updated at a regular interval based on the rate of change of the information. It is currently anticipated that the tiles would not need to be updated more than once a year, and likely less often, as the tile information (roads, terrain, and similar) is fairly static.

The front end of the Tile Manager is based on the widely-used Apache Hypertext Transfer Protocol (HTTP) server.[16] This open-source software provides access to the tile file structure through a standard HTTP request. Given the current location of the user view window and the selected zoom level, the map Application Programming Interface (API) makes a request to the Tile Manager, which responds with the appropriate set of tiles to the HMI application. Which set of tiles to send depends on the selected HMI mapping mode: road map, aerial map, or topographic map.

The tile sources are an essential issue. For the road map, Responder uses the same map tiles used in the Intelligent Roadway Information System (IRIS), the Advanced Transportation Management System (ATMS) used in Districts 1, 2, 5, and 10 [8]. A sample of the IRIS map is

---

[15] https://docs.python.org/2/howto/regex.html

[16] http://httpd.apache.org/

shown in Figure 5.1. The tiles are designed and rendered from OpenStreetMap[17] (OSM) data, and include county boundaries, highway exit numbers, and CHP dispatch boundaries and labels.

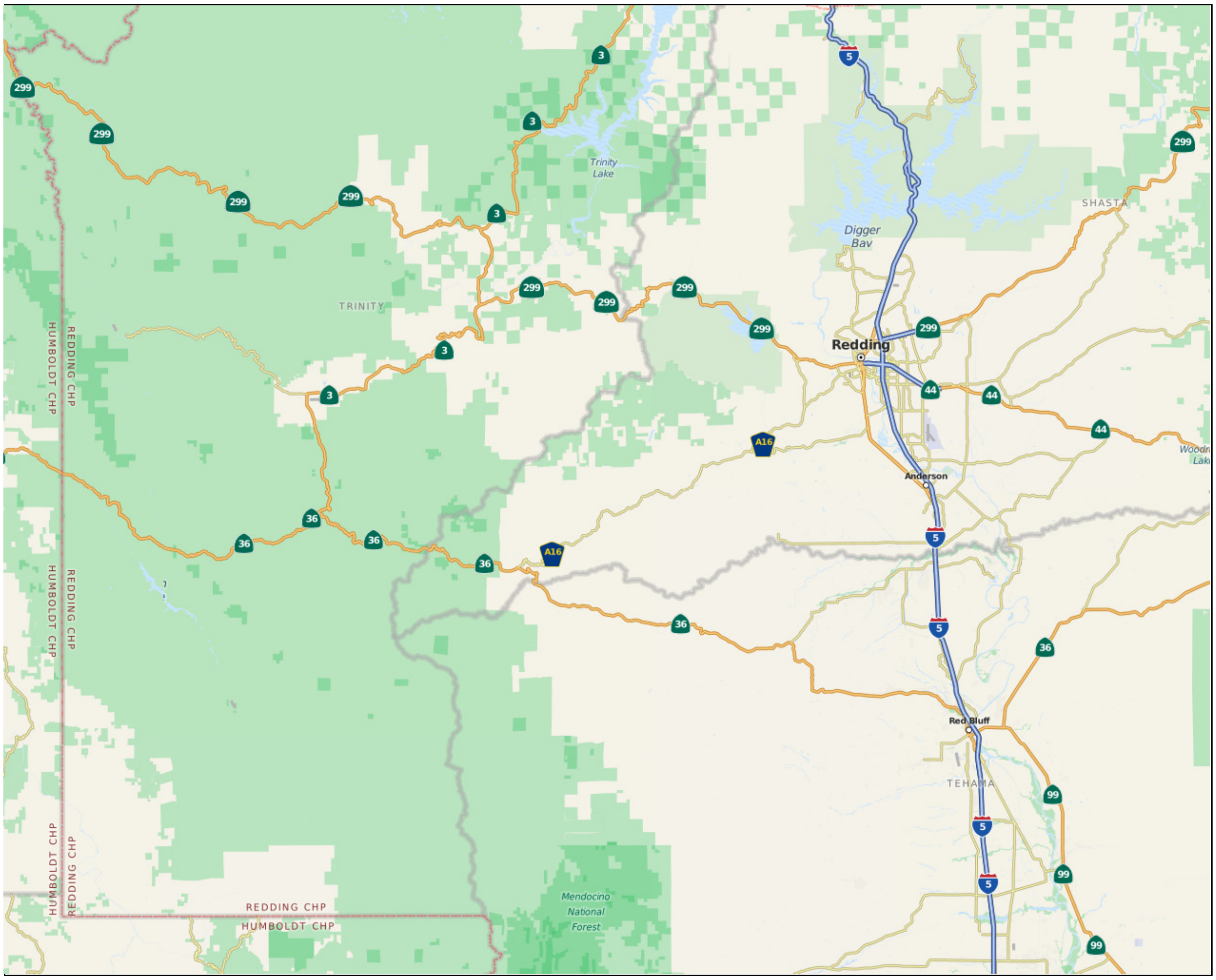


Figure 5.1: Caltrans Intelligent Roadway Information System (IRIS) map tiles are the basis for the Responder road map

The aerial photos and the DHIPP aerial photos were provided by Caltrans DRISI, specifically from Transportation System Information (TSI). These tiles may need more frequent updating than other Responder tiles.

The topographic tiles were developed and rendered by AHMCT, leveraging tool chains and methodologies developed under the IRIS research effort, coupled with significant advancements in AHMCT technology to develop and render 3-dimensional (3D) contoured and shaded topographic map tiles. The tiles were developed and rendered using the toolchain consisting of

[17] https://www.openstreetmap.org/

GDAL[18] (Geospatial Data Abstraction Library), ImageMagick,[19] and Mapnik.[20] The primary source for the topographic data was the National Elevation Dataset (NED)[21] from the United States Geological Survey (USGS). However, many other datasets and shape files were sourced from various government agencies. A sample of the Responder topographic map is shown in Figure 5.2.

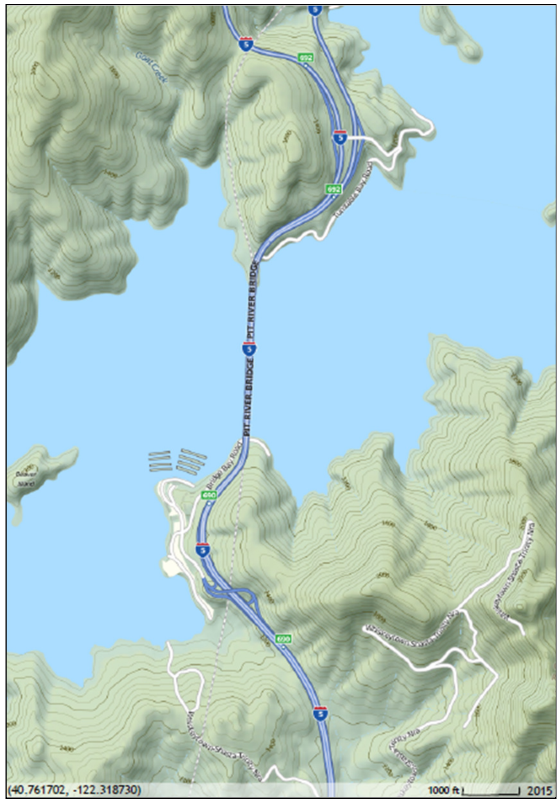


Figure 5.2: Responder topographic map

<u>Communications Arbiter</u>

The Communications Arbiter supports interfaces to Wi-Fi, cellular modems, satellite modems, and any other current or future Transmission Control Protocol / Internet Protocol-based (TCP/IP-based) network modem with minimal configuration. As designed, the Responder implementation includes a Wi-Fi interface, a cellular communications modem with Verizon service, and a Broadband Global Area Network (BGAN) satellite communications modem and antenna. As discussed in Appendix C, based on AHMCT's extensive route surveys of cellular signal strength from T-Mobile, AT&T, and Verizon Wireless, it was clearly determined that cellular data service in rural districts is best provided by Verizon Wireless. In almost all cases, Verizon coverage is a superset of AT&T and T-Mobile coverage areas. The Communications Arbiter was designed and

[18] http://www.gdal.org/
[19] http://www.imagemagick.org/
[20] http://mapnik.org/
[21] http://nationalmap.gov/elevation.html

developed to provide an assortment of communications options that have various data rates, speeds, and availabilities.

Sorted from low to high:

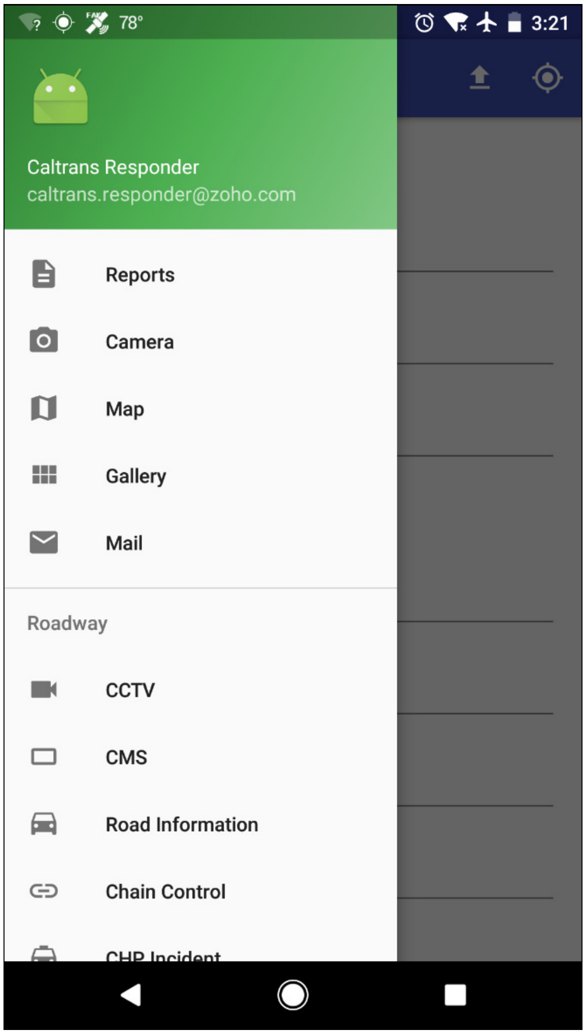
- Speed: Satellite → Cellular → Wi-Fi
- Cost: Wi-Fi → Cellular → Satellite
- Availability: Wi-Fi → Cellular → Satellite

The Communications Arbiter selects the optimal communications channel based on these factors, weighting functions, and rules set by the Responder system administrator. Other factors could also be incorporated into the arbitration algorithm. As implemented, the Communications Arbiter is extensible and can support future communications systems as they become available and make sense for Caltrans. This could include, for example, data communications over the 800 MHz radio, modems in the 700 MHz band, and in the Industrial, Scientific, and Medical (ISM) bands. The Communications Arbiter handles all communications between the various wireless backhaul systems and the Report and Feed Managers. In the current implementation, Wi-Fi is used only for communications between the Responder managers and the app—it is not used for Internet communications.

Human Machine Interface (HMI) App

The Responder HMI app runs on an Android tablet or smartphone. The tablet provides a better form factor, particularly for annotating photos and maps. The app is written in Java. There are seven primary screens: report list, report entry, gallery, maps, weather, roadway, and mail. Each screen includes an icon and name identifying the screen type, and a screen-specific menu to access configuration and any appropriate options. The app also includes a navigation drawer for quick access to the app's screens.

Navigation Drawer



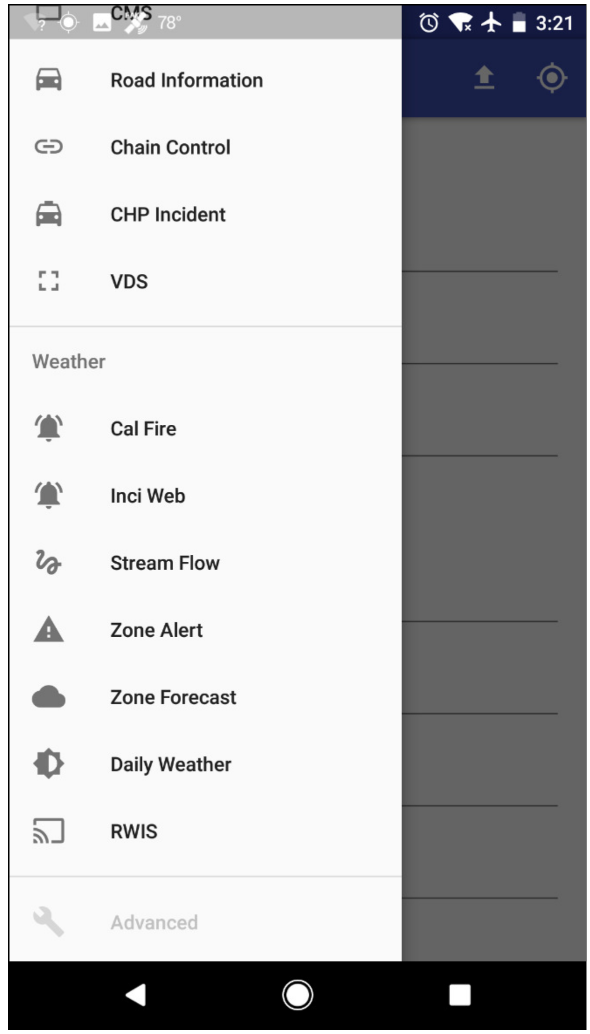


Figure 5.3: Responder app navigation drawer, top and bottom portions

The navigation drawer is a simple menu providing access to the app's other screens. The menu, as shown in Figure 5.3, includes Reports, Map, Gallery, Mail, Roadway, and Weather. This menu is available anywhere in the application by either swiping from the left side of the screen towards the center, or by clicking on the application icon (a.k.a. "the hamburger", three horizontal lines) in the upper-left corner of the screen. We found that a navigation drawer is the best choice for an app such as Responder, i.e. one with many functional views.

Reports Screen

The Reports screen provides a list of existing incident reports, identified by date and time (creation as well as last update), location (county/route/postmile), user, and organization. The user can select any existing incident report on the list in order to make changes or additions to that incident report. The user adds a new incident report by clicking the plus (+) sign in the lower-right corner of the screen. The Reports menu also supports sorting by user name, organization, location, creation time, and update time, all either ascending or descending. The Reports screen is shown in Figure 5.4. The Reports menu is shown in Figure 5.5. Finally, the same Reports screen, now sorted in ascending order by creation time, is shown in Figure 5.6.

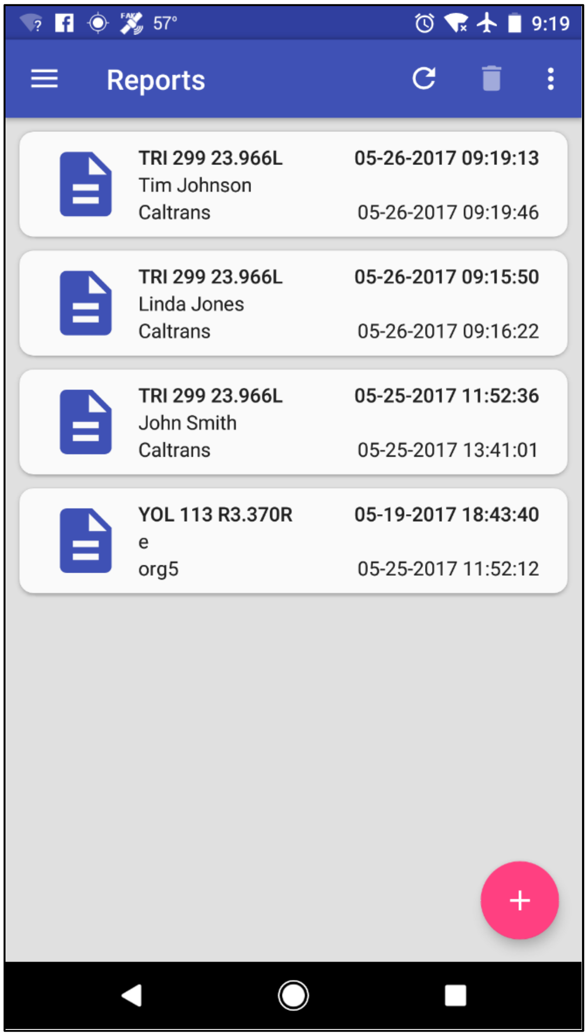


Figure 5.4: Reports screen

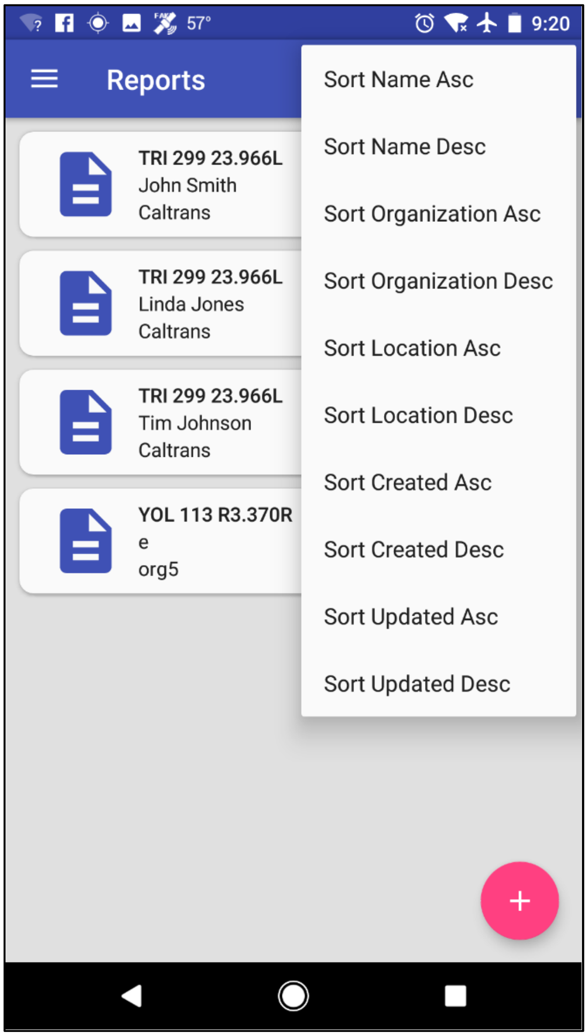


Figure 5.5: Reports menu

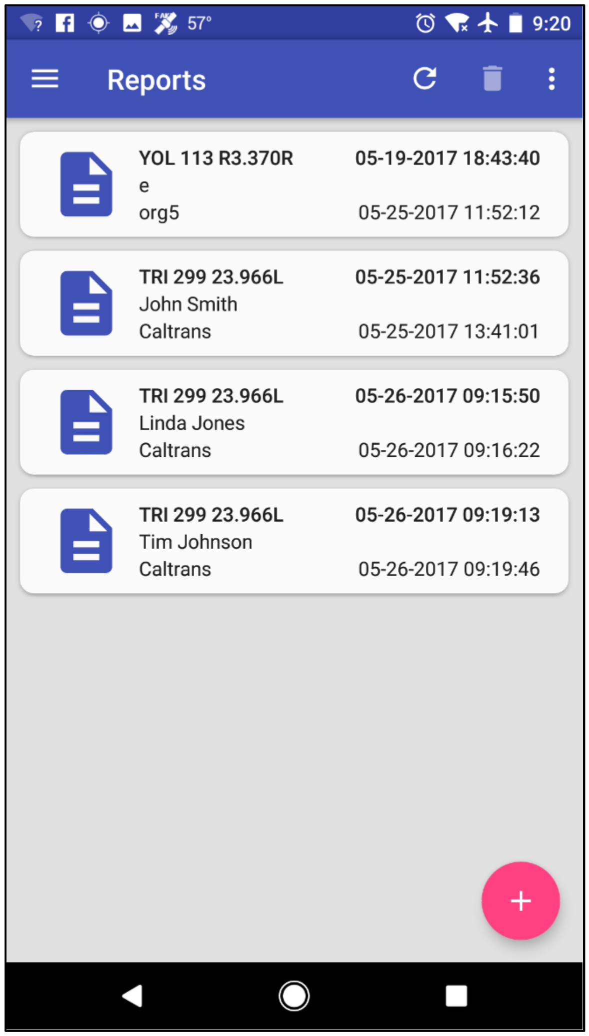


Figure 5.6: Reports screen, in ascending order by creation time

<u>Report Entry Screen</u>

The Report Entry screen is the heart of the Responder app. Here, the user inputs the primary information regarding an incident. Some fields on this screen are populated automatically, such as the latitude and longitude as provided by the included GPS sensor. Others, such as county/route/post mile, are also automatically populated—here, by mapping from latitude/longitude using a high-resolution geospatial database developed by AHMCT, including a data point approximately every 50 feet for every California highway. This mapping could normally be done using the existing Caltrans post mile web service; however, as Internet connectivity cannot be assumed for Responder, an on-board database was essential. The Report screen provides input fields for organization (including district), incident start and stop date and time, incident reporter, location note, infrastructure type, highway direction, lanes blocked, type of vehicles involved, type of incident, any special considerations (e.g. hazmat). The Report screen also has a free-form text field where the user can type in a detailed description of the incident. The user can also use voice entry with text recognition instead of typing. This approach has been tested in relatively quiet conditions, but has not been attempted in a noisy roadside environment. A sample Report Entry screen is shown in Figure 5.7 – 5.8. Options for infrastructure type, incident type, vehicle type, and special considerations are provided in Tables 5.1-5.4, respectively, while the corresponding screen dialogs are shown in Figures 5.9 – 5.10, respectively. Multiple selections can be made for each of these entries. These options were developed in close collaboration with the project TAG.

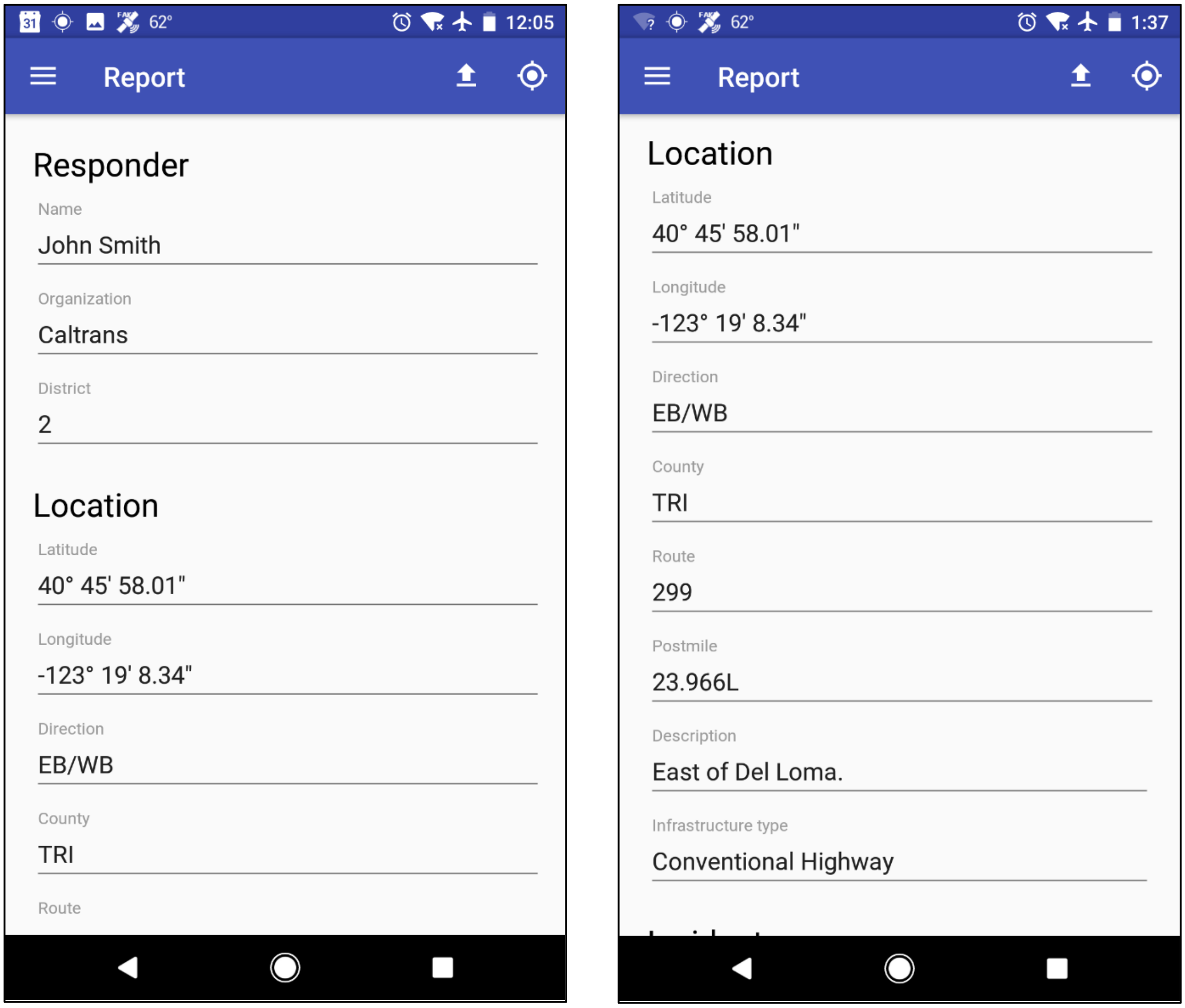


Figure 5.7: Sample Report Entry screen, part 1 and 2 / 4

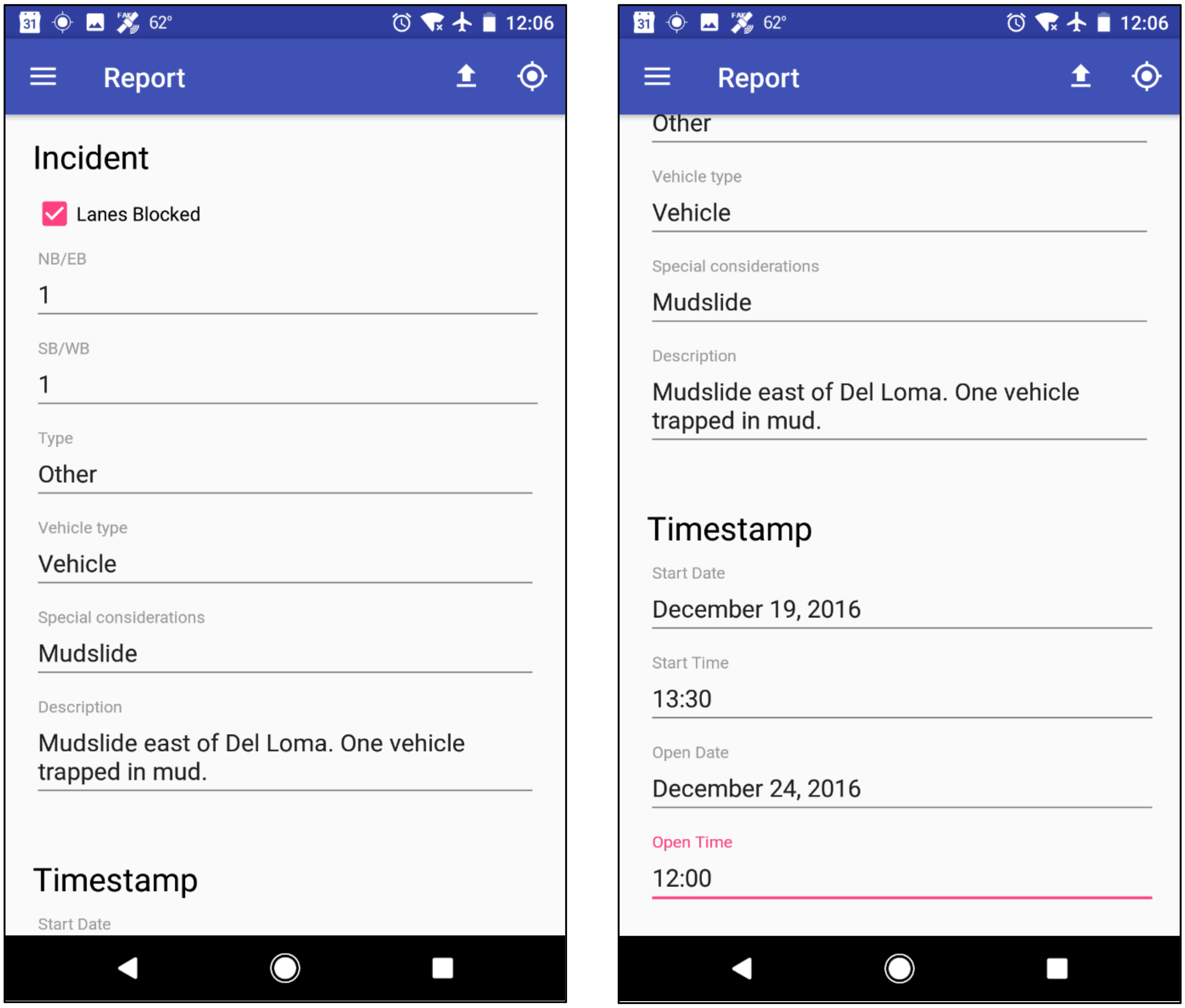


Figure 5.8: Sample Report Entry screen, part 3 and 4 / 4

Table 5.1: Options for infrastructure type on Report Entry screen

Bridge	Connector	Conventional Highway
Mainline	Off Ramp	On Ramp
Rest Area	Surface Street	Tunnel

Table 5.2: Options for incident type on Report Entry screen

Abandoned Vehicle	Accident Major Injuries	Accident Minor Injuries
Accident No Details	Accident Property Damage	Disabled Vehicle
Emergency Closure	Jumper	Possible Fatality
Vehicle Fire	Other	

Table 5.3: Options for vehicle type on Report Entry screen

Aircraft	Bicyclist	Big Rig
Bus	Motorcycle	Pedestrian
State Equipment	Trailer	Train
Truck	Vehicle	Other

Table 5.4: Options for special considerations on Report Entry screen

Avalanche	Bomb	Damaged Hybrid / Electric Vehicle
Dust	Fire	Flood
Fog	Gas Leak	Hazmat
Mudslide	Power Lines Down	Roadway Debris
Rockslide	Secondary Incident	Spilled Load
Other		

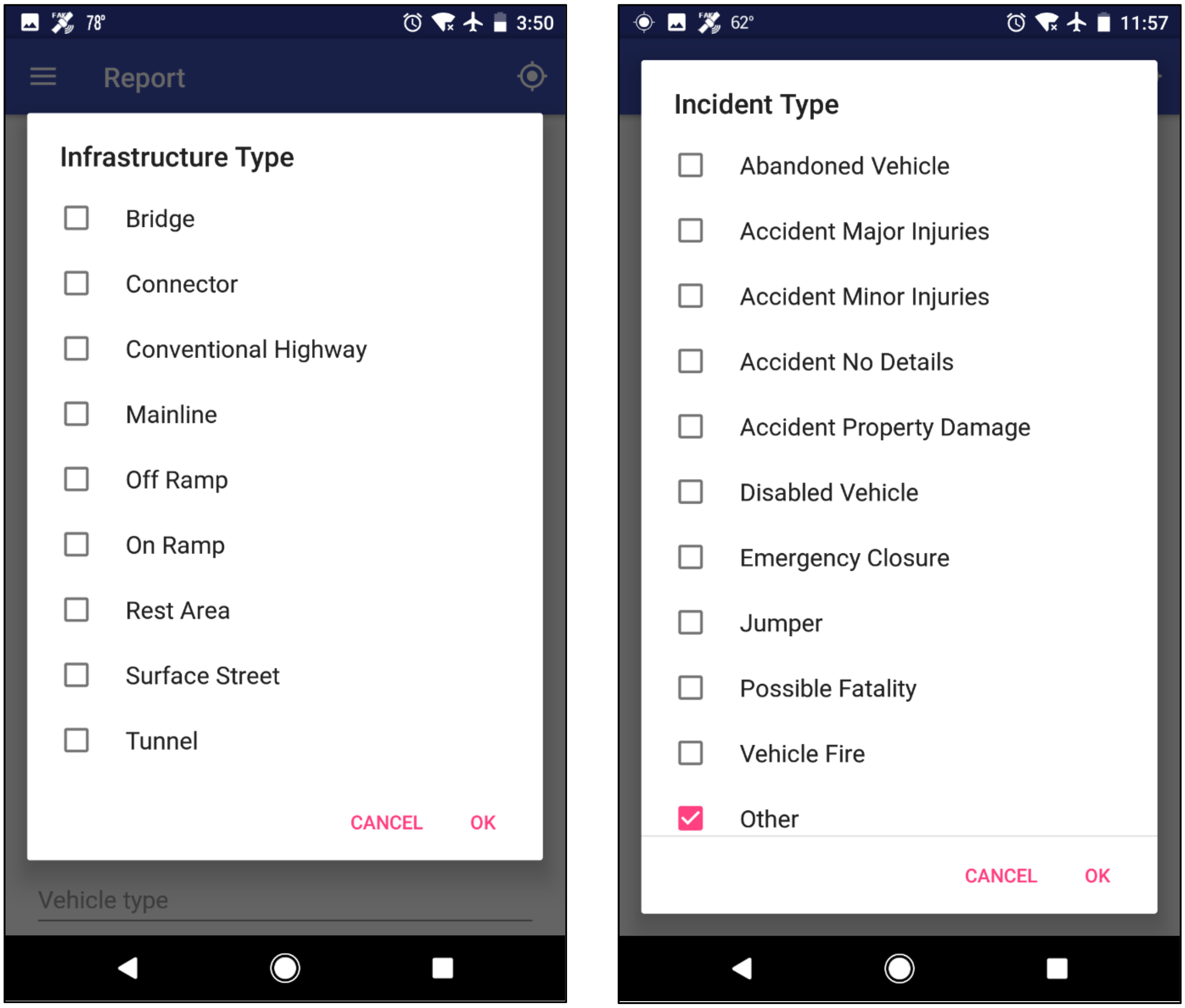


Figure 5.9: Infrastructure type (left) and Incident type (right) dialogs for Report Entry

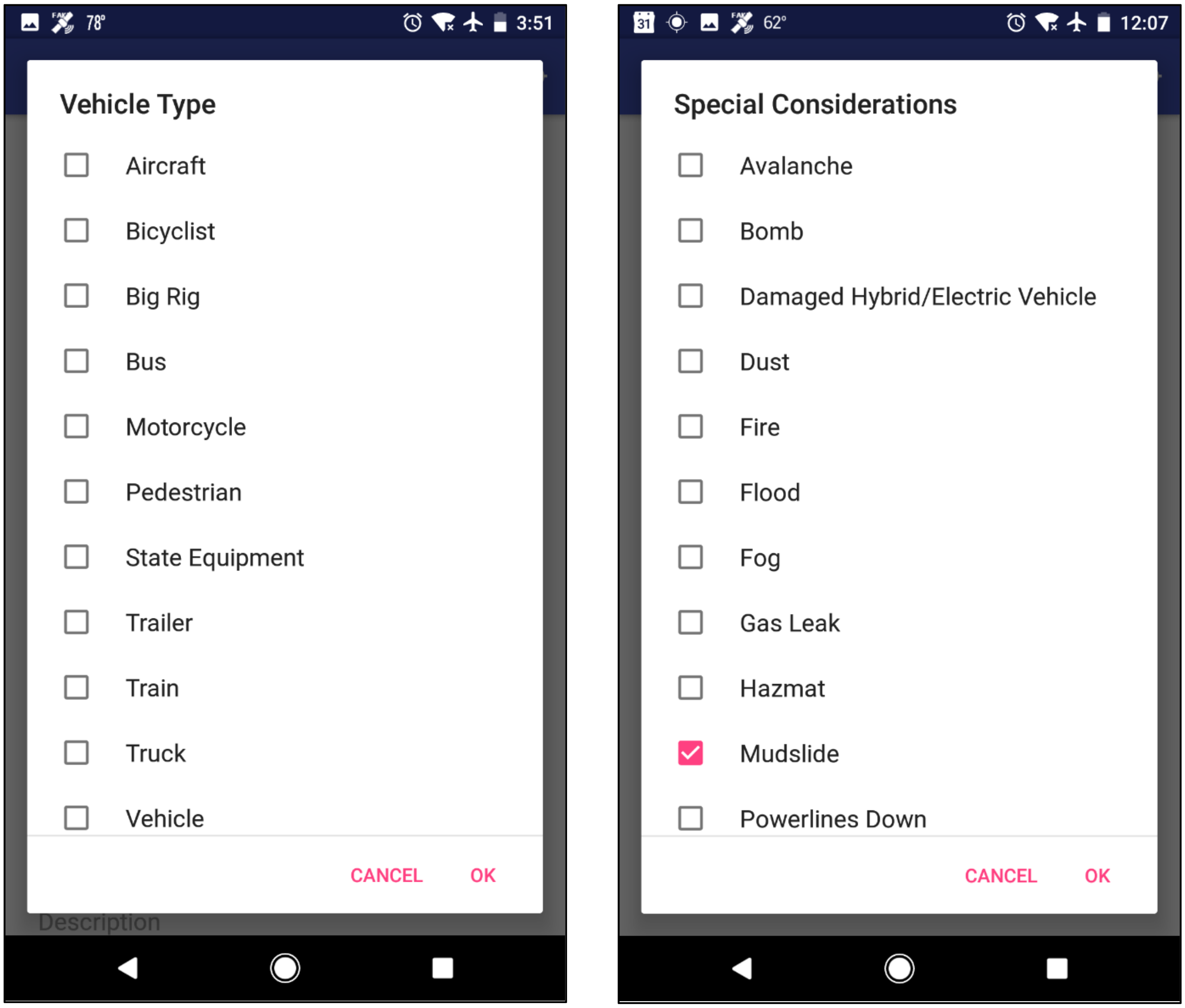


Figure 5.10: Vehicle type (left) and Special considerations (right) dialogs for Report Entry

<u>Gallery Screen</u>

The Gallery screen, as illustrated in Figure 5.11, is similar to those found in standard Android apps like the Gallery app and Google Photos. It provides thumbnails of all images related to this incident. This will include photos; snapshots of maps, aerial photos, and topo maps; and annotations of any of these. Once a user selects an image by clicking and holding, the user can annotate the image by clicking on the pencil icon near the upper-right corner. The counterclockwise and clockwise arrows support rotation of the selected images. The Gallery menu, shown in Figure 5.12, allows the user to delete one or more selected images.

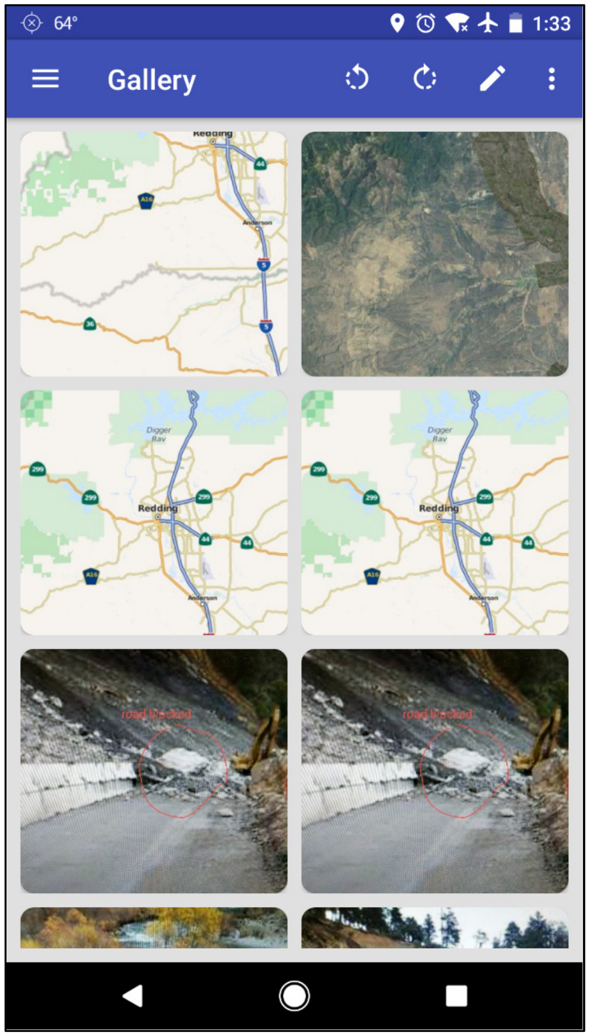


Figure 5.11: Sample Gallery screen

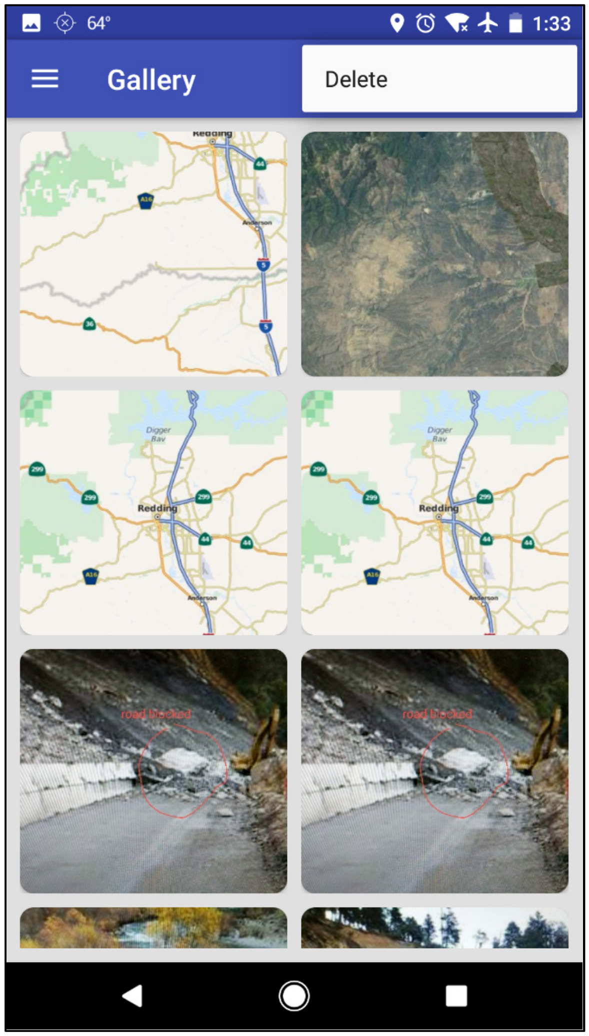


Figure 5.12: Gallery menu

<u>Map Screen</u>

The Map screen, shown in Figures 5.13 – 5.15, provides maps, with the initial view set by the current location of the user, and the default zoom level. The map view has three available modes: standard road map, aerial images, and topographic map. Figure 5.13 shows a road map. Figure 5.14 shows a topographic map. Finally, Figure 5.15 shows an aerial photo. The user chooses the view mode from the action menu. Zooming is done by the usual "pinch" gesture, as well as the "double-click-slide" gesture, as currently used on most smart devices. Panning is done via "swiping" gestures. The user can take a snapshot of the current map view and annotate the snapshot from the Gallery.

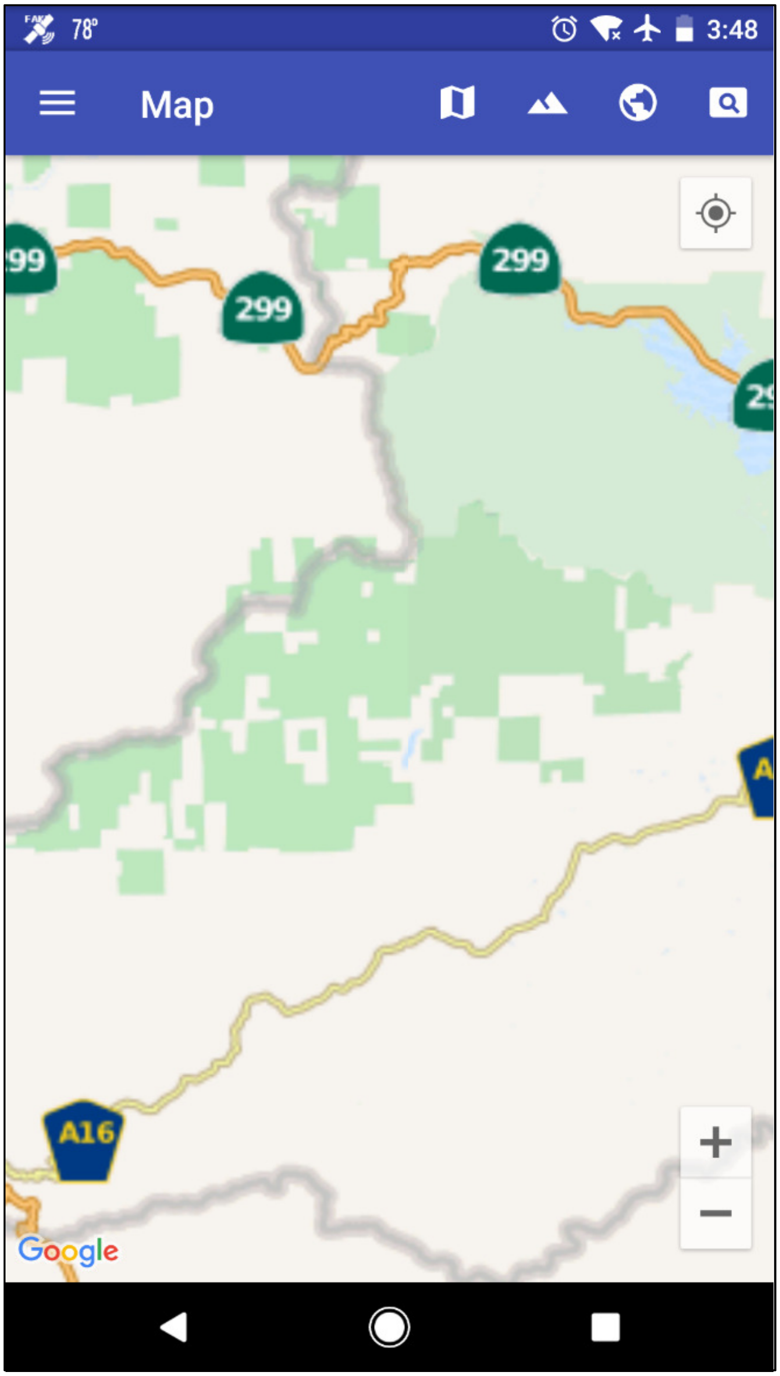


Figure 5.13: Sample Map screen, road map

Figure 5.14: Sample Map screen, topo map

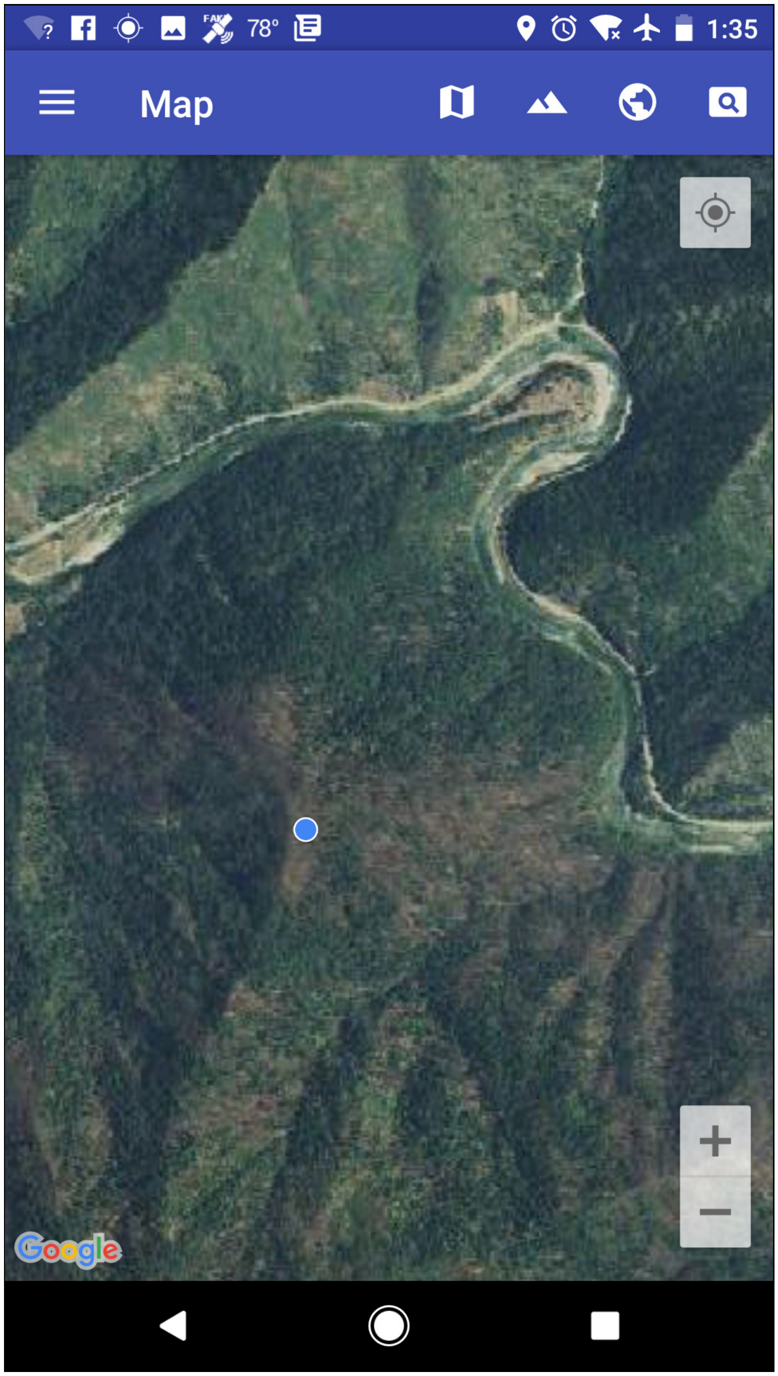


Figure 5.15: Sample Map screen, aerial photo

<u>Weather Screen</u>

The Weather screen, shown in Figure 5.16, provides a menu allowing the user to request the latest weather-related information. This includes weather, zone forecasts, zone alerts, RWIS data, projected stream flows, and wildland fires.

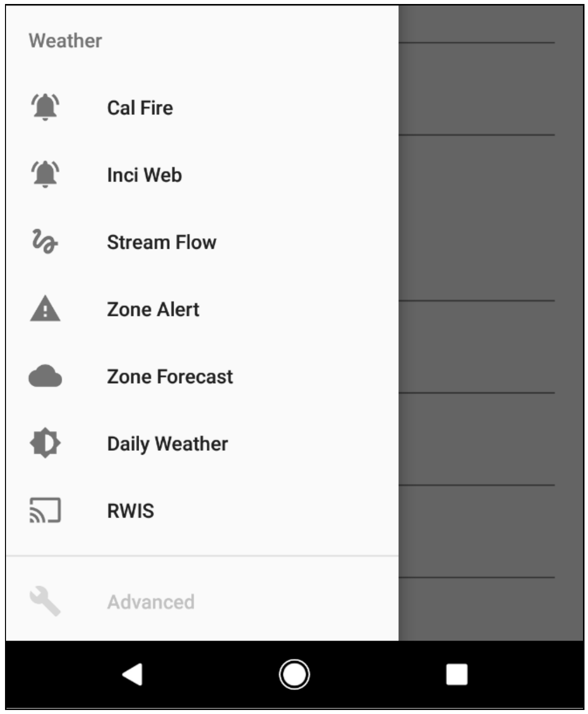


Figure 5.16: Weather screen

<u>Roadway Screen</u>

The Roadway screen, shown in Figure 5.17, provides essentially a menu allowing the user to request the roadway-related information. This includes chain controls where relevant, CHP Computer-Aided Dispatch (CAD) incidents, road information, road camera still images, and CMS messages. Roadway information is provided for all of California, as well as for approximately 30 miles over the border into neighboring states Arizona, Nevada, and Oregon.

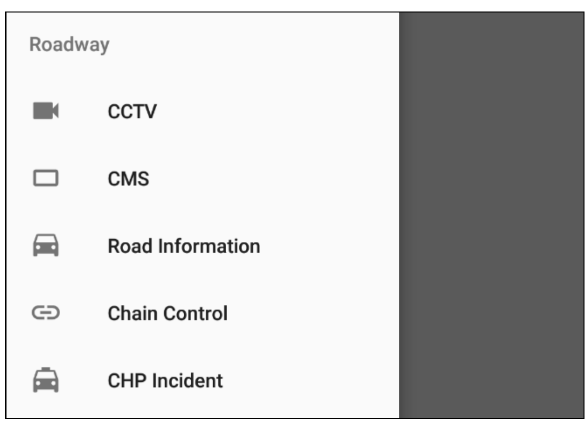


Figure 5.17: Roadway screen

Mail Screen

The Mail screen allows the user to preview the auto-generated incident report message, select recipients from a contact list, and send the message. The screen shows the message recipients, and a preview of the message body. This body is generated based on the user's inputs on the report screen. The preview also shows any images that will be attached, based on the user's selections on the gallery screen. To add recipients, the user clicks on the "Recipients" field, and selects from the contact list. Finally, assuming that the message is as the user intended, they can send it by pressing the send button, i.e. the right-facing triangle near the upper-right. See Figure 5.18 for a sample Mail screen. The contact list, which allows selection of multiple contacts, is shown in Figure 5.19. The app includes a configurable default contact list. The inbox entry for the received email is shown in Figure 5.20. The resulting received email report is shown as it appears in Microsoft Outlook in Figure 5.21, and in Mozilla Thunderbird in Figure 5.22. Note that the exact appearance of the received email is email client-dependent. For example, notice the difference in attachment display between Figures 5.21 and 5.22. As Caltrans has standardized on Outlook, this will not bne an issue unless other agencies are included as recipients.

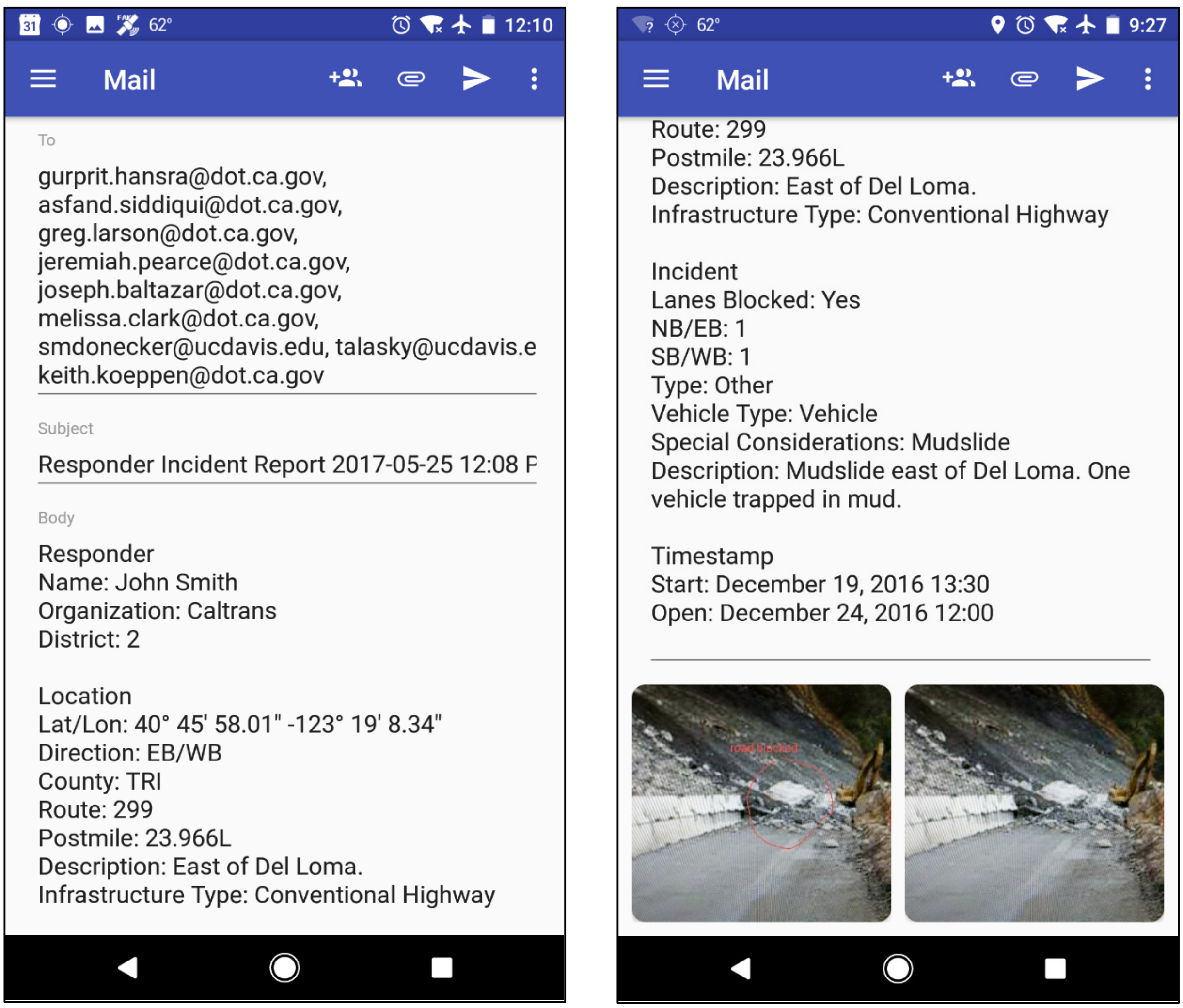


Figure 5.18: Sample mail screen

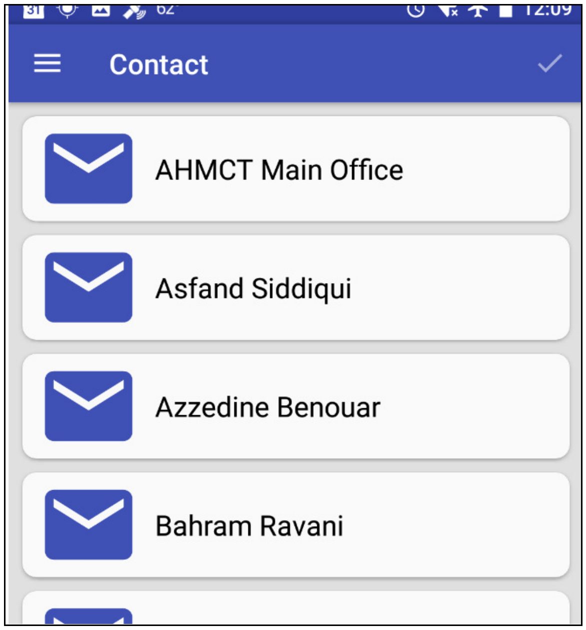


Figure 5.19: Contact list

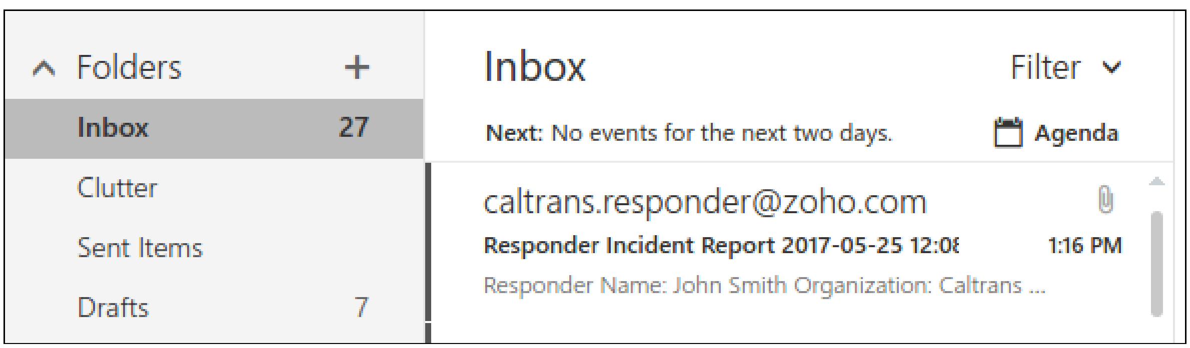
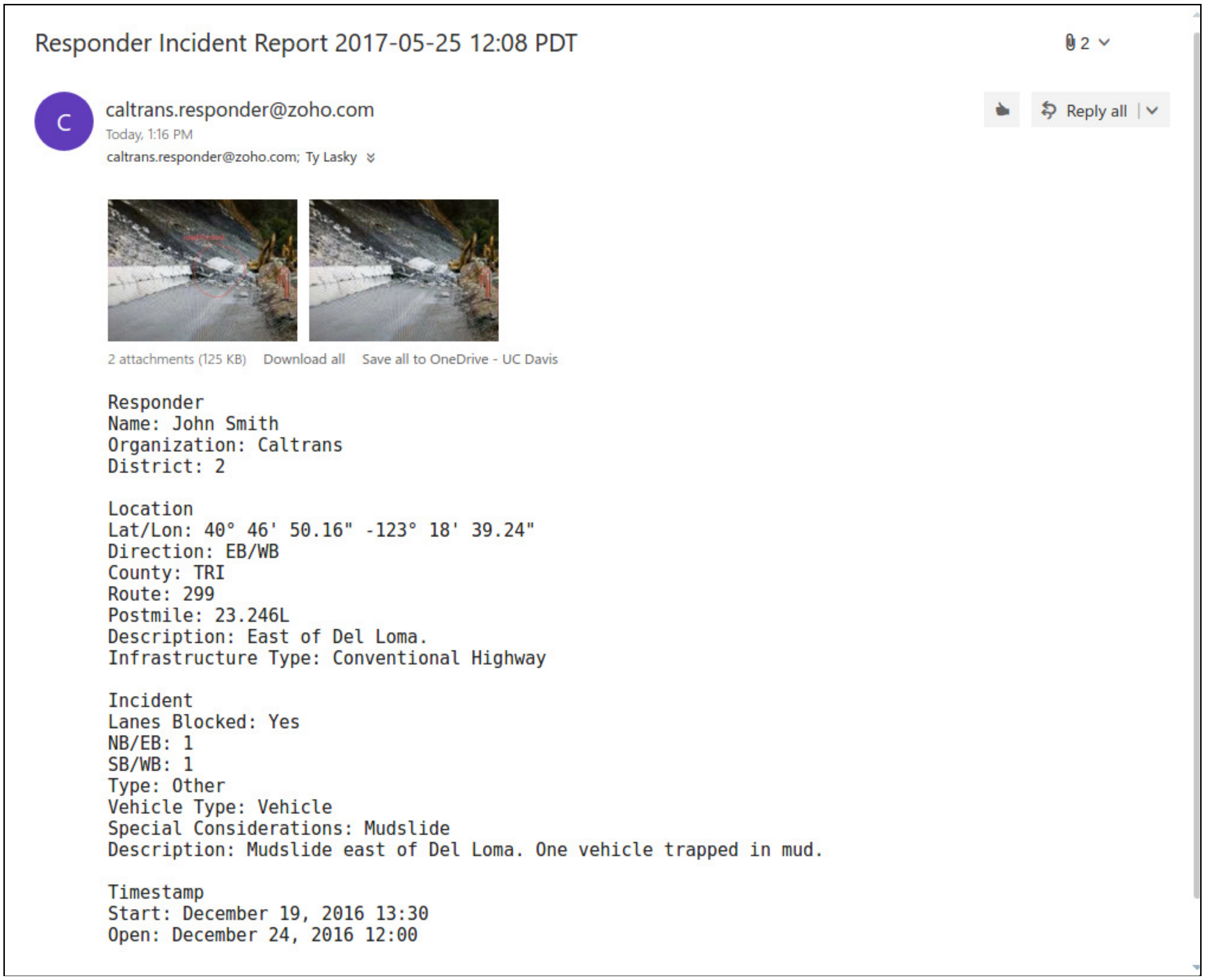


Figure 5.20: Example received email inbox entry



Responder Incident Report 2017-05-25 12:08 PDT

caltrans.responder@zoho.com
Today, 1:16 PM
caltrans.responder@zoho.com; Ty Lasky

Reply all

2 attachments (125 KB) Download all Save all to OneDrive - UC Davis

Responder
Name: John Smith
Organization: Caltrans
District: 2

Location
Lat/Lon: 40° 46' 50.16" -123° 18' 39.24"
Direction: EB/WB
County: TRI
Route: 299
Postmile: 23.246L
Description: East of Del Loma.
Infrastructure Type: Conventional Highway

Incident
Lanes Blocked: Yes
NB/EB: 1
SB/WB: 1
Type: Other
Vehicle Type: Vehicle
Special Considerations: Mudslide
Description: Mudslide east of Del Loma. One vehicle trapped in mud.

Timestamp
Start: December 19, 2016 13:30
Open: December 24, 2016 12:00

Figure 5.21: Example received email report as it appears in Microsoft Outlook

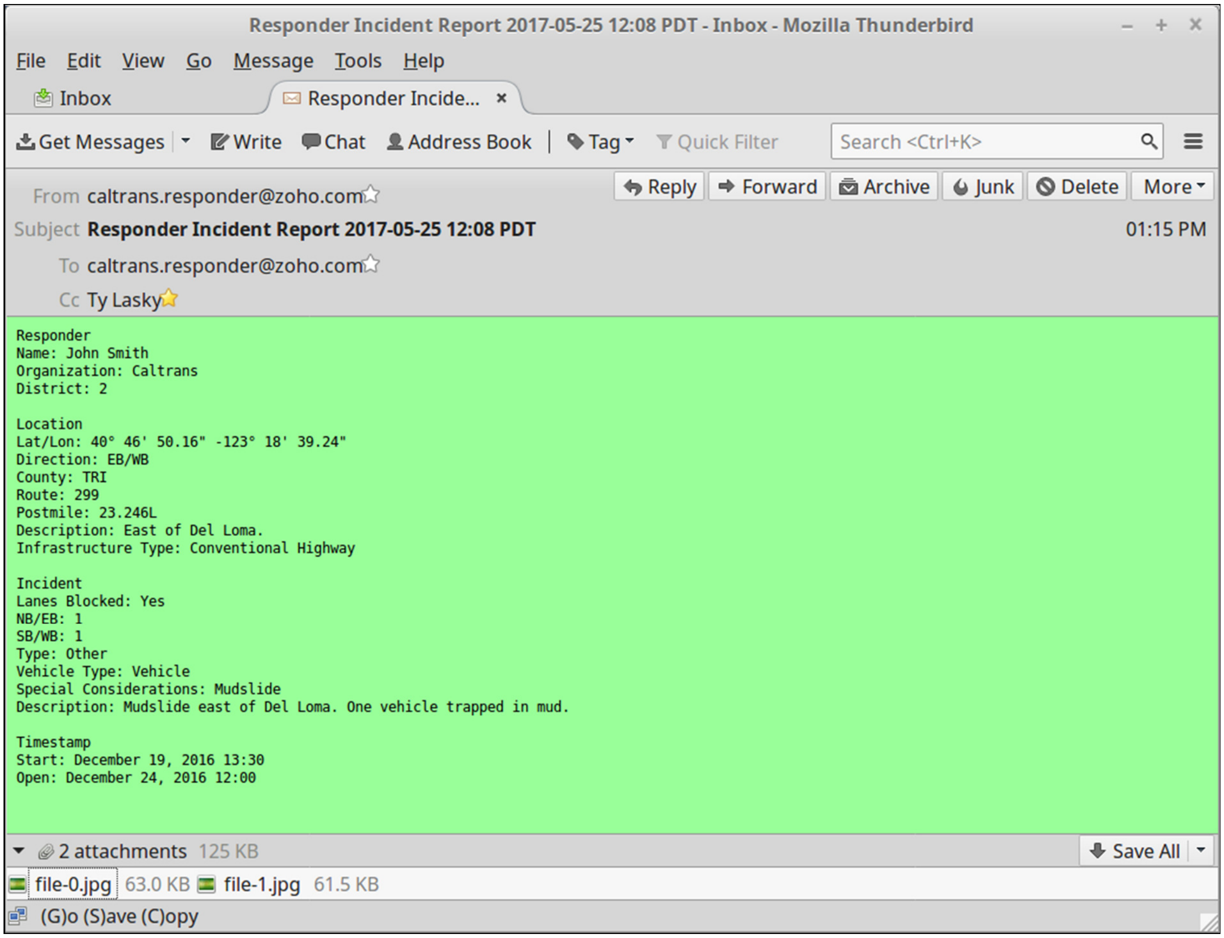


Figure 5.22: Example received email report as it appears in Mozilla Thunderbird

Hardware

HMI

The Responder HMI app will run on Android tablets and smartphones running Android version 7.0 and higher and has specifically been developed and thoroughly tested on a Google Nexus 6 smartphone and a Google Nexus 9 tablet. The Responder HMI app was also tested on a Google Pixel smartphone. Based on image and map snapshot annotation, the tablet form-factor is preferred. The Responder test system includes a Google Nexus 9 tablet. A screen shot from this tablet's home page is shown in Figure 5.23.

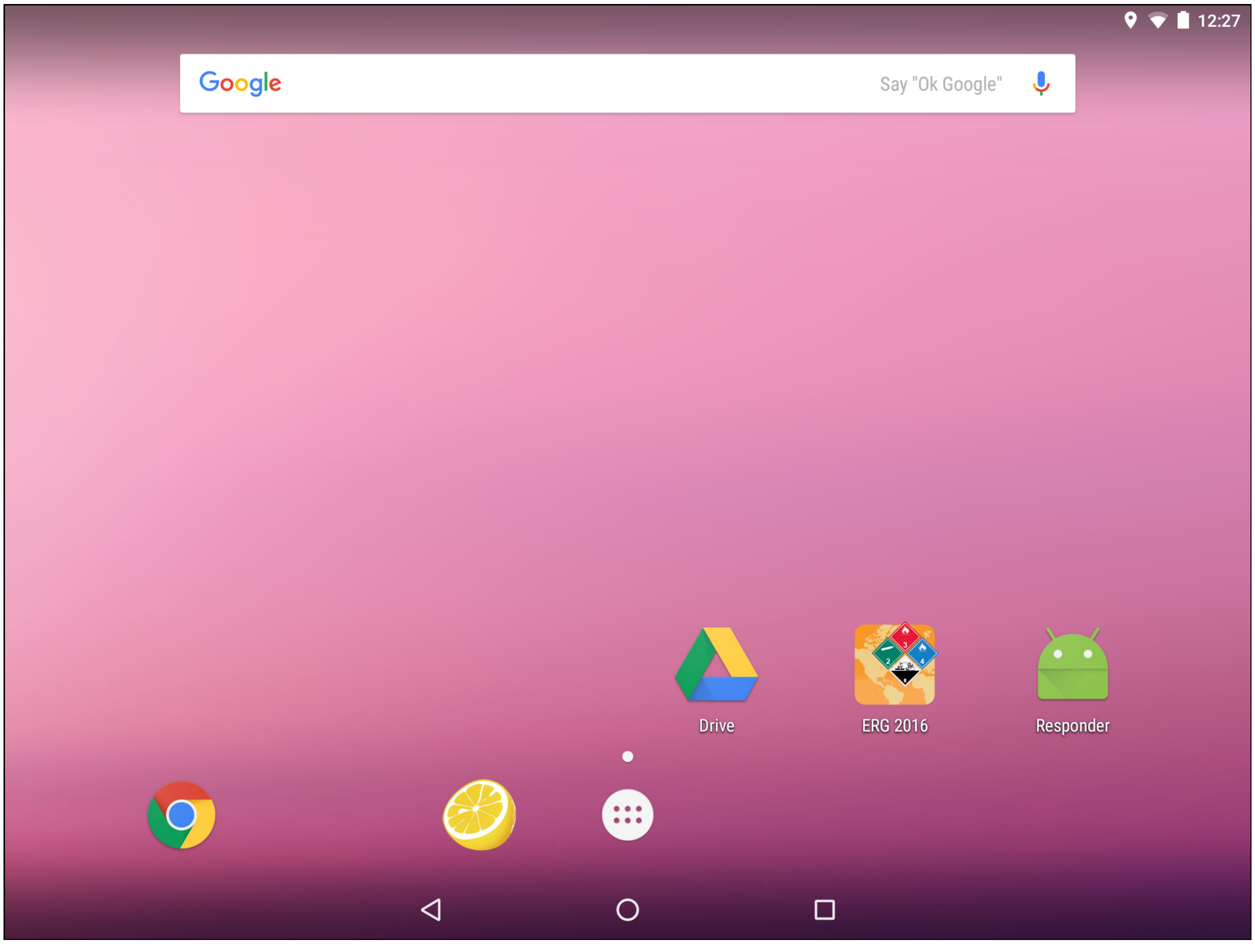


Figure 5.23: Responder HMI tablet screen shot, including icons for the Responder app and the ERG 2016 app for hazmat info

System Box

The Responder System box incorporates all of the COTS electronics into a tightly-integrated, commercially-manufactured case. The box contains a Sierra Wireless GX450 cellular modem employing Verizon service. The modem is also compatible with AT&T service, the Linux-based system embedded computer (Logic Supply Nuvo-3100VTC embedded computer with i7 / 1 TB / 4-port switch), and the satellite transceiver electronics. The box was designed by AHMCT to fit these components, provide environmental protection including cooling, and integrate well into the Responder test vehicle, a Caltrans 2014 Dodge Ram Quad Cab (C# 7009878). The case was manufactured to our design by Protocase.[22] The manufactured cases are quite cost-competitive vs. manually customizing a generic case, and the quality is significantly higher. Figures 5.24 and 5.25 show the internals of the system box, and the system box mounted in the vehicle, respectively. Figure 5.24 shows the satellite modem (Hughes 9450-C11 BGAN), cellular modem (Sierra

[22] http://www.protocase.com

Wireless GX450), and system computer (Neousys rugged Intel Ivy Bridge compact in-vehicle computer).

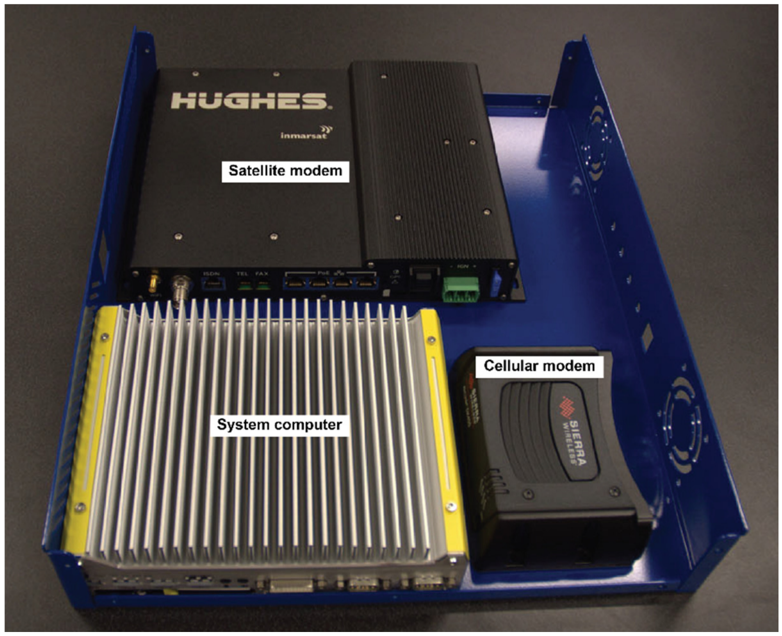


Figure 5.24: Responder system box internal view

Figure 5.25: Responder system box mounted under right rear seat in vehicle

Satellite Communications

The satellite communication is provided by a Hughes 9540-C11 BGAN mobile satellite terminal. This system includes a satellite antenna which is mounted on the light bar above the roof (see Figure 5.26), and the transceiver incorporated into the Responder system box (see Figure 5.24). The antenna autonomously tracks the geostationary Inmarsat BGAN satellite. Note that the Hughes 9540-C11 BGAN mobile satellite terminal has not been designed or tested for mobile operation in the Responder system, i.e. it should only be used when the vehicle is stationary. The system supports up to 464 kbps shared data rate and 128 kbps streaming IP (Internet Protocol). Hughes provides further information including technical specifications.[23] Satellite communication will generally be the last choice for the Responder system, as it is slower and more expensive than cellular; however, satellite communications should be available as long as there is line-of-sight to the satellite. Caltrans has expressed concerns about rain fade—this issue must be addressed in more extended field testing.

Figure 5.26: Satellite antenna mounted on vehicle light bar

For optimal satellite communication for the vehicular Responder system, it is important to park the truck at or near an optimal heading for a given district. In general, the truck should be parked pointing approximately southeast (135 degrees). For a more precise heading, the truck should be parked according to the azimuth angle in Table 5.5.

[23] http://www.hughes.com/resources/hughes-9450-c11-flyaway-system-data-sheet/download

Table 5.5: Truck heading for optimal satellite communication in each Caltrans district for the Inmarsat 4-F3 (Americas)[24]

District	Elevation (degrees)	Azimuth (degrees)
1	35.5	128.0
2	36.6	130.3
3	38.9	130.9
4	39.2	129.5
5	42.3	130.7
6	41.4	132.8
7	44.7	133.9
8	45.1	135.5
9	41.5	135.1
10	39.5	131.0
11	46.5	135.0
12	45.2	134.5

Cellular Communications

Cellular communication is provided by a Sierra Wireless AirLink GX450 LTE (Long-Term Evolution) cellular modem (see Figure 5.27), incorporated into the system box (see Figure 5.24). This modem has been used by AHMCT in similar projects, and has been quite reliable. The cellular antenna is shown in Figure 5.28. Cellular communication uses Verizon service. As discussed in Appendix C, AHMCT has performed a cellular signal coverage and strength survey over all snow-affected routes in California, which provides a very good representation of performance for the rural and semi-rural areas targeted for Responder use. Throughout the areas surveyed, Verizon almost uniformly provided better coverage and signal strength. For future implementation, Caltrans could opt to incorporate multiple cellular modems using diverse service providers. Based on our survey data, this option was not pursued in the test system.

[24] www.dishpointer.com

Figure 5.27: Responder system cellular modem

Figure 5.28: Responder system diversity antenna on right side of the vehicle light bar. This incorporates antennas for Wi-Fi, cellular, and GPS.

Wi-Fi Communications

For communications between the Responder system box and the HMI, Responder uses Wi-Fi. The system box includes Expansion 2.4 GHz Wi-Fi cards (see Figure 5.29). The Wi-Fi supports the Institute of Electrical and Electronics Engineers (IEEE) 802.11b/g/n protocols. To provide long range, the router uses a high-gain Wi-Fi antenna incorporated in the diversity antenna shown in Figure 5.28. This arrangement meets the system requirement of at least a 200 feet range for the responder to operate away from the vehicle. Typically, the range is much longer.

Figure 5.29: Responder system Wi-Fi card installed inside the Responder computer system (Logic Supply Nuvo-3100VTC embedded computer)

Portable Responder System

As part of its vision for the Responder system, Caltrans expressed interest in a portable version of Responder that could be used independently of a vehicle. In the current research, AHMCT designed implemented such a portable Responder system. For maximum cost efficiency as well as flexibility in field operation and support, AHMCT designed the portable Responder to use the exact same components as the vehicle-based Responder system, to the extent possible. The same Responder system box components noted above are integrated into a Pelican case for environmental protection and for portable convenience. In this implementation, there is no system box case; rather, the components are integrated directly inside the Pelican 1550 case. The case contains the necessary antennas (satellite antenna and integrated cellular, GPS, and Wi-Fi antenna) including magnetic mounts, and cabling, for ease of use and portability. The portable Responder system can be powered from a 12-volt charger receptacle or a direct connection to a vehicle battery. This would make it easier for Caltrans to share a small number of portable Responder systems among multiple districts (perhaps within each region), as opposed to having vehicle-integrated systems which must stay with the vehicle "owned" by an individual district. Other power options may be used with the portable Responder system, including a generator, rechargeable batteries, etc. Each power option must be considered for anticipated Caltrans operations vs. that approach's pros and cons (e.g. weight, emissions, and vehicle dependence). The portable system components were procured during this research. The portable Responder system stored in its ruggedized case is shown in Figure 5.30. The deployed portable Responder system is shown in Figure 5.31.

Caltrans requested a method for securing the portable Responder system. One tentative approach for Caltrans consideration and validation is shown in Figure 5.32. This method is not guaranteed to secure the system. The method has not been tested for any level of crashworthiness. AHMCT does not have facilities or resources required for such testing. Prior to Caltrans relying on this method, AHMCT strongly recommends that Caltrans validate the method's crashworthiness, or that Caltrans has the method validated by a third party.

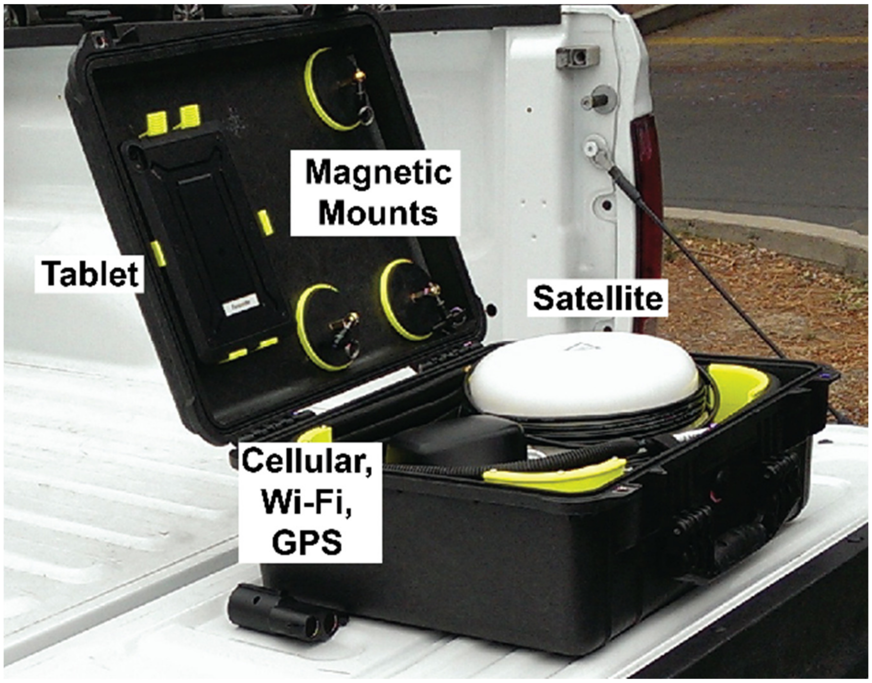


Figure 5.30: Portable Responder system in its ruggedized case

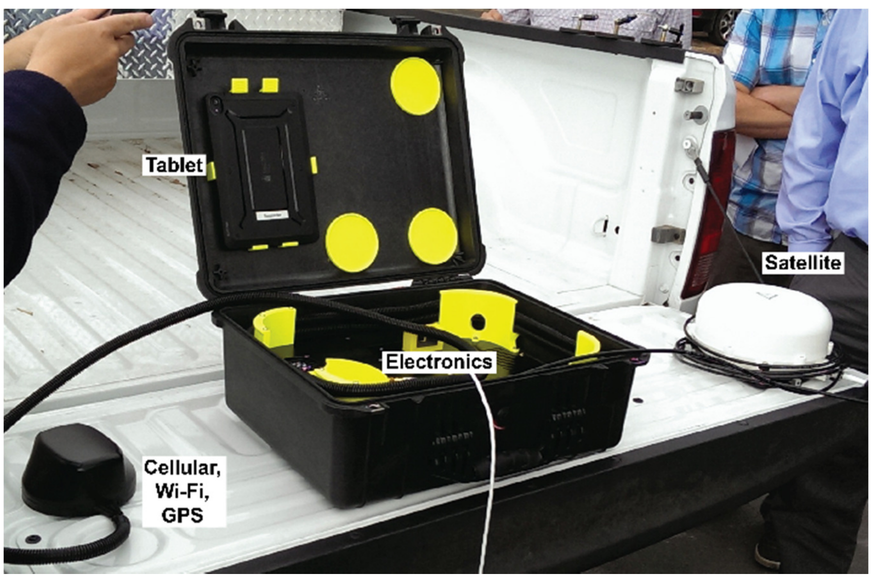


Figure 5.31: Portable Responder system deployed

Figure 5.32: Tentative method for restraining the Portable Responder system

CHAPTER 6:
RESPONDER SYSTEM INSTALLATION

For this project, the in-vehicle Responder system was installed on a Caltrans supervisor truck, a 2014 Dodge Ram Quad Cab pick-up truck (C# 7009878). This system was graciously provided by Caltrans District 6. Front, side, and rear views of the truck before installation are shown in Figures 6.1 – 6.3. The Responder truck's rear seat area is shown in Figure 6.4.

Figure 6.1: Responder truck before installation: front view

Figure 6.2: Responder truck before installation: side view

Figure 6.3: Responder truck before installation: rear view

Figure 6.4: Responder truck rear seat area before installation

The in-vehicle Responder system was designed to be tightly integrated, yet also able to be fairly easily installed in the range of Caltrans supervisor vehicles. All Responder component installations will vary depending on the vehicle configuration. The installation under this research is considered fairly typical and representative. The in-vehicle system box, manufactured by Protocase, as implemented for the test vehicle in the current research was designed to fit under the right rear seat of the Dodge Ram Quad Cab. This dictated the maximum outer dimensions of the case. It also had implications on the system's thermal management. If Responder is installed on a different type of supervisor vehicle, it may be necessary to revise case dimensions. The case layout is based on the system components selected (see Chapter 5), and any case design must accommodate these components, and provide appropriate mounting and ventilation along with fans for thermal management. The case must also fit in the target location. The system box installation location without the box is shown in Figure 6.5, and with the box in Figure 6.6. The system box is secured using the frame below the seat; as such, no mounting holes are drilled in the vehicle floorboard. In fact, no holes or permanent modifications to the vehicle were ever made during installation.

The Responder system is powered by the vehicle and is controlled by the ignition switch and a system cutoff switch located near the bottom of the vehicle center console. It is recommended that the Responder system only be used when the vehicle is running. Additionally, there are use cases where the vehicle operator may want to disable the Responder system, thus necessitating the cutoff switch.

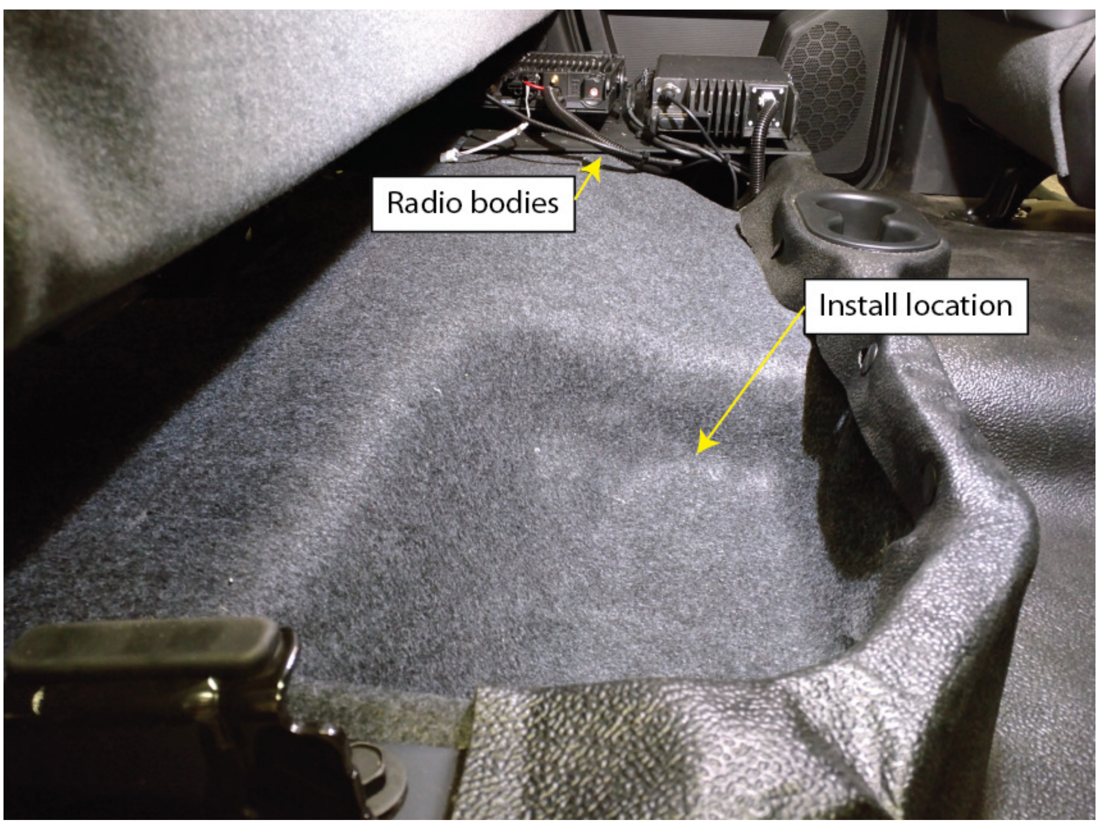


Figure 6.5: Responder system box in-vehicle install location

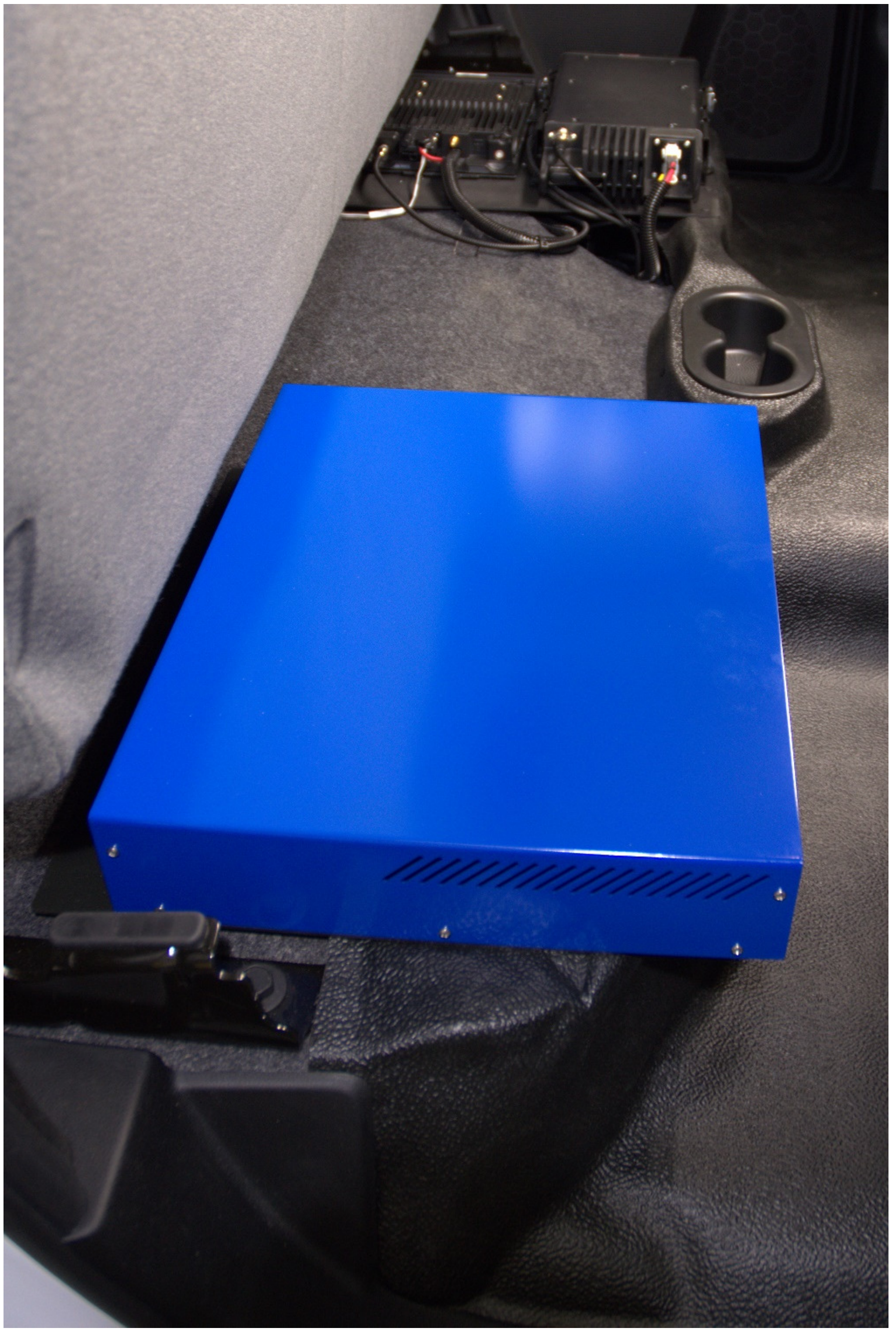


Figure 6.6: Responder system as installed in the vehicle

The antenna installations are shown in Figure 6.7. The vehicle's voice radio antennas are seen at the left (permanent mount) and attached to the center of the roof of the vehicle. While these radios and antennas are not part of Responder, there is always the possibility of Radio Frequency (RF) interference between the systems. The RF interference issue must be addressed in the integration design, and tested as part of installation. The Responder satellite antenna is mounted in the center of the truck's light bar. The diversity antenna incorporates a long-range Wi-Fi antenna, a cellular antenna, and a GPS antenna, all mounted on a ground plane at the right side of the light bar. By using the standard Caltrans light bar mount for Responder antenna mounting, no holes are drilled in the vehicle body. In addition, the antenna mounting hardware will be compatible with most Caltrans trucks with similar light bar mount installed as a standard package. The "universal" antenna mounting hardware design is an important consideration for Caltrans.

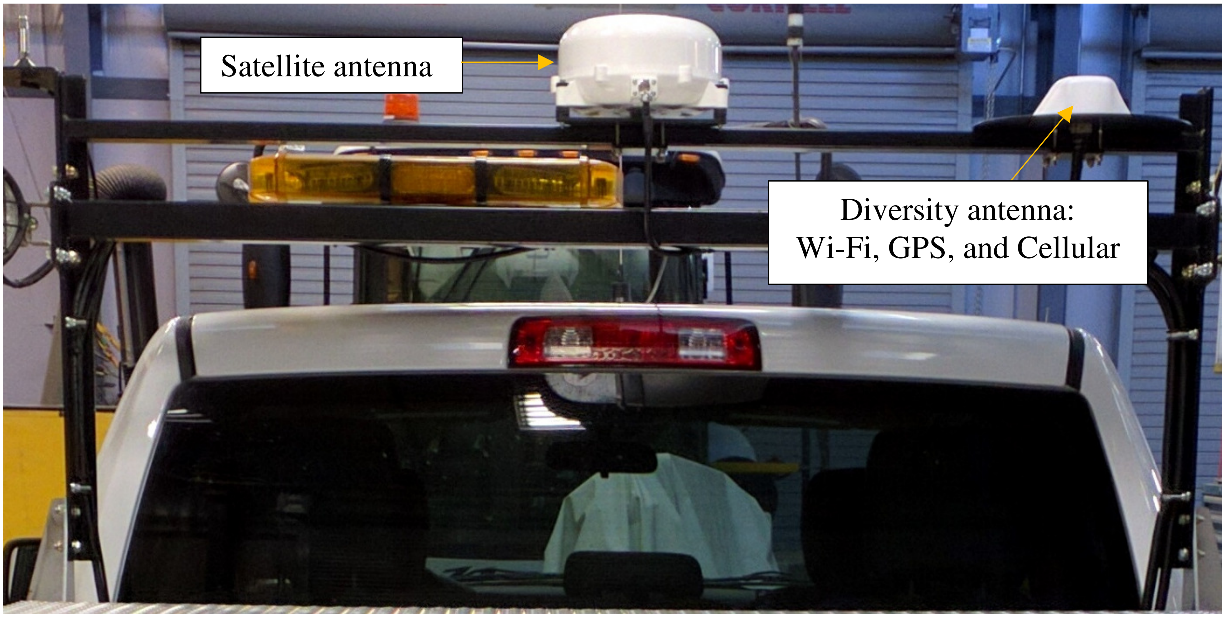


Figure 6.7: Responder system antennas

CHAPTER 7:
SYSTEM TESTING AND DEMONSTRATION

Under the current research, the Responder system components were tested in-house by AHMCT. The complete system was also tested by AHMCT. The Responder system as developed and tested by AHMCT provides all of the essential functionality, and meets the extensive system requirements. The system was demonstrated to Caltrans on several occasions (see Figure 7.1), and is ready for detailed field testing by the Caltrans district. Such further verification testing by Caltrans personnel is needed in order to fully assess the viability of Responder for implementation in Caltrans. This testing is in progress under a follow-on research project that allows month-long test periods in each of the four participating Caltrans districts (2, 3, 4, and 9).

Figure 7.1: Responder system demonstration to Caltrans personnel

Radio Measurements

Radio frequency (RF) interference is an important consideration in the design of any complex communications system. Responder certainly falls into this category. The Responder system includes Wi-Fi communication between the vehicle and the HMI, along with cellular and satellite communication. In addition, the vehicle includes two radios, a high-band system at 800 MHz and a low-band system at 47 MHz. The two radios are not part of the Responder system, but must coexist with it. The Responder communications systems, by their design, should not interfere with each other, and should present no interference to the vehicle radios. However, there is concern regarding interference from the vehicle radios to the Responder communications systems. The most vulnerable Responder subsystem is the satellite communications antenna with its very sensitive receiver. Caltrans users, in the past, have seen interference from high-band truck radios to prior versions of the antenna used in the satellite system. Such interference can completely overwhelm the satellite system front-end, rendering communications impossible. Since the satellite system is the last-resort communications option for Responder, this is an important consideration.

The radios were installed in the Responder truck by the California Office of Emergency Services (OES). Antenna locations are shown in Figure 6.7. In-vehicle install of the radio head units is shown in Figure 7.2, with the radio body installations under the rear seat shown in Figure 7.3. Upon installation, OES measured the RF output for both radios, and impedance match between the installed antenna and the radio was verified to be within specification. In addition, the center frequency and bandwidth of each antenna was measured and verified.

Figure 7.2: In-vehicle radio head install

Figure 7.3: In-vehicle radio body install

Mitigation of Radio Frequency Interference

When transmitting, the 800 MHz radio has spurious emissions which are approximately 70 dB below the transmit signal power. To keep these emissions from interfering with the satellite receiver in the frequency range of 1518 – 1559 MHz, we have employed an in-line band pass filter at the output of the radio. We specified and ordered a cavity band pass filter from K&L Microwave with a center frequency of 838 MHz, pass band of 64 MHz, insertion loss of 0.15 dB, and a stop band attenuation of 80 dB at 1525 MHz. This band pass filter easily installs into the radio system by disconnecting the antenna cable from the radio, adding a short pigtail from the radio to the band pass filter, and then connecting the antenna cable to the other end of the filter.

CHAPTER 8: CONCLUSIONS AND FUTURE RESEARCH

Key contributions of this research project included:

- Migration of the Responder system to the latest computing and communications technologies, including smartphone and tablet systems
- Design and development of Phase III Responder system
- System testing by AHMCT, including reporting.

The use of the Responder system is expected to enhance Caltrans first response capabilities by providing needed information to responders, and allowing responders to report on the scene and the incident to others in the organization. This will lead to increased safety for Caltrans personnel, improved safety and mobility for the traveling public, and enhanced resource utilization.

The Responder system redesign and development has led to a system that is ready for extended field testing by Caltrans. Caltrans and AHMCT are executing a follow-up study for the Responder system. The focus of this study is one-month extensive field testing periods by each of the four participating Caltrans districts (2, 3, 4, and 9). Each district will have the Responder system for a one-month period to allow the opportunity for comprehensive field testing. The mix of districts and timeframes will provide rural, semi-rural, and urban testing in a wide range of environmental conditions. It is anticipated that this testing will identify some bugs, and will also lead district personnel to request additional features or enhancements. AHMCT will address these in the study. The goal of the study is to provide Caltrans with a field-ready system to support first responders in rural environments, in a manner that is also effective in urban scenarios.

Following Caltrans field testing, it is expected that the Responder system will be ready for full-scale implementation. The hardware components are all COTS, and have been tightly integrated in a design well-suited to Caltrans supervisor vehicles. The HMI hardware is based on COTS tablets and/or smartphones. Communications systems and services are COTS, and can easily be procured for additional systems. The Responder hardware design is well-suited for either 3rd-party installation or in-house installation by Caltrans DOE. The custom Responder software (both managers and HMI app) has been developed to meet Caltrans' Responder requirements, and can be adapted as future needs arise. Software installation is a relatively straight-forward process, and is well-suited for broader implementation. District-specific configuration is also intuitive and well-documented.

The Responder system was developed over three phases, with initial development by WTI, and final development and implementation by AHMCT. It was designed specifically for Caltrans' requirements. However, the architecture and implementation of Responder is quite flexible. Responder capabilities would be very useful to any DOT. In fact, variations on the Responder system would be extremely useful for other agencies, e.g. public safety (CHP and similar), fire, and similar first responder agencies. Responder could be adapted and/or extended for application in any of these agencies. AHMCT recommends consideration of a pooled fund study for National use of Responder in DOTs, or, more broadly, in first responder agencies. Short of such a pooled fund study, adapting Responder for a specific agency or state's needs would be a logical next step.

REFERENCES

1. S. Donecker, K. Yen, B. Ravani, and T. Lasky, "Mobile Real Time Information System for Snow Fighter Supervisors - System Design & Test," AHMCT Research Center Rept. # UCD-ARR-15-09-30-01, 2015.
2. S.M. Donecker, T.A. Lasky, and B. Ravani, "A Mechatronic Sensing System for Vehicle Guidance and Control," *IEEE/ASME Transactions on Mechatronics*, **8**(4): pp. 500-510, 2003.
3. D.E. Galarus, L.A.F. Koon, and D. Richter, "Redding Responder Business Case and Documentation for Caltrans FSR," Western Transportation Institute, 2009.
4. T.A. Lasky and B. Ravani, "Application of GPS for Vehicle Control in an Automated Highway System Environment," in *Second World Congress on Intelligent Transportation Systems*, Yokohama, Japan, pp. 1102-1107, November, 1995.
5. T.A. Lasky, K.S. Yen, and B. Ravani, "Advanced Construction and Maintenance Systems (Acms) for Winter Operations in Rural Environments," in *Rural Advanced Technology and Transportation Systems International Conference*, Flagstaff, AZ, 1999.
6. T.A. Lasky, K.S. Yen, and B. Ravani, "The Advanced Snowplow Driver Assistance System," in *Sixth Annual World Congress on Intelligent Transportation Systems*, Toronto, Canada, 1999.
7. D. Richter, K. Bateman, and D. Galarus, "Responder Phase 2 Final Report," Western Transportation Institute, 2009.
8. T. Swanston, K. Yen, B. Ravani, and T. Lasky, "Enhancement and Technical Support of Intelligent Roadway Information System (Iris) in Caltrans Districts 1, 2, 5 and 10," AHMCT Research Center Rept. # UCD-ARR-14-12-31-01, 2014.
9. K. Yen, M. Darter, H. Nguyen, B. Ravani, and T. Lasky, "Development and Field-Operational Testing of a Mobile Real-Time Information System for Snow Fighter Supervisors," AHMCT Research Center Rept. # UCD-ARR-06-12-31-07, 2006.
10. K. Yen, B. Ravani, and T. Lasky, "Research Planning for Caltrans Emergency Maintenance Response," AHMCT Research Center Rept. # UCD-ARR-11-06-30-01, 2011.
11. K.S. Yen, H.-S. Tan, A. Steinfeld, C.H. Thorne, B. Bougler, E. Cuelho, P. Kretz, D. Empey, R.R. Kappesser, H.A. Ghaida, M. Jenkinson, S. Owen, W.-B. Zhang, T.A. Lasky, and B. Ravani, "Advanced Snowplow Development and Demonstration: Phase I: Driver Assistance," AHMCT Rept. # UCD-ARR-99-06-30-03, 1999.
12. K.S. Yen, H.-S. Tan, A. Steinfeld, C.H. Thorne, S.M. Donecker, B. Bougler, P. Kretz, D. Empey, R.R. Kappesser, H.A. Ghaida, M. Jenkinson, S. Owen, W.-B. Zhang, T.A. Lasky, and B. Ravani, "Development of an Advanced Snowplow Driver Assistance System (Asp-Ii)," AHMCT Rept. # UCD-ARR-00-06-30-02, 2000.
13. K.S. Yen, H.-S. Tan, A.-J. van Zadelhoff, J. Lins, B. Bougler, K. Hawley, A. Nazari, A. Steinfeld, P. Kretz, V. Reveles, R. Battersby, M. Jenkinson, S.R. Owen, W.-B. Zhang, T.A. Lasky, and B. Ravani, "A Rural Field Test of the Roadview System," AHMCT Rept. # UCD-ARR-02-06-30-01, 2002.

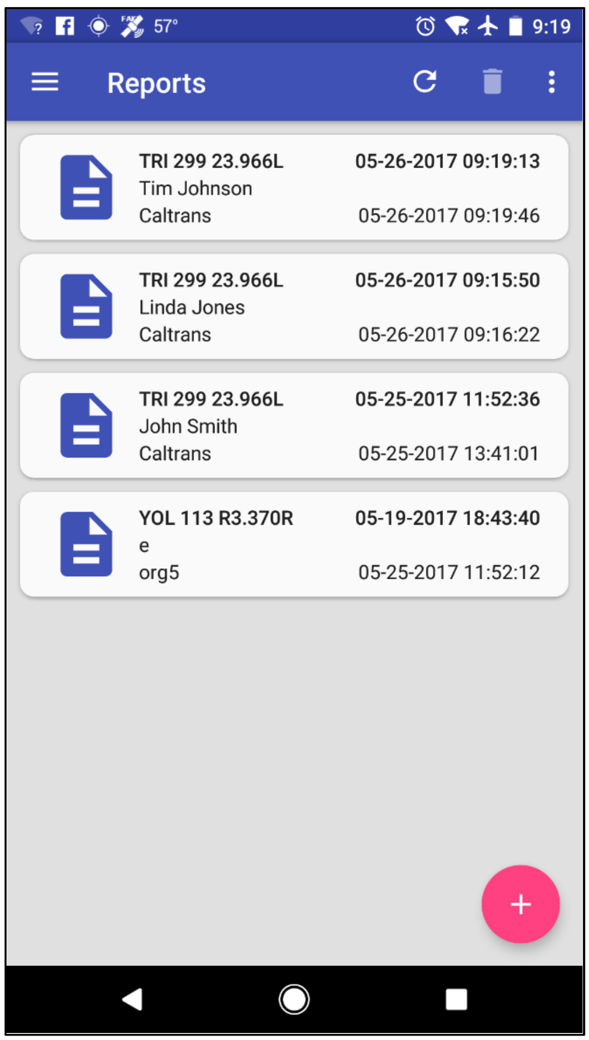
APPENDIX A:
RESPONDER SYSTEM QUICK START GUIDE

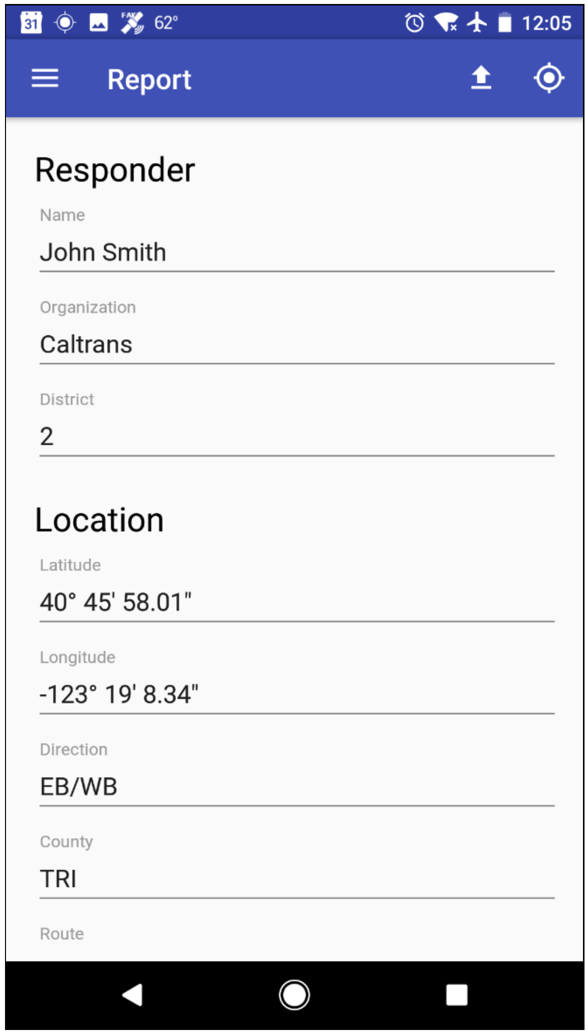
The basic workflow for entering and updating an incident is provided here. The process is very intuitive.

<u>Entering an Incident</u>

Initiating an Incident Report

Go to the Reports screen, click the plus sign (+) in the lower-right corner. This will initiate a new incident report, and the app will switch to the Report Entry screen. When the user clicks the crosshairs icon in the upper-right of the Report Entry screen, the app will populate the latitude and longitude as provided by the tablet's GPS sensor. County/route/post mile are also automatically populated at that point.



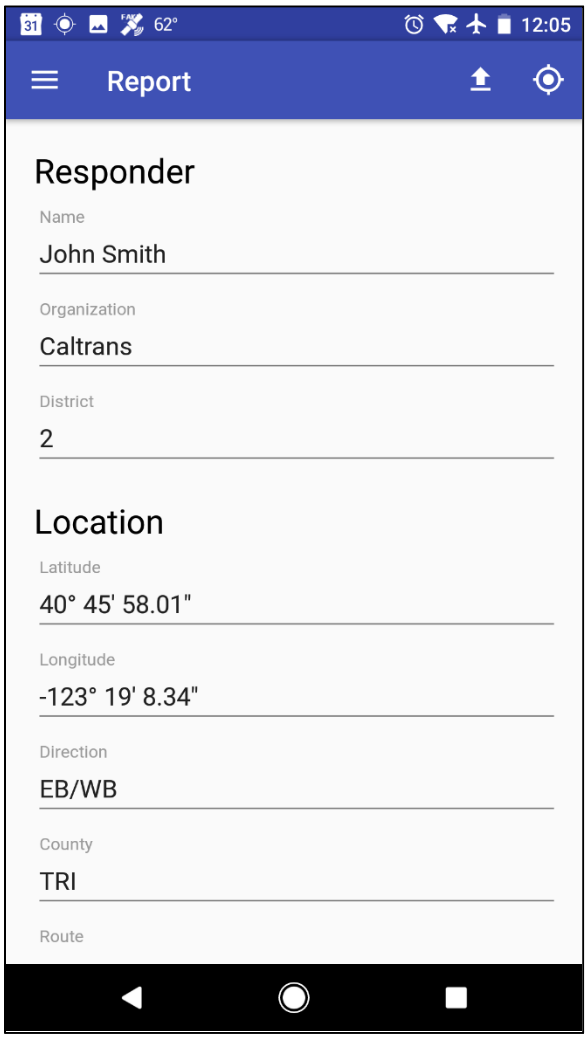


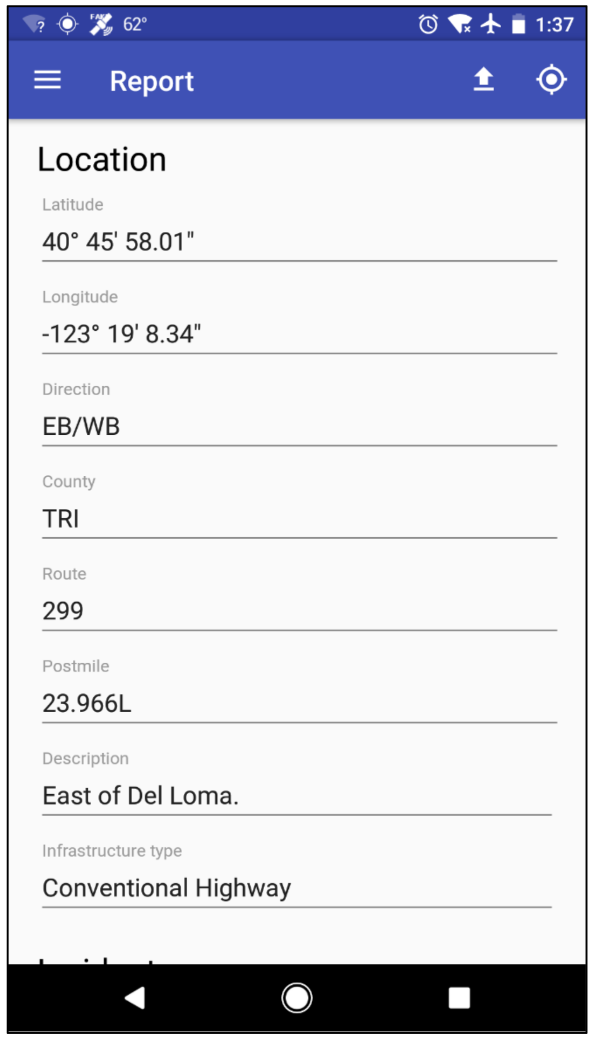
Entering Incident Information

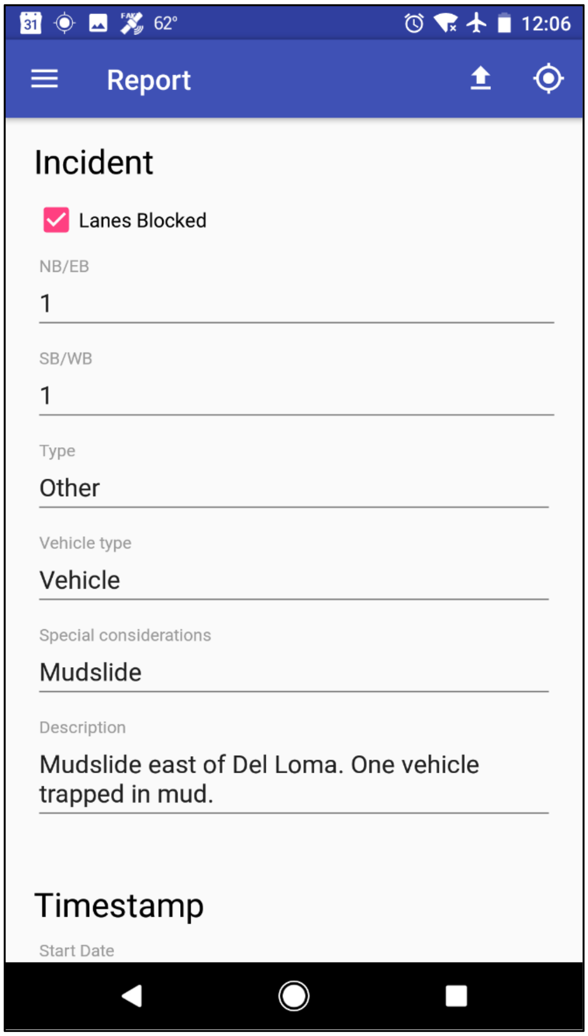
On the Report Entry screen, select (by clicking) each information field, and enter the appropriate information, either using the keyboard, voice input, or the associated dialog. The Report Entry screen provides input fields for:

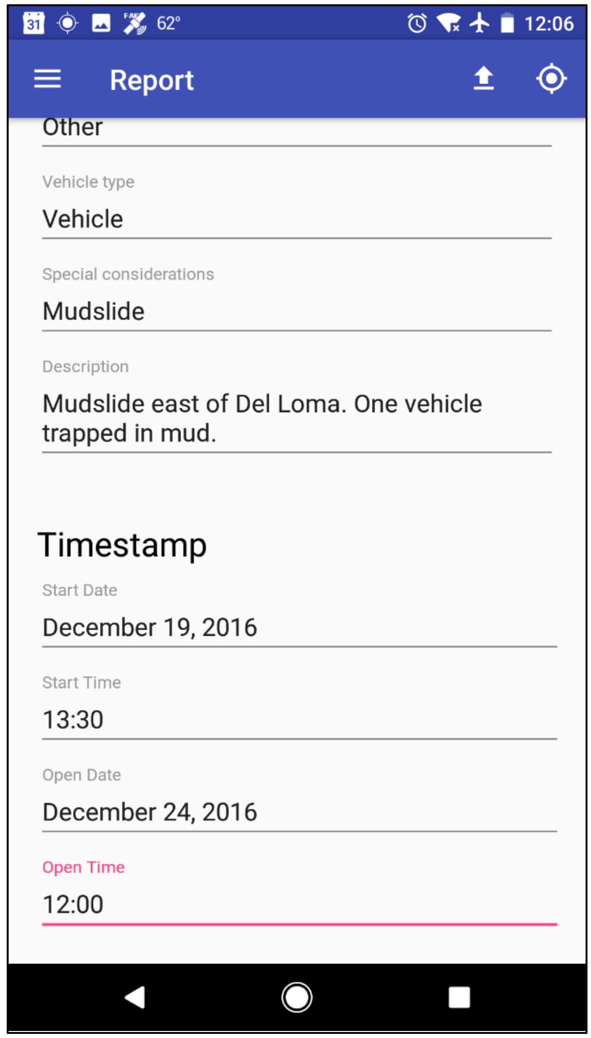
- organization (including district)
- incident start and stop date and time
- incident reporter name and organization
- location description
- infrastructure type
- highway direction

- lanes blocked
- type of vehicles involved
- type of incident
- special considerations (e.g. hazmat)
- detailed description of the incident.





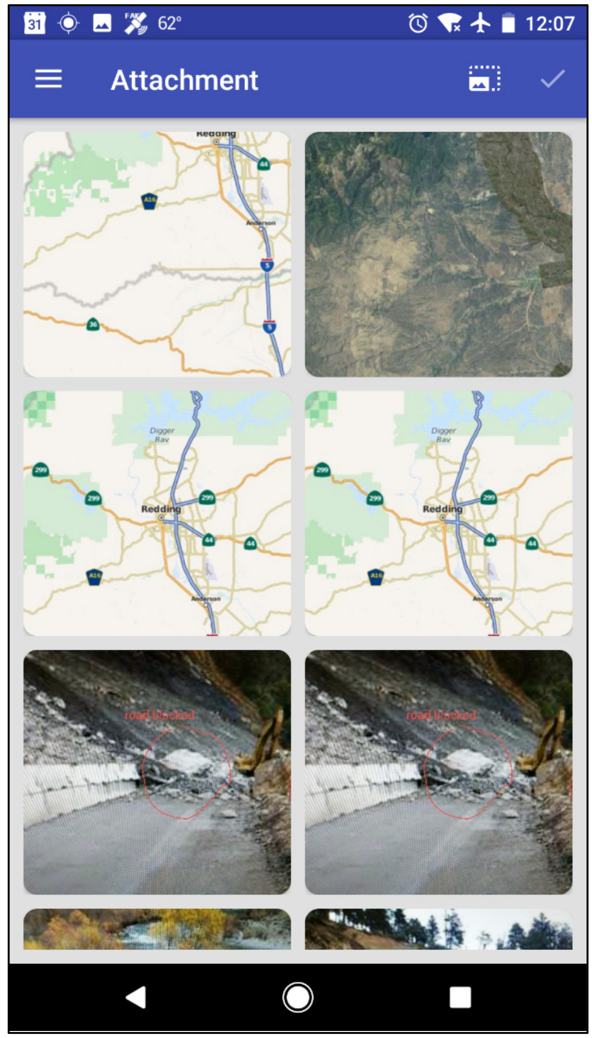




Adding Photos

The camera can be selected from the Navigation Drawer by clicking on the Camera entry. The user can then take a photo. The camera controls are standard, including the simple one-touch round button to take a photo. Each photo is added to the Gallery screen.

The Gallery screen (left, below) supports annotation, rotation, and deletion of images. To add photos to a report mail, the user can simply select the desired images by clicking and holding on the images, all within the Attachment screen (right, below). This screen is entered by clicking on the paperclip icon on the Mail screen.

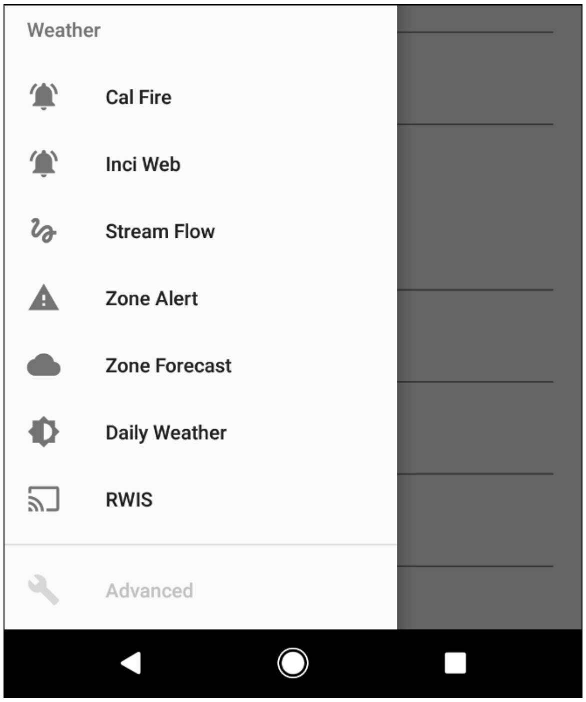


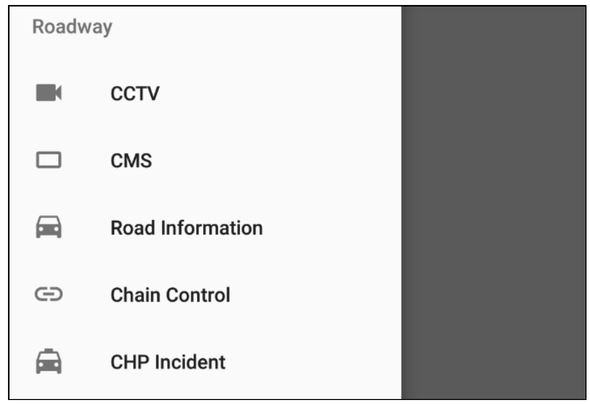
Annotating Photos and Other Images

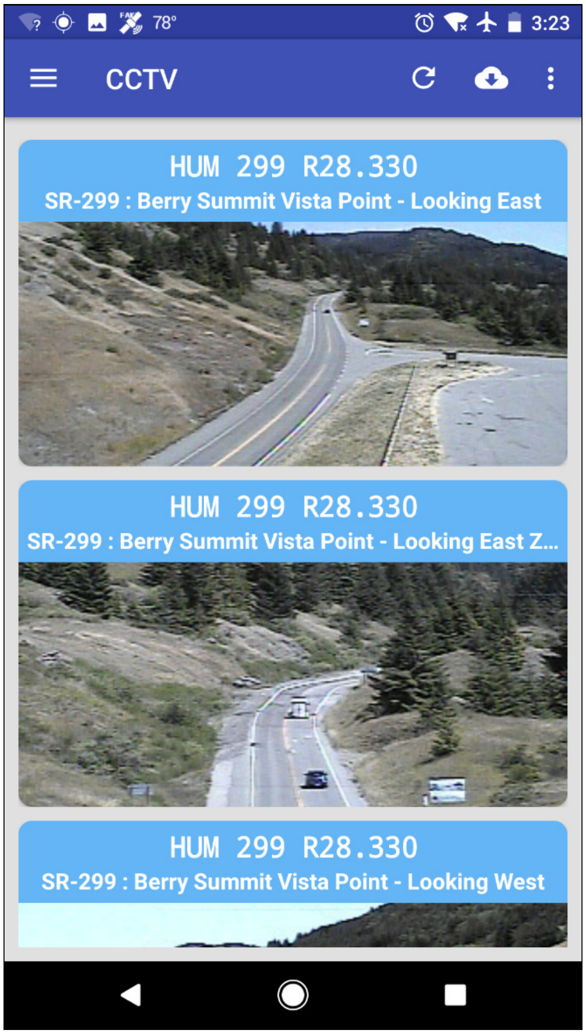
For any photo or other image in the Gallery, including map snapshots, tap on that image to view it full screen, including access to annotation tools. Alternatively, click and hold on the image, and select the pencil icon to begin annotating the image. Any annotated image will also be saved to the gallery

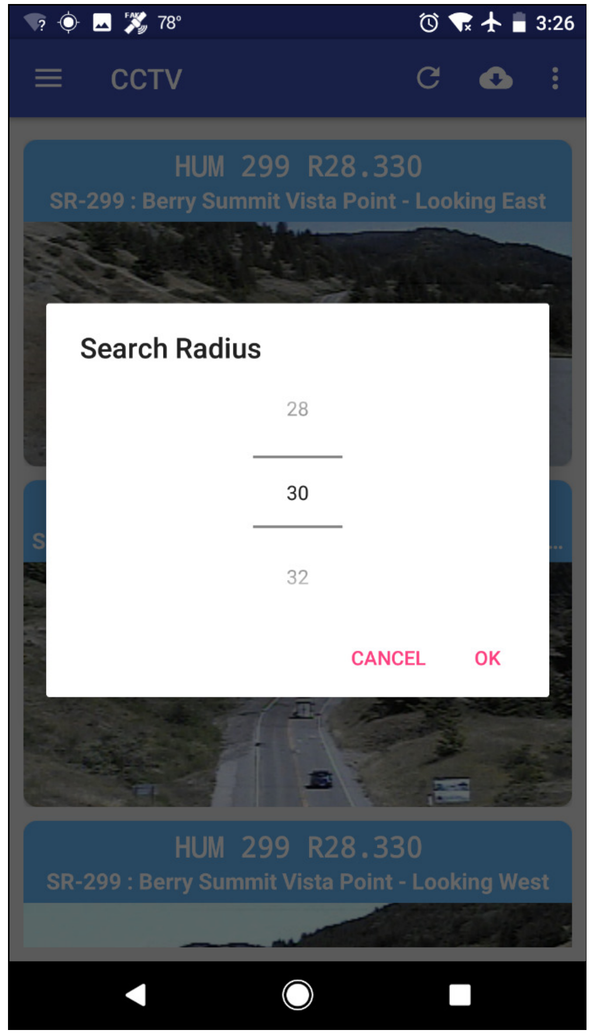
Checking Related Information

During an incident, the responder may need to check related information to help decide appropriate actions. To do this, navigate to the Weather or the Roadway menus, both part of the Navigation Drawer. Each of these has several pieces of information. The Weather menu includes weather, zone forecasts, zone alerts, RWIS data, projected stream flows, and wildland fires. The Roadway menu includes chain controls where relevant, CHP incidents, road information, road camera still images, and CMS messages. Upon selecting the item, the corresponding information will be shown in a separate screen. Many of these information sources includes a radius setting (in miles) to control the amount of information downloaded and/or displayed. The radius setting is located in the menu for the appropriate screens.

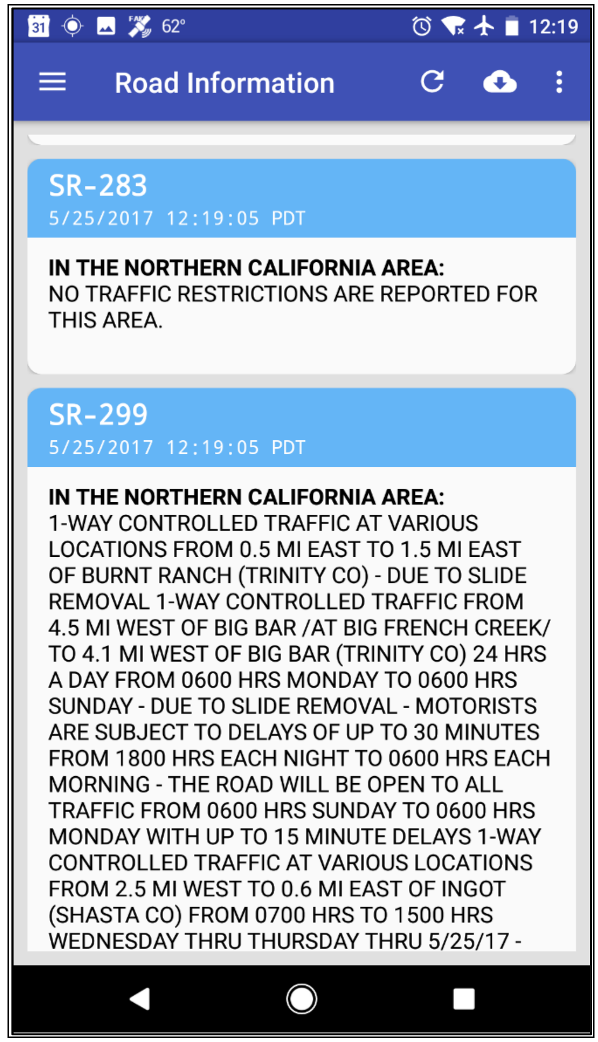

Weather
Cal Fire
Inci Web
Stream Flow
Zone Alert
Zone Forecast
Daily Weather
RWIS
Advanced

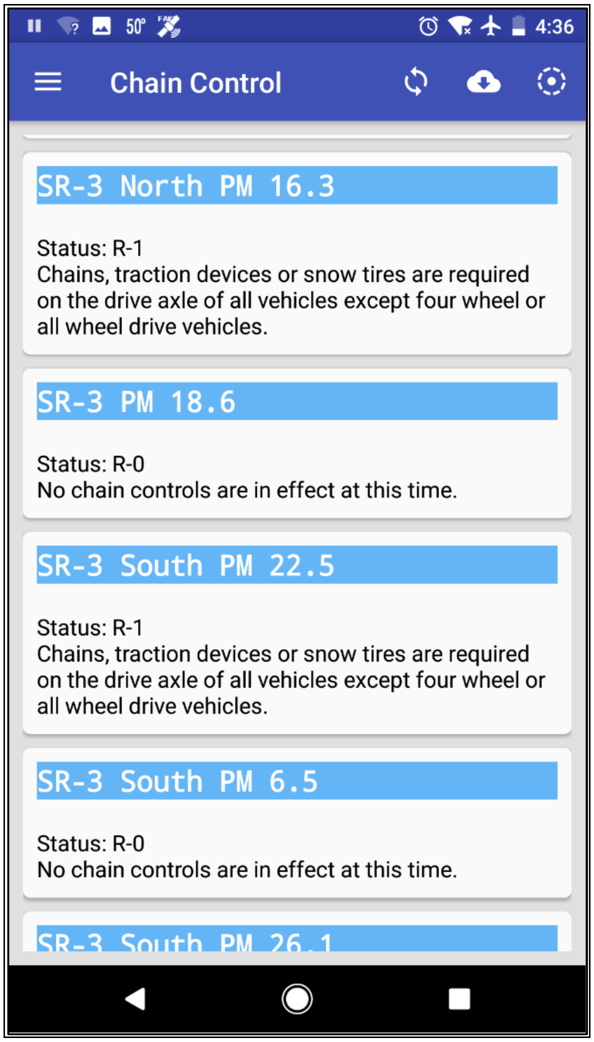

Roadway
CCTV
CMS
Road Information
Chain Control
CHP Incident

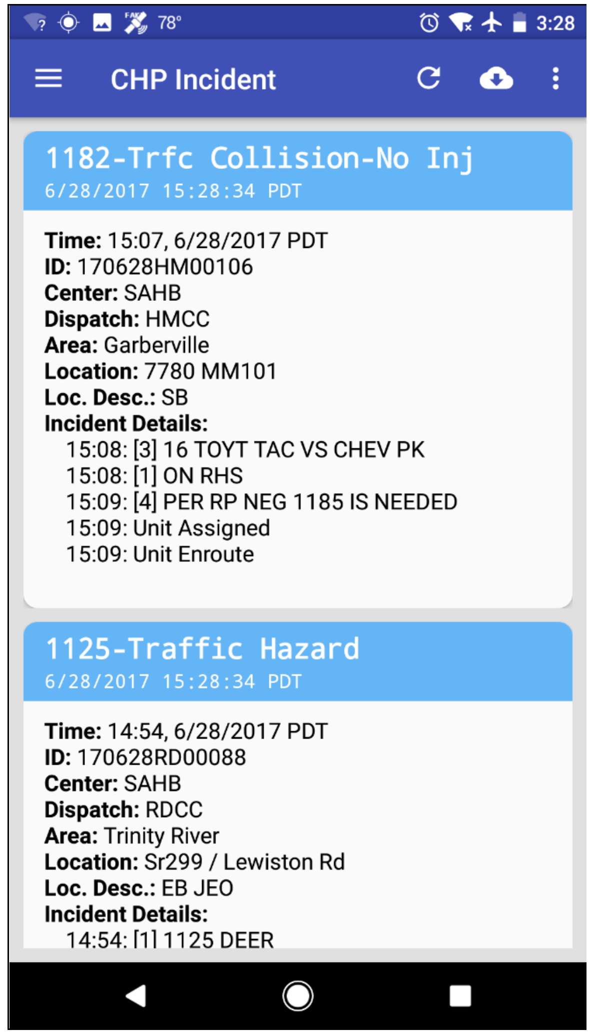

78°
3:23
CCTV
HUM 299 R28.330
SR-299 : Berry Summit Vista Point - Looking East
HUM 299 R28.330
SR-299 : Berry Summit Vista Point - Looking East Z...
HUM 299 R28.330
SR-299 : Berry Summit Vista Point - Looking West

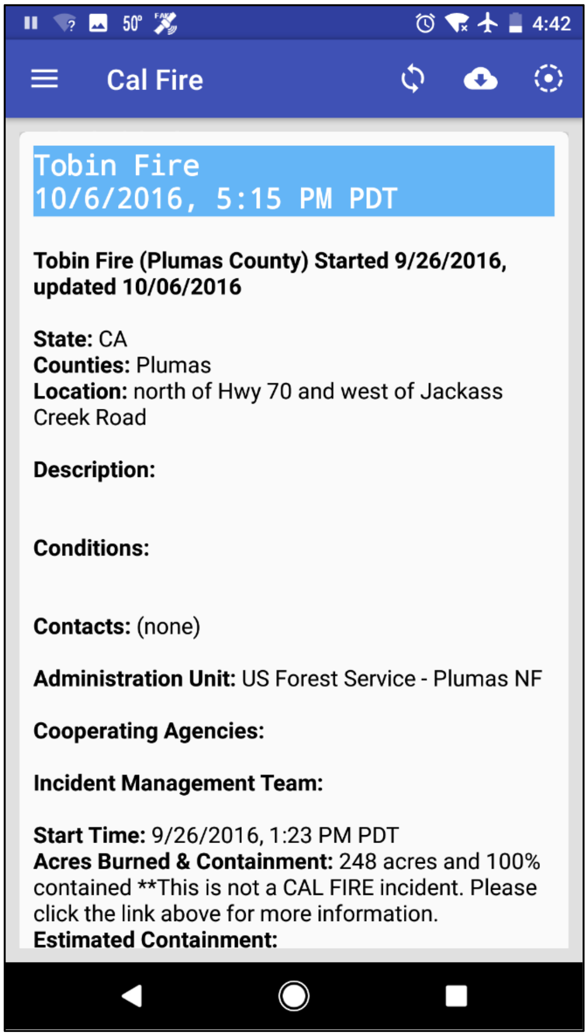

78°
3:26
CCTV
HUM 299 R28.330
SR-299 : Berry Summit Vista Point - Looking East
Search Radius
28
30
32
CANCEL
OK
HUM 299 R28.330
SR-299 : Berry Summit Vista Point - Looking West

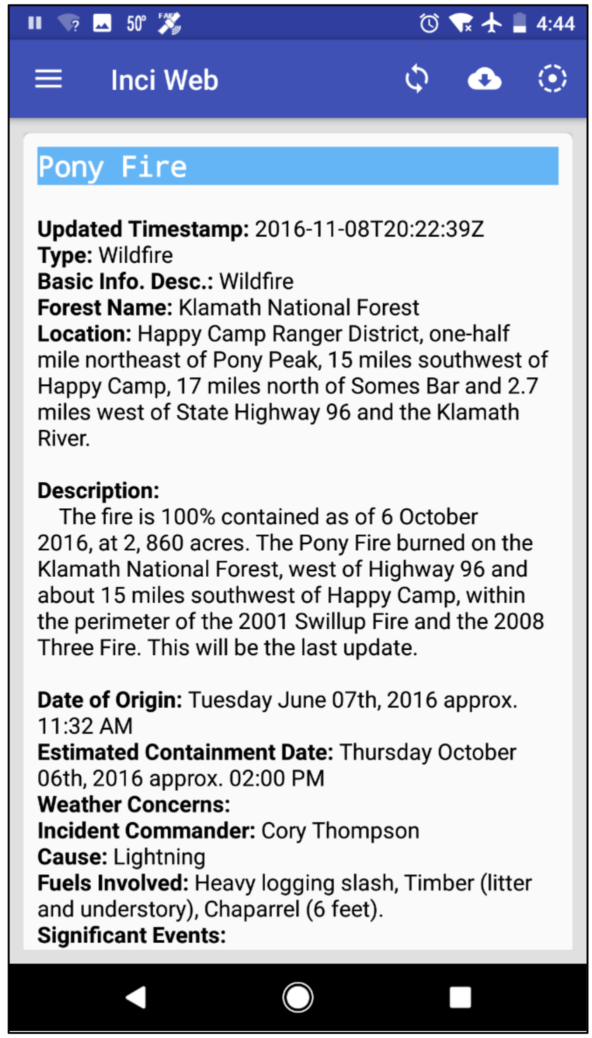

78°
3:27
CMS
HUM 101 87.670
4 - Hum 101 PM 87.7 - S of 101/299 - FNBT
TRI 299 SLIDE
FOR UPDATES
CALL
HUM 101 89.380
5 - Hum 101 PM 89.4 - N of 101/299 - FSBT
TRI 299 SLIDE
FOR UPDATES
CALL
SHA 5 R19.410
10 - Oasis Road S/B - Redding
HWY 299W INFO
TUNE TO
1610 AM
SHA 5 R10.850

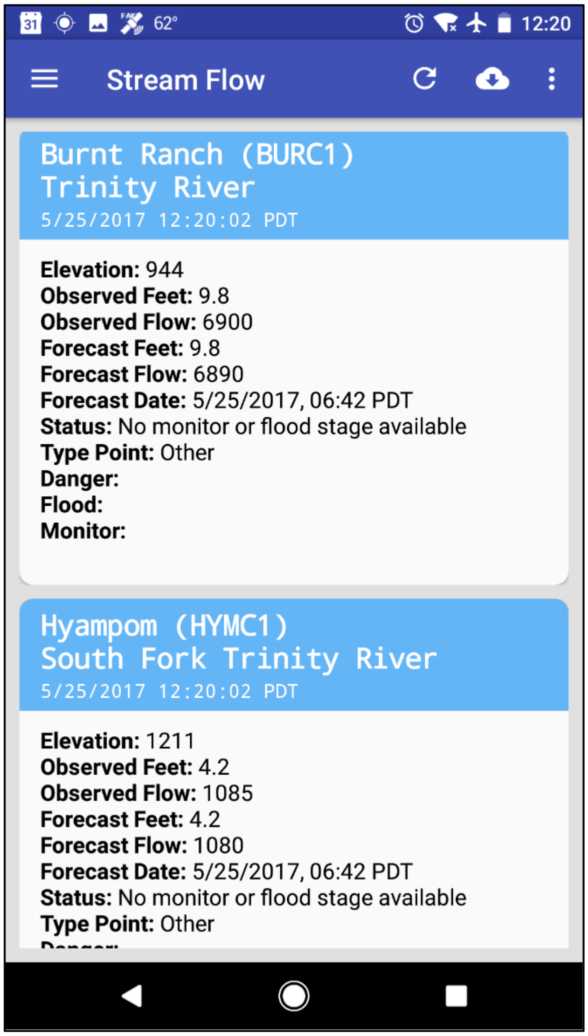

62°
12:19
Road Information
SR-283
5/25/2017 12:19:05 PDT
IN THE NORTHERN CALIFORNIA AREA:
NO TRAFFIC RESTRICTIONS ARE REPORTED FOR THIS AREA.
SR-299
5/25/2017 12:19:05 PDT
IN THE NORTHERN CALIFORNIA AREA:
1-WAY CONTROLLED TRAFFIC AT VARIOUS LOCATIONS FROM 0.5 MI EAST TO 1.5 MI EAST OF BURNT RANCH (TRINITY CO) - DUE TO SLIDE REMOVAL 1-WAY CONTROLLED TRAFFIC FROM 4.5 MI WEST OF BIG BAR /AT BIG FRENCH CREEK/ TO 4.1 MI WEST OF BIG BAR (TRINITY CO) 24 HRS A DAY FROM 0600 HRS MONDAY TO 0600 HRS SUNDAY - DUE TO SLIDE REMOVAL - MOTORISTS ARE SUBJECT TO DELAYS OF UP TO 30 MINUTES FROM 1800 HRS EACH NIGHT TO 0600 HRS EACH MORNING - THE ROAD WILL BE OPEN TO ALL TRAFFIC FROM 0600 HRS SUNDAY TO 0600 HRS MONDAY WITH UP TO 15 MINUTE DELAYS 1-WAY CONTROLLED TRAFFIC AT VARIOUS LOCATIONS FROM 2.5 MI WEST TO 0.6 MI EAST OF INGOT (SHASTA CO) FROM 0700 HRS TO 1500 HRS WEDNESDAY THRU THURSDAY THRU 5/25/17 -

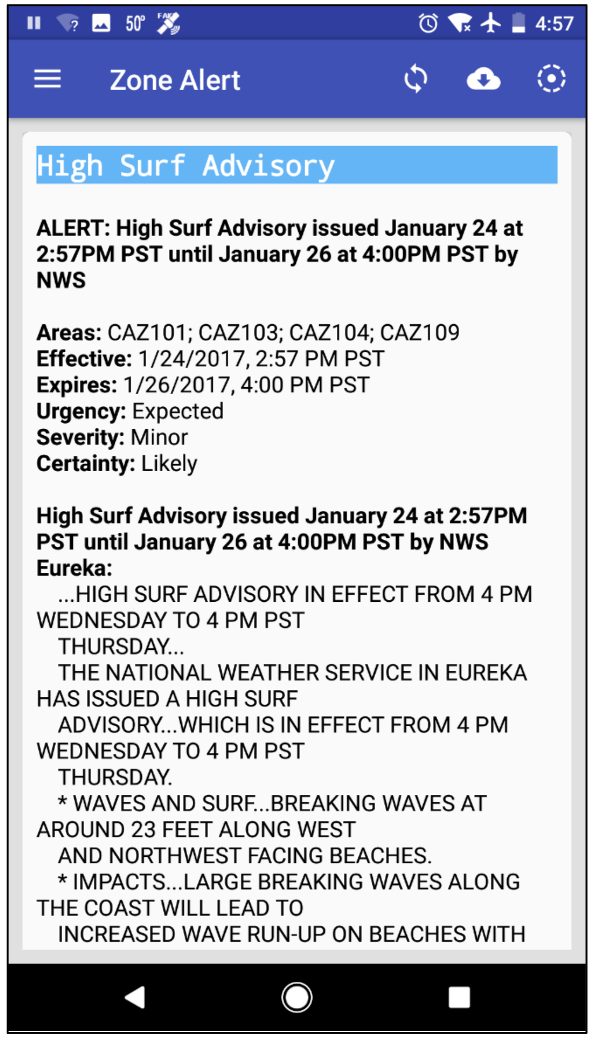

4:36
Chain Control
SR-3 North PM 16.3
Status: R-1
Chains, traction devices or snow tires are required on the drive axle of all vehicles except four wheel or all wheel drive vehicles.
SR-3 PM 18.6
Status: R-0
No chain controls are in effect at this time.
SR-3 South PM 22.5
Status: R-1
Chains, traction devices or snow tires are required on the drive axle of all vehicles except four wheel or all wheel drive vehicles.
SR-3 South PM 6.5
Status: R-0
No chain controls are in effect at this time.

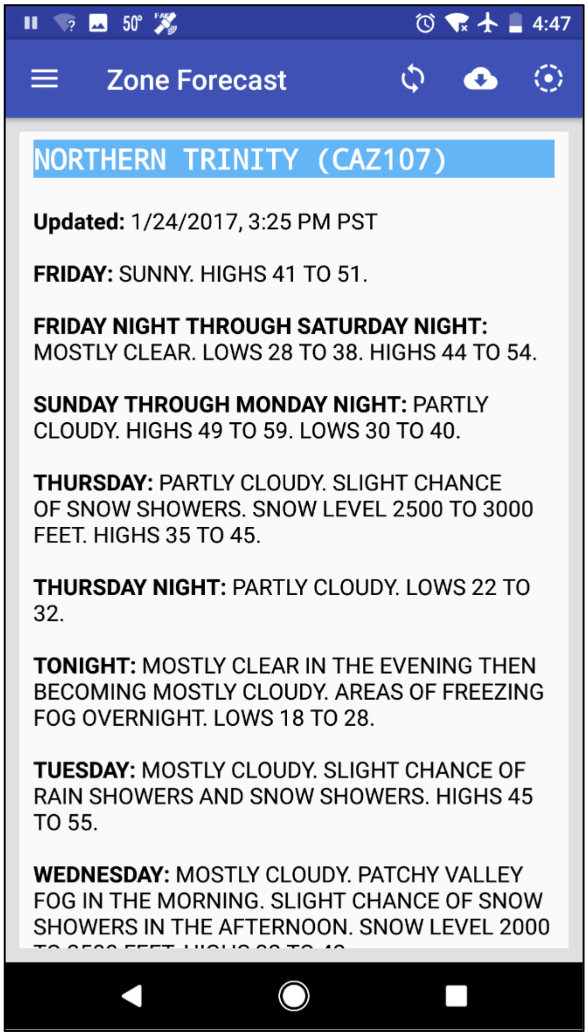

78°
3:28
CHP Incident
1182-Trfc Collision-No Inj
6/28/2017 15:28:34 PDT
Time: 15:07, 6/28/2017 PDT
ID: 170628HM00106
Center: SAHB
Dispatch: HMCC
Area: Garberville
Location: 7780 MM101
Loc. Desc.: SB
Incident Details:
15:08: [3] 16 TOYT TAC VS CHEV PK
15:08: [1] ON RHS
15:09: [4] PER RP NEG 1185 IS NEEDED
15:09: Unit Assigned
15:09: Unit Enroute
1125-Traffic Hazard
6/28/2017 15:28:34 PDT
Time: 14:54, 6/28/2017 PDT
ID: 170628RD00088
Center: SAHB
Dispatch: RDCC
Area: Trinity River
Location: Sr299 / Lewiston Rd
Loc. Desc.: EB JEO
Incident Details:

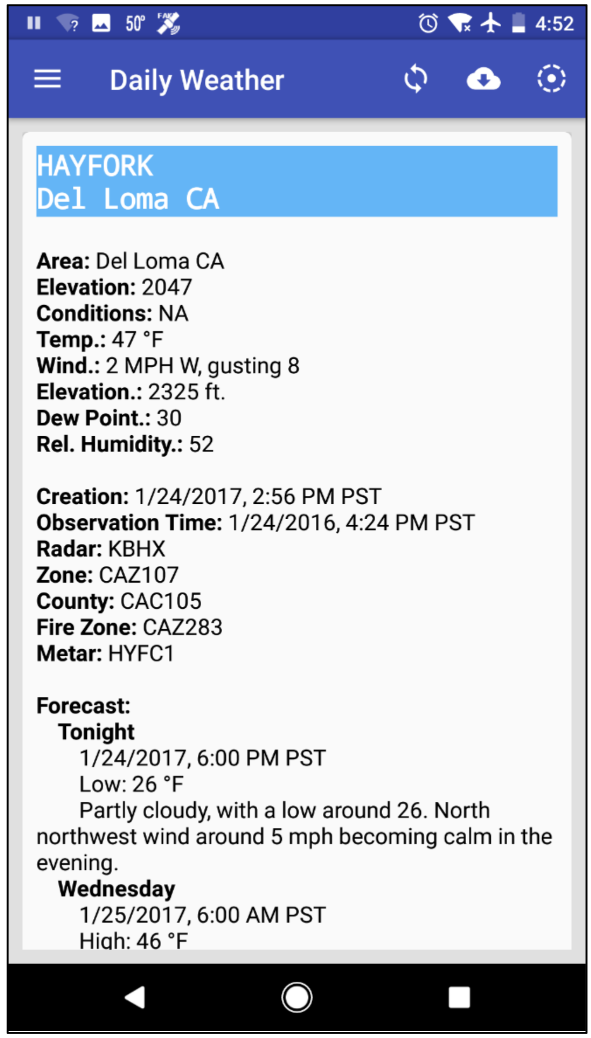

4:42
Cal Fire
Tobin Fire
10/6/2016, 5:15 PM PDT
Tobin Fire (Plumas County) Started 9/26/2016, updated 10/06/2016
State: CA
Counties: Plumas
Location: north of Hwy 70 and west of Jackass Creek Road
Description:
Conditions:
Contacts: (none)
Administration Unit: US Forest Service - Plumas NF
Cooperating Agencies:
Incident Management Team:
Start Time: 9/26/2016, 1:23 PM PDT
Acres Burned & Containment: 248 acres and 100% contained **This is not a CAL FIRE incident. Please click the link above for more information.
Estimated Containment:

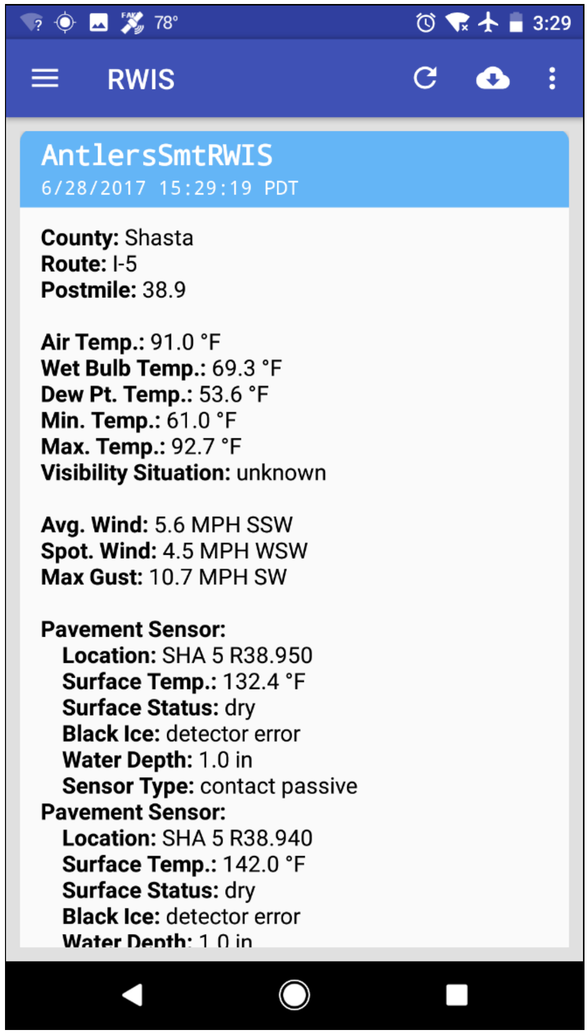

4:44
Inci Web
Pony Fire
Updated Timestamp: 2016-11-08T20:22:39Z
Type: Wildfire
Basic Info. Desc.: Wildfire
Forest Name: Klamath National Forest
Location: Happy Camp Ranger District, one-half mile northeast of Pony Peak, 15 miles southwest of Happy Camp, 17 miles north of Somes Bar and 2.7 miles west of State Highway 96 and the Klamath River.
Description:
The fire is 100% contained as of 6 October 2016, at 2, 860 acres. The Pony Fire burned on the Klamath National Forest, west of Highway 96 and about 15 miles southwest of Happy Camp, within the perimeter of the 2001 Swillup Fire and the 2008 Three Fire. This will be the last update.
Date of Origin: Tuesday June 07th, 2016 approx. 11:32 AM
Estimated Containment Date: Thursday October 06th, 2016 approx. 02:00 PM
Weather Concerns:
Incident Commander: Cory Thompson
Cause: Lightning
Fuels Involved: Heavy logging slash, Timber (litter and understory), Chaparrel (6 feet).
Significant Events:


62°
12:20
Stream Flow
Burnt Ranch (BURC1)
Trinity River
5/25/2017 12:20:02 PDT
Elevation: 944
Observed Feet: 9.8
Observed Flow: 6900
Forecast Feet: 9.8
Forecast Flow: 6890
Forecast Date: 5/25/2017, 06:42 PDT
Status: No monitor or flood stage available
Type Point: Other
Danger:
Flood:
Monitor:
Hyampom (HYMC1)
South Fork Trinity River
5/25/2017 12:20:02 PDT
Elevation: 1211
Observed Feet: 4.2
Observed Flow: 1085
Forecast Feet: 4.2
Forecast Flow: 1080
Forecast Date: 5/25/2017, 06:42 PDT
Status: No monitor or flood stage available
Type Point: Other


50°
4:57
Zone Alert
High Surf Advisory
ALERT: High Surf Advisory issued January 24 at 2:57PM PST until January 26 at 4:00PM PST by NWS
Areas: CAZ101; CAZ103; CAZ104; CAZ109
Effective: 1/24/2017, 2:57 PM PST
Expires: 1/26/2017, 4:00 PM PST
Urgency: Expected
Severity: Minor
Certainty: Likely
High Surf Advisory issued January 24 at 2:57PM PST until January 26 at 4:00PM PST by NWS Eureka:
...HIGH SURF ADVISORY IN EFFECT FROM 4 PM WEDNESDAY TO 4 PM PST THURSDAY...
THE NATIONAL WEATHER SERVICE IN EUREKA HAS ISSUED A HIGH SURF ADVISORY...WHICH IS IN EFFECT FROM 4 PM WEDNESDAY TO 4 PM PST THURSDAY.
* WAVES AND SURF...BREAKING WAVES AT AROUND 23 FEET ALONG WEST AND NORTHWEST FACING BEACHES.
* IMPACTS...LARGE BREAKING WAVES ALONG THE COAST WILL LEAD TO INCREASED WAVE RUN-UP ON BEACHES WITH


4:47
Zone Forecast
NORTHERN TRINITY (CAZ107)
Updated: 1/24/2017, 3:25 PM PST
FRIDAY: SUNNY. HIGHS 41 TO 51.
FRIDAY NIGHT THROUGH SATURDAY NIGHT: MOSTLY CLEAR. LOWS 28 TO 38. HIGHS 44 TO 54.
SUNDAY THROUGH MONDAY NIGHT: PARTLY CLOUDY. HIGHS 49 TO 59. LOWS 30 TO 40.
THURSDAY: PARTLY CLOUDY. SLIGHT CHANCE OF SNOW SHOWERS. SNOW LEVEL 2500 TO 3000 FEET. HIGHS 35 TO 45.
THURSDAY NIGHT: PARTLY CLOUDY. LOWS 22 TO 32.
TONIGHT: MOSTLY CLEAR IN THE EVENING THEN BECOMING MOSTLY CLOUDY. AREAS OF FREEZING FOG OVERNIGHT. LOWS 18 TO 28.
TUESDAY: MOSTLY CLOUDY. SLIGHT CHANCE OF RAIN SHOWERS AND SNOW SHOWERS. HIGHS 45 TO 55.
WEDNESDAY: MOSTLY CLOUDY. PATCHY VALLEY FOG IN THE MORNING. SLIGHT CHANCE OF SNOW SHOWERS IN THE AFTERNOON. SNOW LEVEL 2000

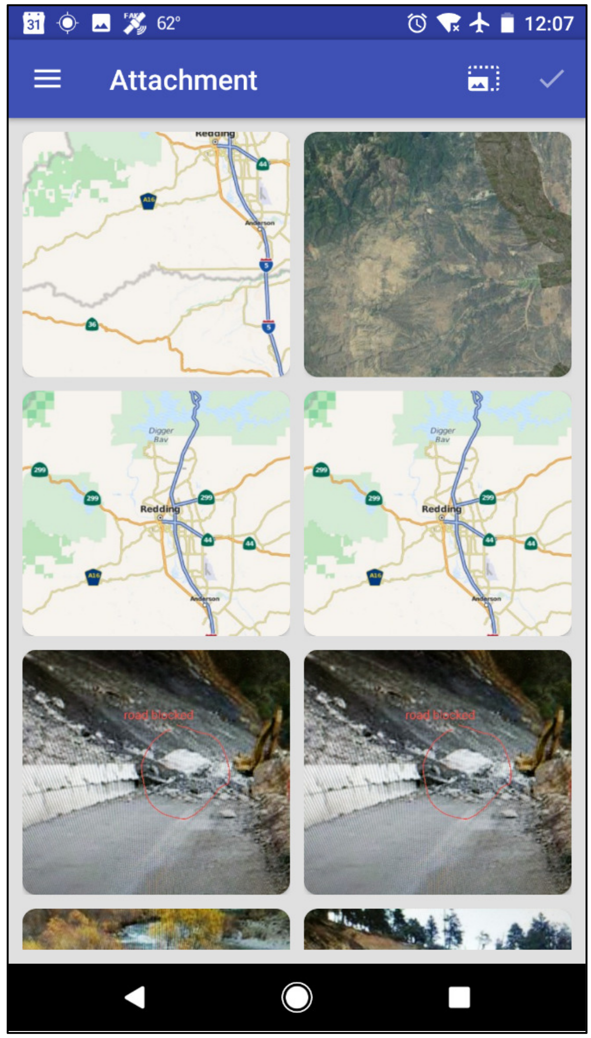

4:52
Daily Weather
HAYFORK
Del Loma CA
Area: Del Loma CA
Elevation: 2047
Conditions: NA
Temp.: 47 °F
Wind.: 2 MPH W, gusting 8
Elevation.: 2325 ft.
Dew Point.: 30
Rel. Humidity.: 52
Creation: 1/24/2017, 2:56 PM PST
Observation Time: 1/24/2016, 4:24 PM PST
Radar: KBHX
Zone: CAZ107
County: CAC105
Fire Zone: CAZ283
Metar: HYFC1
Forecast:
Tonight
1/24/2017, 6:00 PM PST
Low: 26 °F
Partly cloudy, with a low around 26. North northwest wind around 5 mph becoming calm in the evening.
Wednesday
1/25/2017, 6:00 AM PST
High: 46 °F

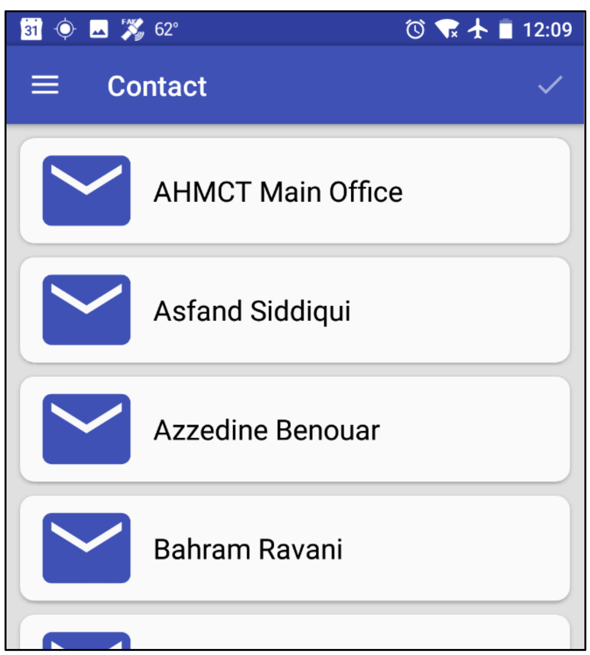


<u>Previewing and Sending an Incident Mail</u>

To preview the auto-generated incident report message, navigate to the Mail screen. The screen shows the mail recipients, and a preview of the mail body. This body is generated based on the user's inputs on the Report Entry screen. The preview also shows any images that will be attached, based on the user's selections on the Attachment screen, which is accessed by clicking the paperclip icon on the Mail screen. To add recipients, click on the "Recipients" field, and select from the contact list. Finally, assuming that the message is as the user intended, send it by pressing the "SEND" button at the bottom of the screen.

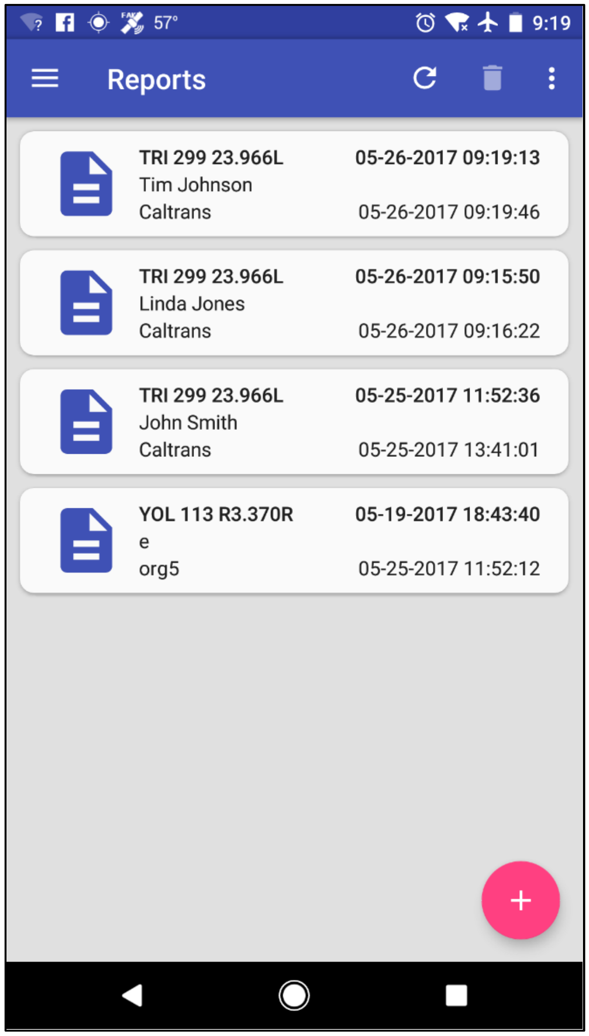

62°
12:10
Mail
To
gurprit.hansra@dot.ca.gov,
asfand.siddiqui@dot.ca.gov,
greg.larson@dot.ca.gov,
jeremiah.pearce@dot.ca.gov,
joseph.baltazar@dot.ca.gov,
melissa.clark@dot.ca.gov,
smdonecker@ucdavis.edu, talasky@ucdavis.e
keith.koeppen@dot.ca.gov
Subject
Responder Incident Report 2017-05-25 12:08 F
Body
Responder
Name: John Smith
Organization: Caltrans
District: 2
Location
Lat/Lon: 40° 45' 58.01" -123° 19' 8.34"
Direction: EB/WB
County: TRI
Route: 299
Postmile: 23.966L
Description: East of Del Loma.
Infrastructure Type: Conventional Highway


62°
12:07
Attachment
Redding


62°
12:09
Contact
AHMCT Main Office
Asfand Siddiqui
Azzedine Benouar
Bahram Ravani

Editing an Existing Incident

To edit an existing incident, navigate to the Reports list, and select that report. Incidents are identified by date and time, user name, organization name, and location. Clicking on an incident will then load that incident, and switch to the Report Entry screen for subsequent editing, using similar procedures as those for entering a new incident.



.

APPENDIX B: RESPONDER SYSTEM USER GUIDE

The Responder system is designed to be quite intuitive, and to leverage well-known interfaces and interactions with mobile apps. However, some guidance may be needed for use of the system.

Responder Software Startup

Responder In-Vehicle System Startup

The Responder in-vehicle system box starts up automatically when the vehicle is started and the system power switch is in the on position, and shuts down when either the key or the system power switch is turned off. The system will continue to run if the engine is stopped if key is left in the on or accessory position and the system power switch remains on. The system power switch allows the vehicle to be operated without the Responder system turned on. It is recommended that the engine be left running while the Responder system is in use, to avoid draining the vehicle battery.

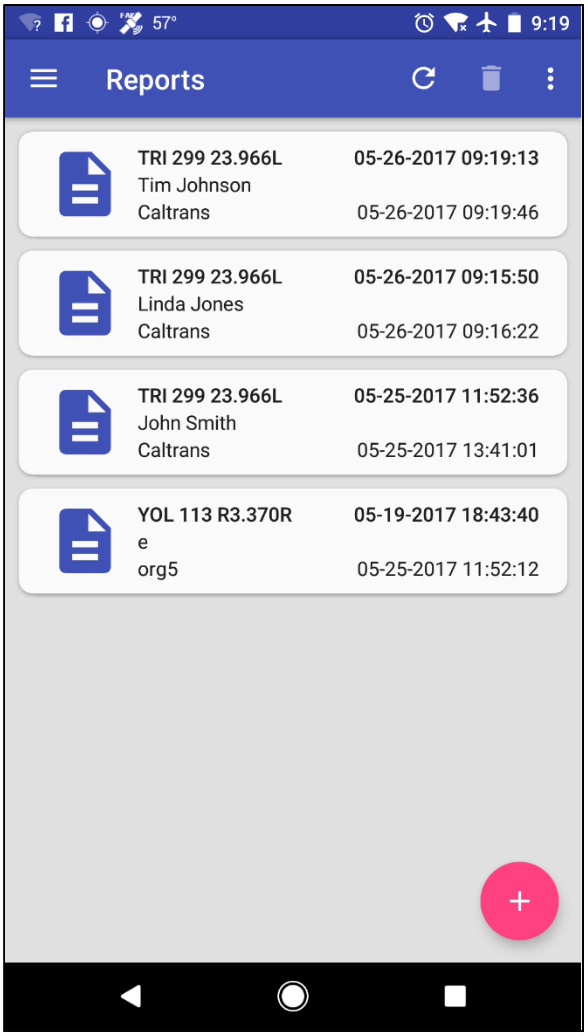
Powering on the HMI Tablet or Smartphone

Press and release the power button. The device will boot up. When it reaches a normal Android home screen, the device is fully booted and ready.

Responder App Startup

The Responder app is started like any other Android tablet or smartphone app. Assuming the Responder icon is visible on the screen, the user simply taps the icon once. If it is not, then the user must enter the main menu (the method varies by Android version), swipe to find the Responder app icon, and tap it. It is strongly recommended that the Responder icon be installed onto the HMI device's main screen.

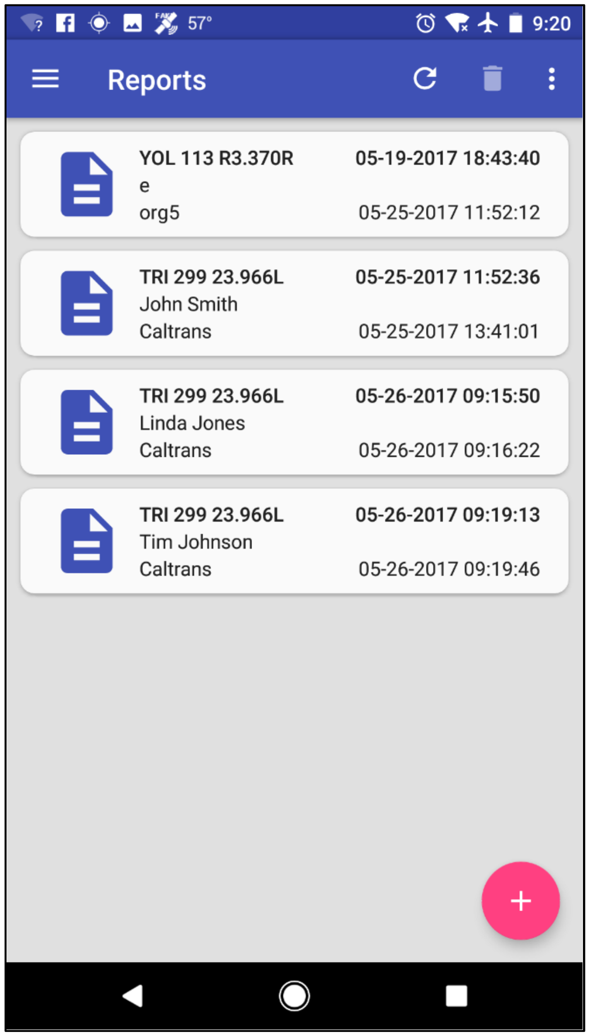
On startup, Responder will begin at the Reports screen, where the user can add a new incident, or select an existing incident to modify.



Using the Responder HMI App

Creating a New Incident Report

On the app's Reports screen, **tap the plus sign (+)** in the lower-right corner of the screen. This initiates a new incident report, and switches to the Report Entry screen for detailed data entry.



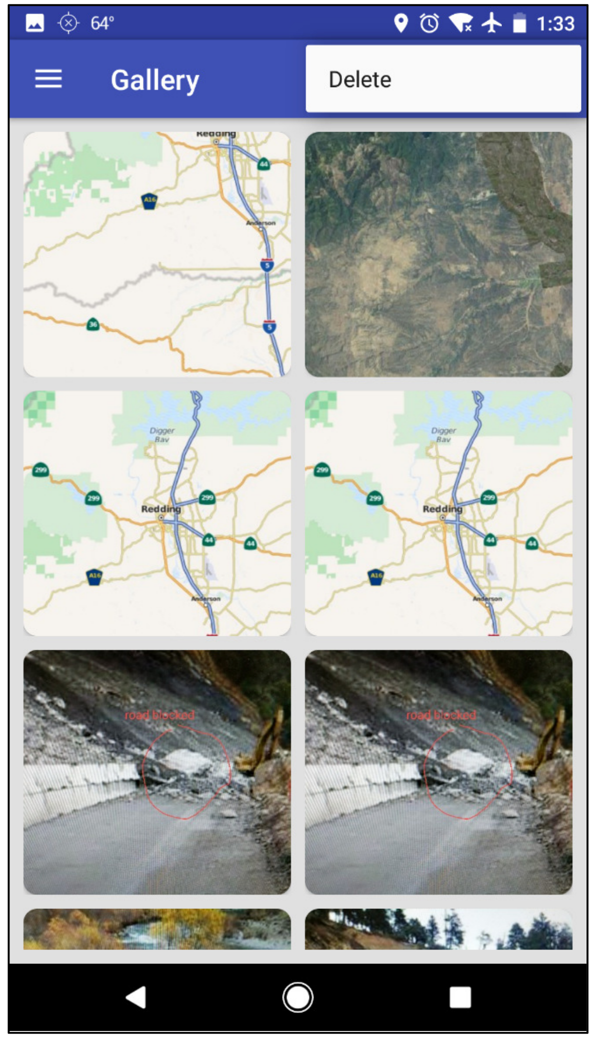
Selecting an Existing Incident Report for Editing

On the Reports screen, **tap the entry for the incident to be edited**. Incidents are identified by date and time, user name, organization name, and location. This will then load that incident, and switch to the Report Entry screen for subsequent editing.

Gallery Screen

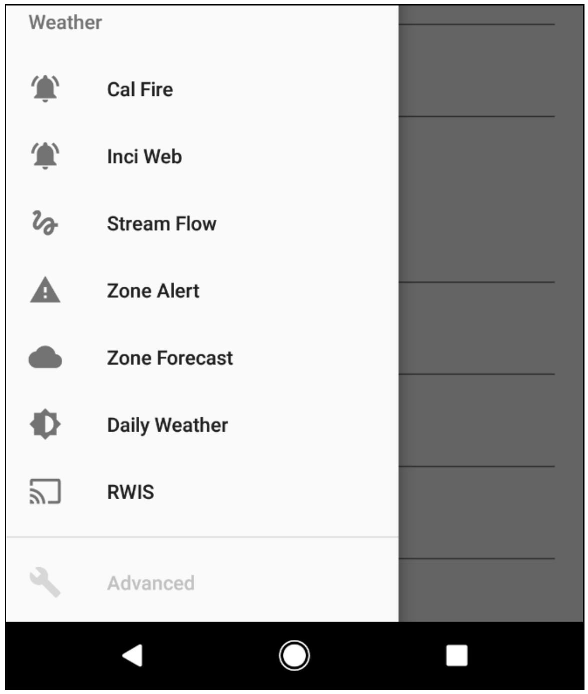
The Gallery screen provides a grid of photos and other images related to the current incident. It is similar to those found in standard Android apps like the Gallery app and Google Photos. It provides thumbnails of all images related to this incident. This will include photos; snapshots of maps, aerial photos, and topo maps; and annotations of photos and snapshots. The gallery screen allows the user to annotate an image by clicking on that image and selecting the pencil icon in the upper-right. It also allows the user to rotate selected images.

To **delete photos, click and hold on the image(s) to be deleted**. Then **click the action menu icon in the upper right corner, and select delete**. Use caution in doing so, as this cannot be undone.



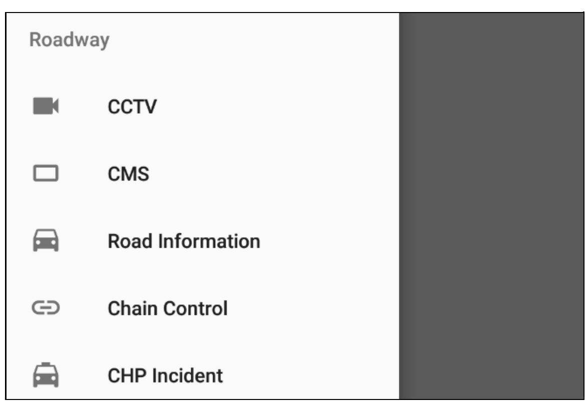
Weather Menu

The Weather menu, located in the Navigation Drawer, allows the user to request the latest weather-related information. This includes weather, zone forecasts, zone alerts, RWIS data, projected stream flows, and wildland fires. To view any information, **click the related item** to bring up the information screen.



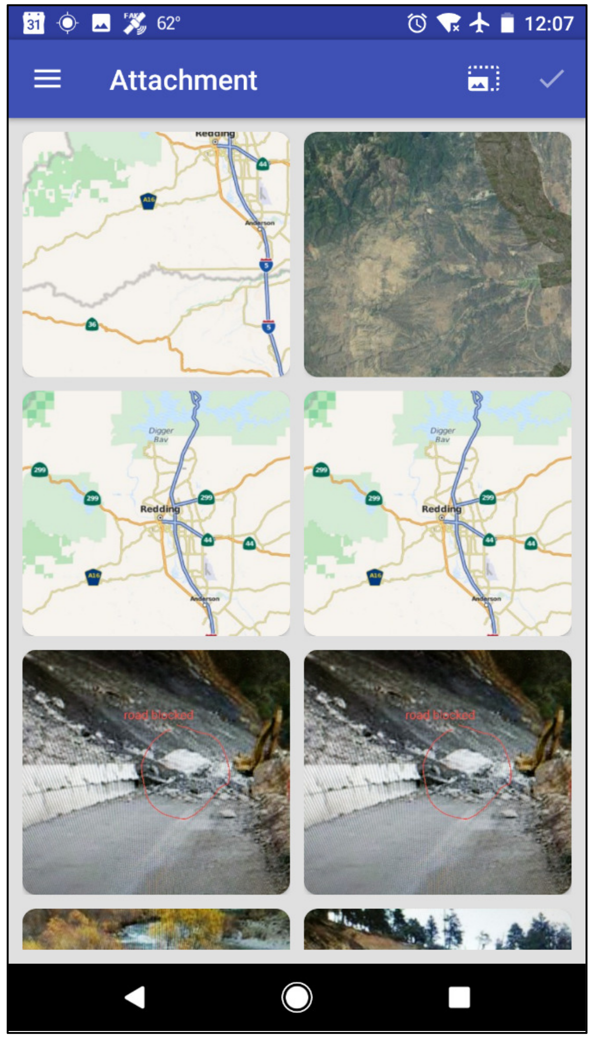
Roadway Menu

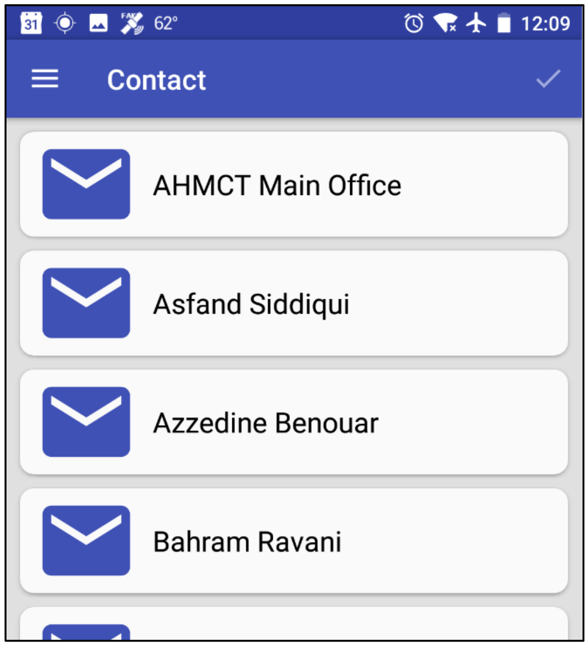
The Roadway menu allows the user to request current roadway-related information. This includes chain controls where relevant, CHP CAD incidents, road information, road camera still images, and CMS messages. Roadway information is provided for all of California, as well as for approximately 30 miles over the border into neighboring states of Arizona, Nevada, and Oregon. To view any information, **click the related item** to bring up the information screen.



Mail Preview / Send

The Mail screen allows the user to preview the auto-generated incident report mail, select recipients from a contact list, attach images, and send the message. The screen shows the message recipients, and a preview of the message body, including attachment thumbnails. This body is generated based on the user's inputs on the report screen. The preview shows any images that will be attached, based on the user's selections on the Attachment screen. **To add recipients**, the user clicks on the contacts icon (person with + sign) and selects from the Contact list. The Contact list allows selection of multiple recipients in one operation. To add attachments, the user clicks on the paperclip icon, and selects multiple images by clicking and holding on the images. Finally, assuming that the message is as the user intended, they can **send it by pressing the send button (right-facing triangle)** at the top-right of the screen.





Responder System Maintenance

Responder In-Vehicle System Maintenance

The in-vehicle system should need minimal maintenance. The system box vents should be checked regularly for dust and dirt build-up depending on environmental conditions, and cleaned as needed. Additionally, the system cover should be opened once or twice a year depending on vehicle environmental conditions, and the internal compartments inspected and cleaned as necessary. This will maintain proper airflow and cooling for the system. If any of the system cabling (power, communications) had to be left exposed, these should be checked regularly for signs of wear, and replaced if the cable is compromised in any way.

Responder HMI Hardware Maintenance

The Responder HMI hardware is a standard Android smartphone or tablet, and should be maintained as such. The unit should be charged regularly. For optimal battery life, it is best if the unit is not fully discharged, and is not left on the charger once the unit is fully charged. In addition, the unit should not be left in a vehicle in extreme temperatures, particularly in very high temperatures. Exposing the unit to very high temperatures for any extended duration can compromise the unit’s battery life.

Smartphone and tablet batteries do have limited lifetime. If the unit will no longer take a charge, or the charge only lasts for a short time relative to its known previous pattern, it may be time to replace the battery, or the device. Some units have a replaceable battery. For these units, follow the manufacturer’s instructions for removing the battery, order the correct replacement battery, and install the replacement. If the battery is not replaceable, you will need to replace the entire unit. Whichever method is used, be sure to properly recycle the unit and/or battery.

The screen should be cleaned regularly to improve Responder app readability. To clean the screen, use a soft, lint-free cloth, e.g. a microfiber cloth. Do not use a paper towel, as this can scratch the screen. Do not use Windex or other chemicals or cleaning solvents; this can destroy special coatings on some screens. If the screen is extremely dirty, you can use a cleaning solution of one part distilled water, one part 70% alcohol. Be sure to turn the unit's power completely off before using this cleaning solution. Note that simply turning the unit's screen off is not sufficient.

Frequently Asked Questions

Why am I not getting GPS data?

First, verify that the GPS notification icon is indicating the no signal state. Next, make sure that location is enabled on the tablet. Swipe down the notification bar and verify that the location icon is enabled. Click on the icon if necessary. If the GPS notification icon is still indicating the no signal state, then you need to move to another location to acquire a suitable GPS solution/lock. If you are in a GPS-compromised location, you will get either a reduced accuracy solution, or no solution. Examples include in a building, in a metal shelter or lean-to, under heavy tree foliage, and in deep ravines or canyons.

Where can find saved incidents?

Saved incidents are located in the Reports screen, identified by location, responder name, responder location, creation timestamp, and last updated timestamp. Selecting an existing incident report will switch to the Report screen for continued editing.

When is communications with the internet established?

Internet communications will be available to the Responder app whenever the in-vehicle system can establish a connection. If cellular signal or satellite is available, then communications will be established. If neither is available, communications will not occur during that time. All email transmission requests will be stored for future transmission, to occur when communications is next established, up to a configurable expiration time.

How do I clean the tablet screen?

The screen should be cleaned regularly to improve Responder app readability. To clean the screen, use a soft, lint-free cloth, e.g. a microfiber cloth. Do not use a paper towel, as this can scratch the screen. Do not use Windex or other chemicals or cleaning solvents; this can destroy special coatings on some screens. If the screen is extremely dirty, you can use a cleaning solution of one part distilled water, one part 70% alcohol. Be sure to turn the unit's power completely off before using this cleaning solution. Note that simply turning the unit's screen off is not sufficient.

What do I do if the tablet locks up?

Tablets could lock up for many reasons. This could be related to the state of several installed applications or the operating system. If the tablet is completely unresponsive, try to power the tablet off and back on again. Generally, holding down the power button long enough (in some cases up to 20 seconds) should bring up a dialog box asking if you want to power off the tablet. Click "Yes". If the dialog gives the option of "Restart", choose that, and simply wait for the system to fully restart. If the dialog gives the options of "Sleep" or "Shut down", choose "Shut down". Then, wait for the tablet to power off, wait a few more seconds, and then press the power button to power back on. Ideally, this will solve whatever caused the tablet to lock up.

If the Responder app is the only app that is locked up, you can bring up the list of running apps by pressing the standard Android "Tasks" icon, wait a few seconds, and then close the app either by clicking the "X" in the upper right corner of the app image, or by swiping the app image to the right.

Why doesn't the tablet connect to the in-vehicle Responder system box?

Typically, if the tablet cannot connect to the Responder system box, then Wi-Fi needs to be enabled and configured.

First, assure that Wi-Fi is enabled. Swipe down the notification bar and click on the Wi-Fi icon.

Next, in the Wi-Fi settings menu, look for the Responder system box's Wi-Fi access point. Select it, and enter the right credentials (password). If you do not know these, check with your supervisor or your district's Responder administrator.

To connect to the Responder system box, you must be in range. The tablet should be able to connect to the Responder system box at least 200 feet from the vehicle.

Why don't I get a satellite signal?

Satellite signal, like any other RF signal, is subject to blockage. Generally, consider environmental factors. If line-of-sight to the satellite is blocked, you will not get satellite communications. Examples include in a vehicle maintenance bay, in a metal shelter or lean-to, under heavy tree foliage, and in deep ravines or canyons. Other possible causes include rain fade; this is subject to additional testing in follow-up research.

What if the tablet gets wet?

If the tablet gets wet, turn it off immediately. Allow the tablet to dry for as long as possible before turning it back on again. Never use a hair dryer, oven, or microwave to speed up the drying process.

APPENDIX C:
RESPONDER SYSTEM MOUNTING BRACKET DESIGNS

Several custom brackets were designed and fabricated for the in-vehicle Responder system. The CAD (Computer-Aided Design) drawings for these brackets are provided in this appendix.

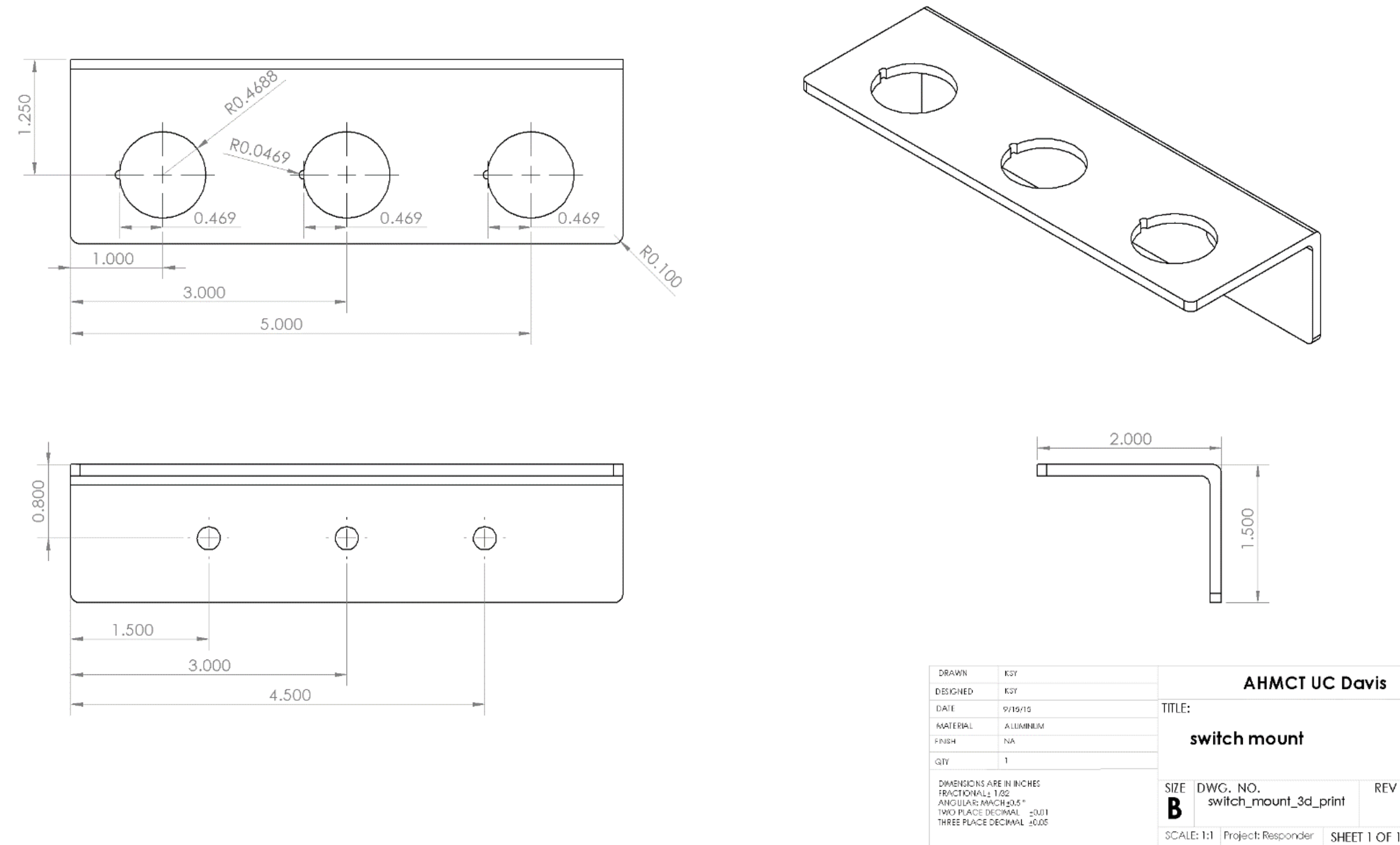


Figure C.1: Switch mount

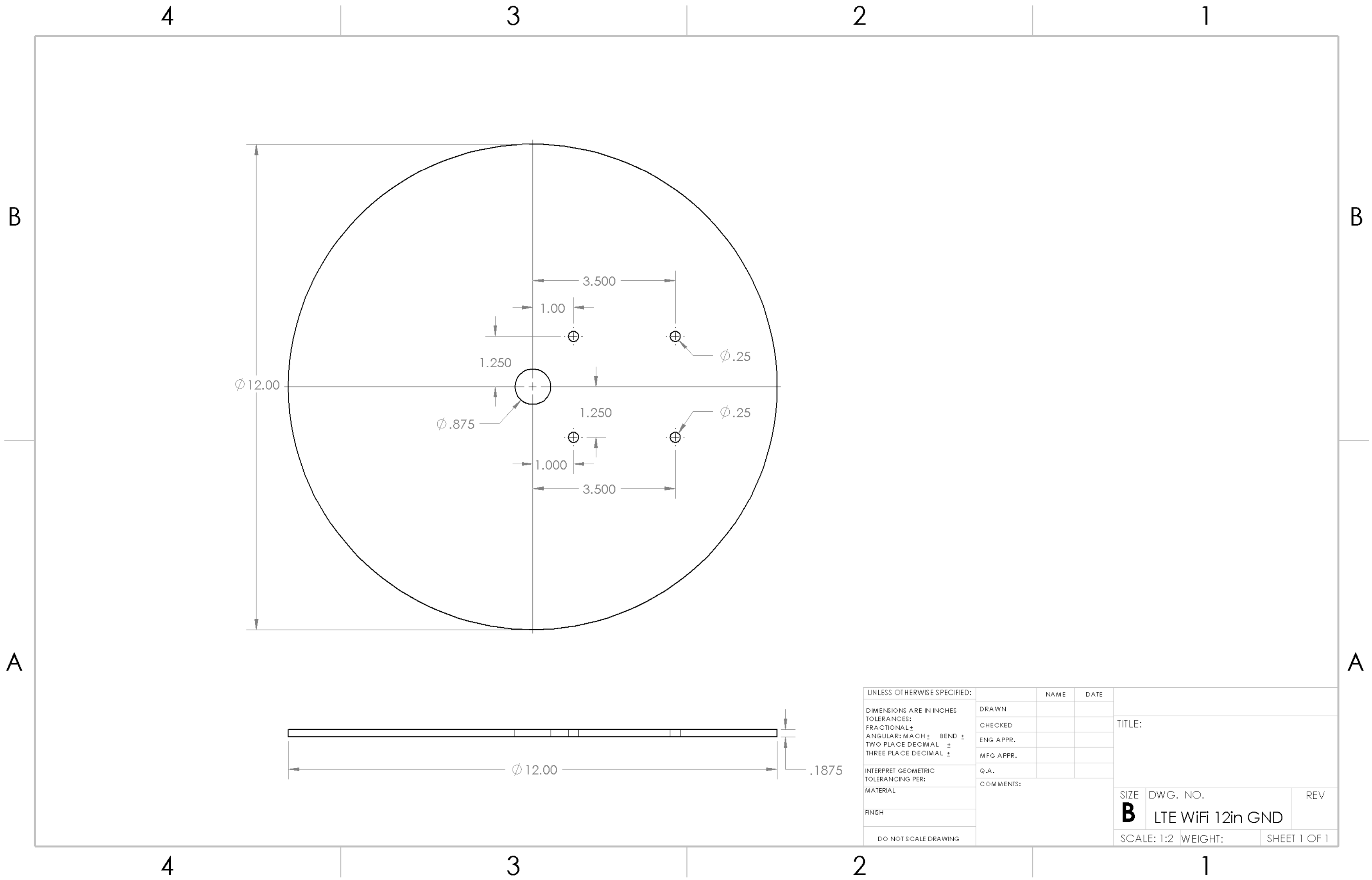


Figure C.2: Upper plate for LTE cellular, GPS, and Wi-Fi antenna mount

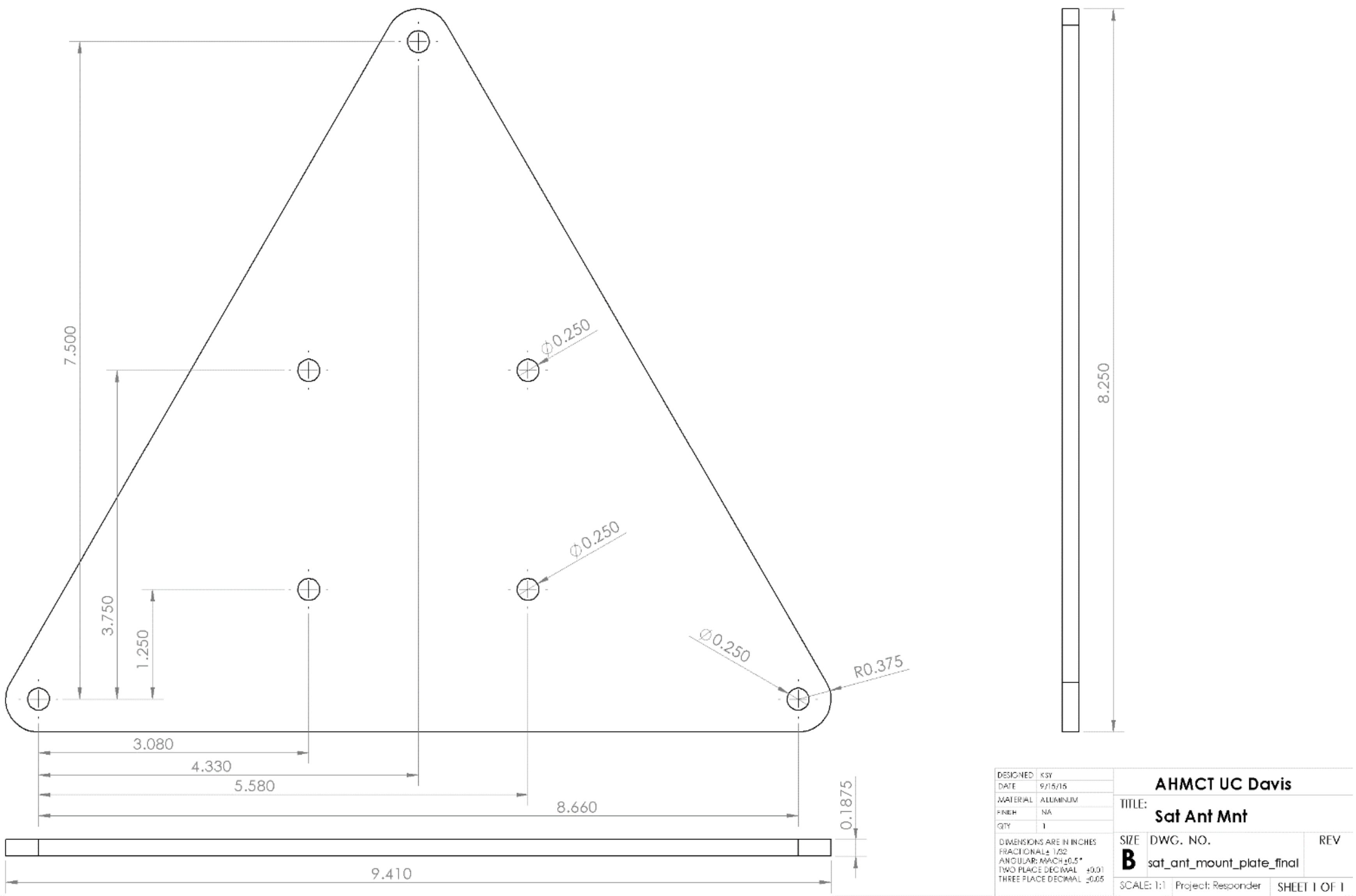


Figure C.3: Upper plate for satellite antenna mount

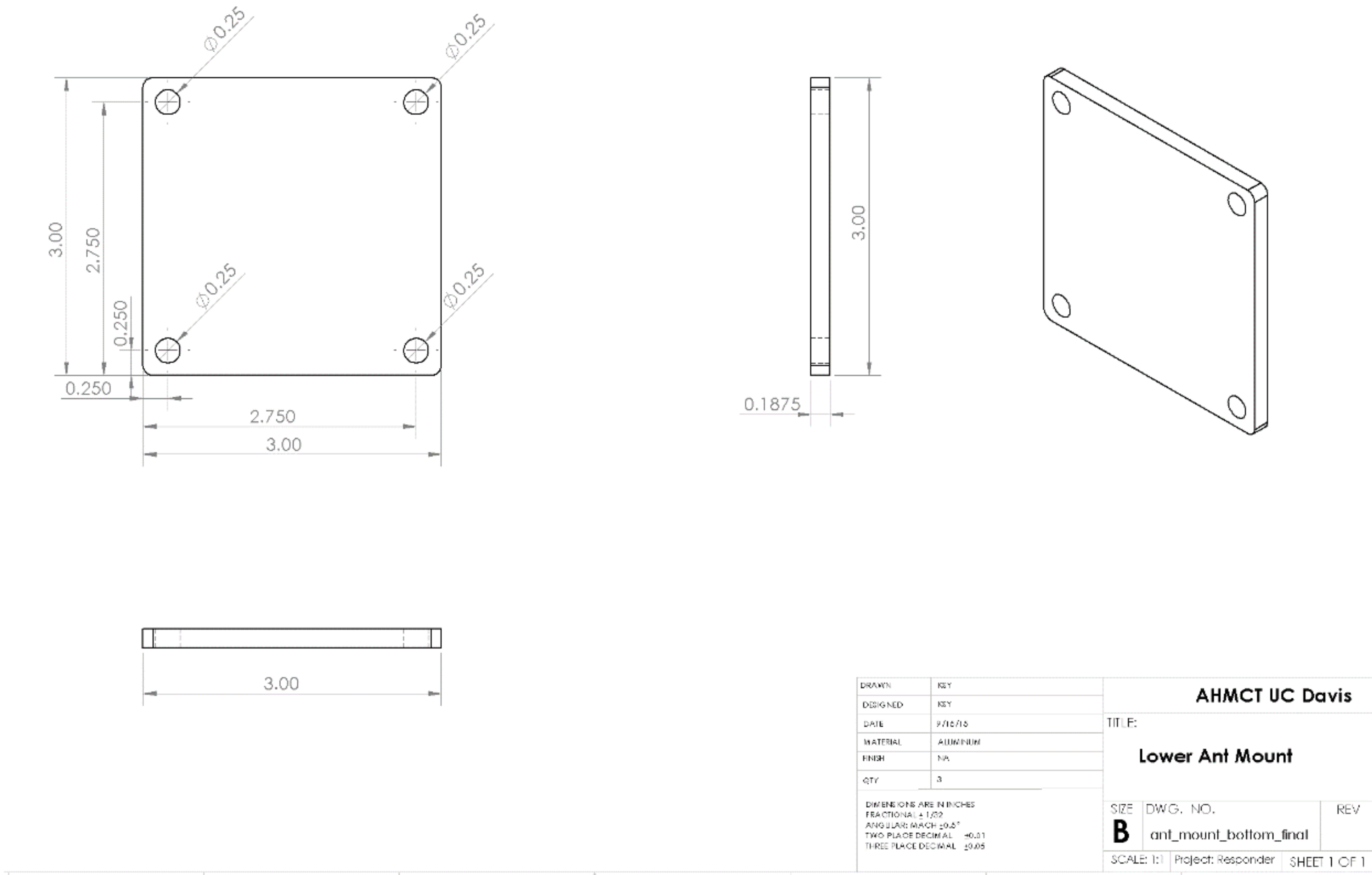


Figure C.4: Lower plate for all antenna mounts

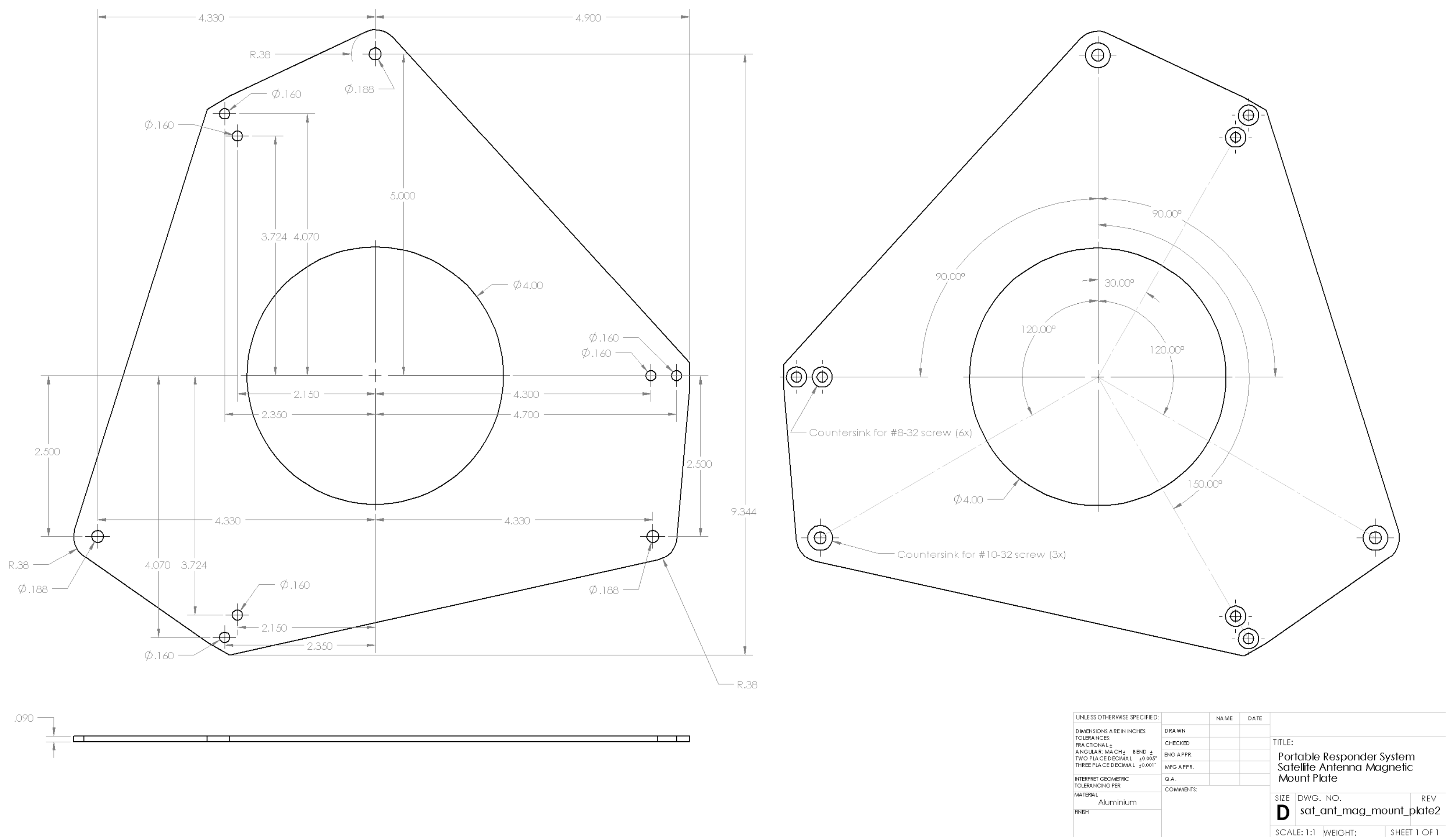


Figure C.5: Portable Responder system satellite antenna magnetic mount plate

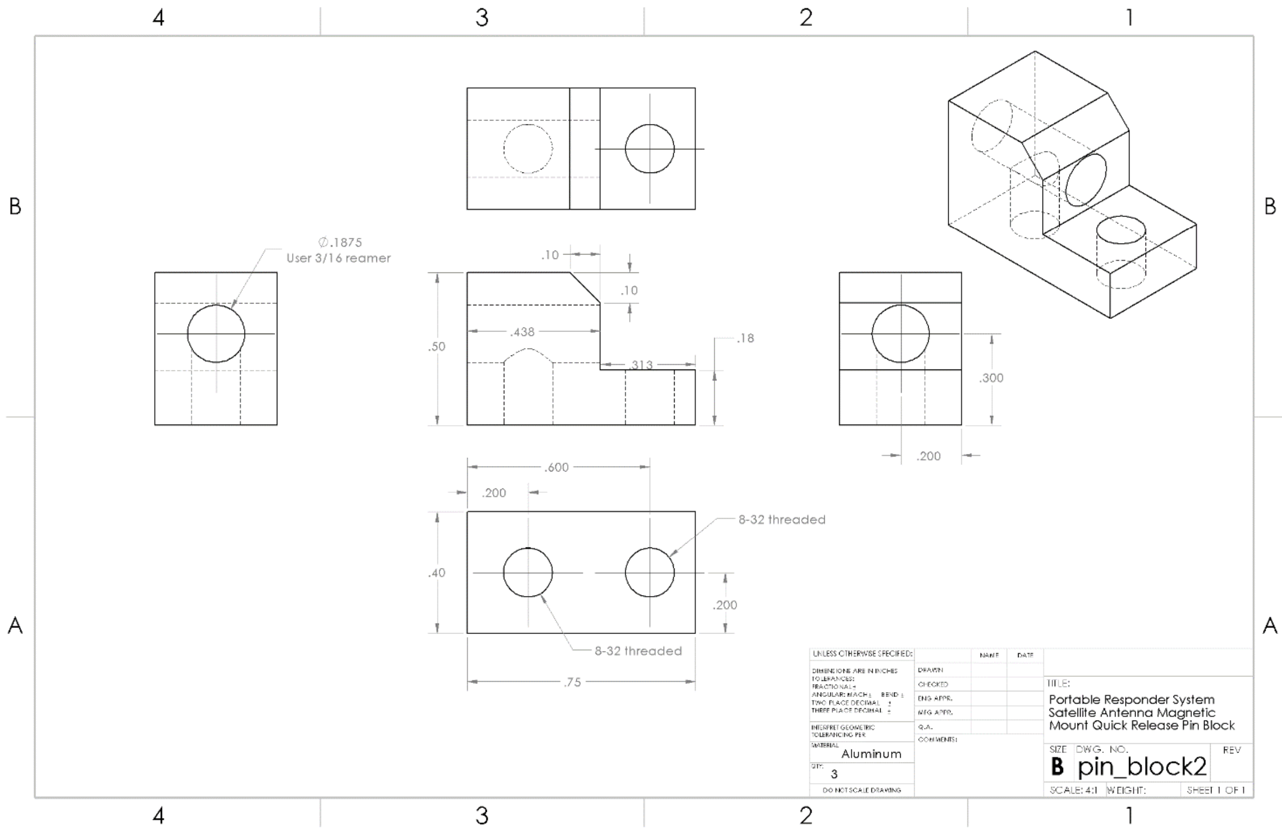


Figure C.6: Portable Responder system satellite antenna mount pin block

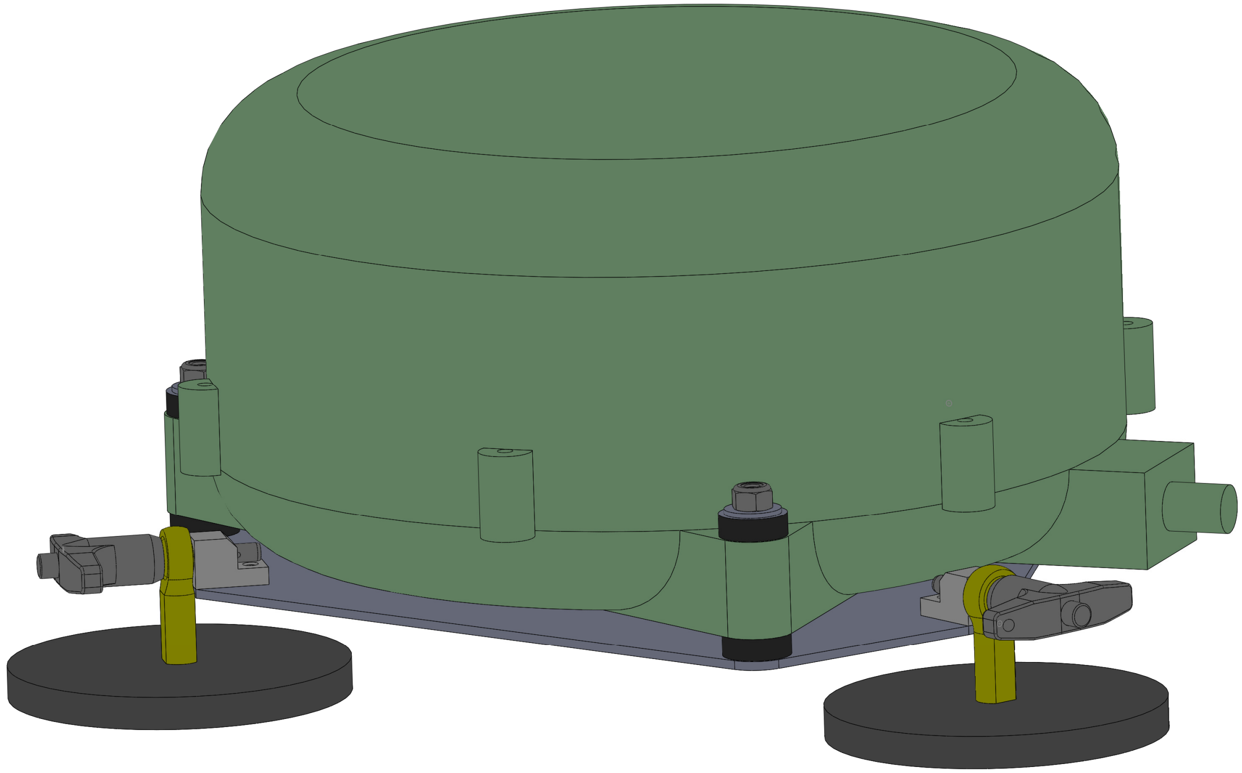


Figure C.7: Portable Responder system satellite antenna mount concept upper view

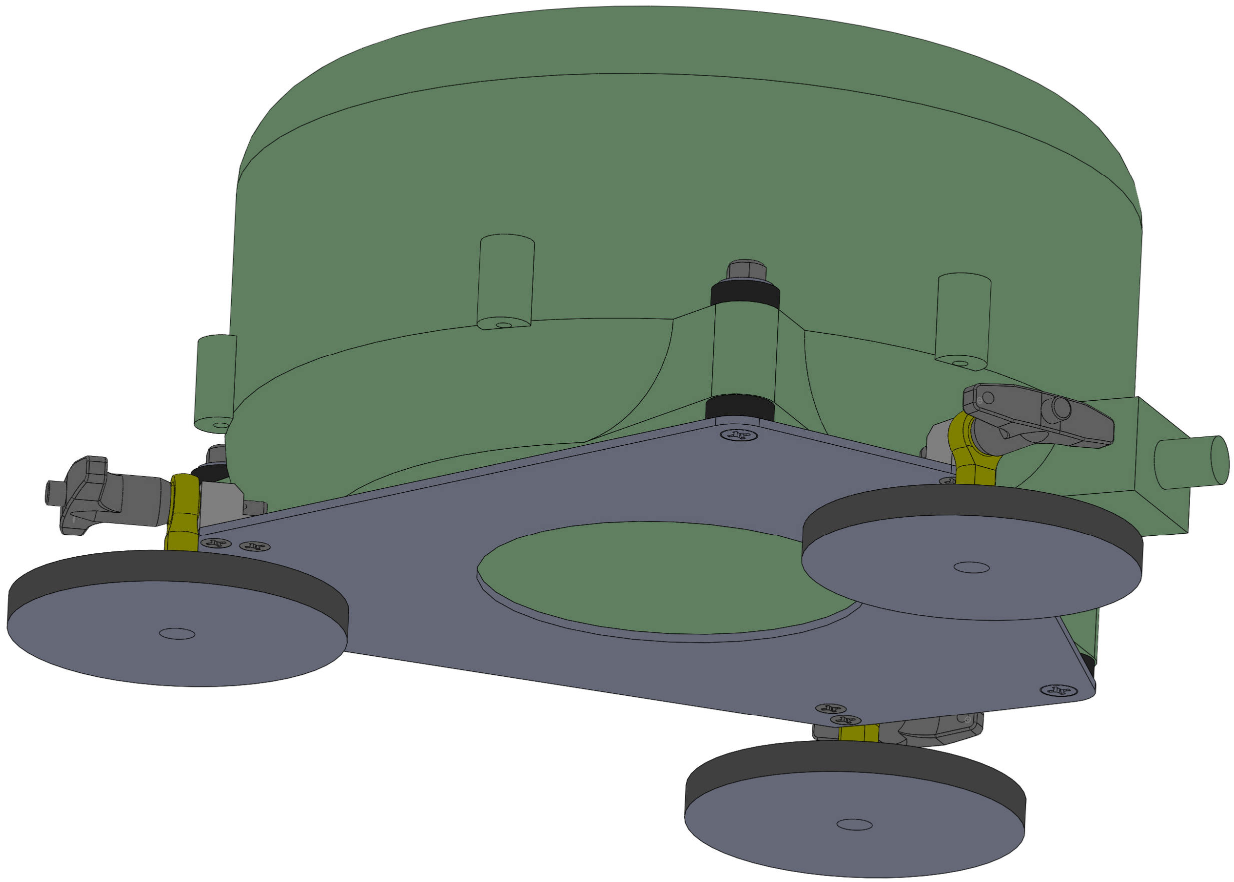


Figure C.8: Portable Responder system satellite antenna mount concept lower view

APPENDIX D:
CELLULAR SIGNAL COVERAGE AND STRENGTH

The Responder system is meant to function well throughout California, i.e. in both rural and urban areas. However, its most challenging design constraints arise in communications-challenged rural areas. The lower reliability and intermittent availability of cellular communications in rural environments was one of the main motivations for Responder. Given this, it is worthwhile to independently quantify the nature of this problem.

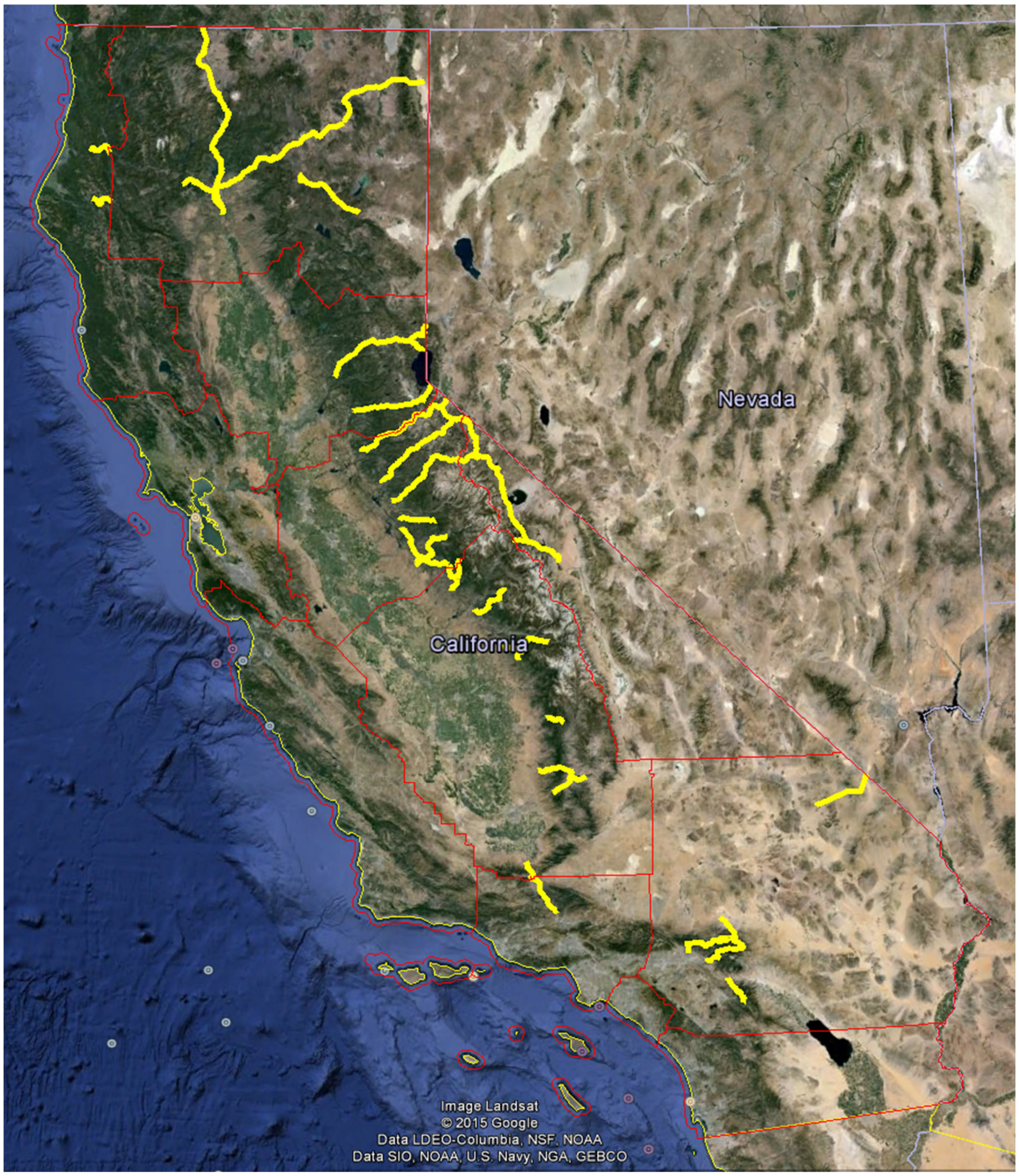


Figure D.1: Snow-affected routes (yellow) for California. Red boundaries represent Caltrans districts.

Under separate research, AHMCT performed a cellular survey on all snow-affected routes in California [1]. This survey determined cellular coverage and signal strength along all state routes where Caltrans performs winter maintenance. The area covered is shown in Figures C.1 – C.4. These snow-affected routes correlate strongly with Caltrans rural areas.

Figure D.2: Snow-affected routes (yellow) for northern California. Red boundaries represent Caltrans districts.

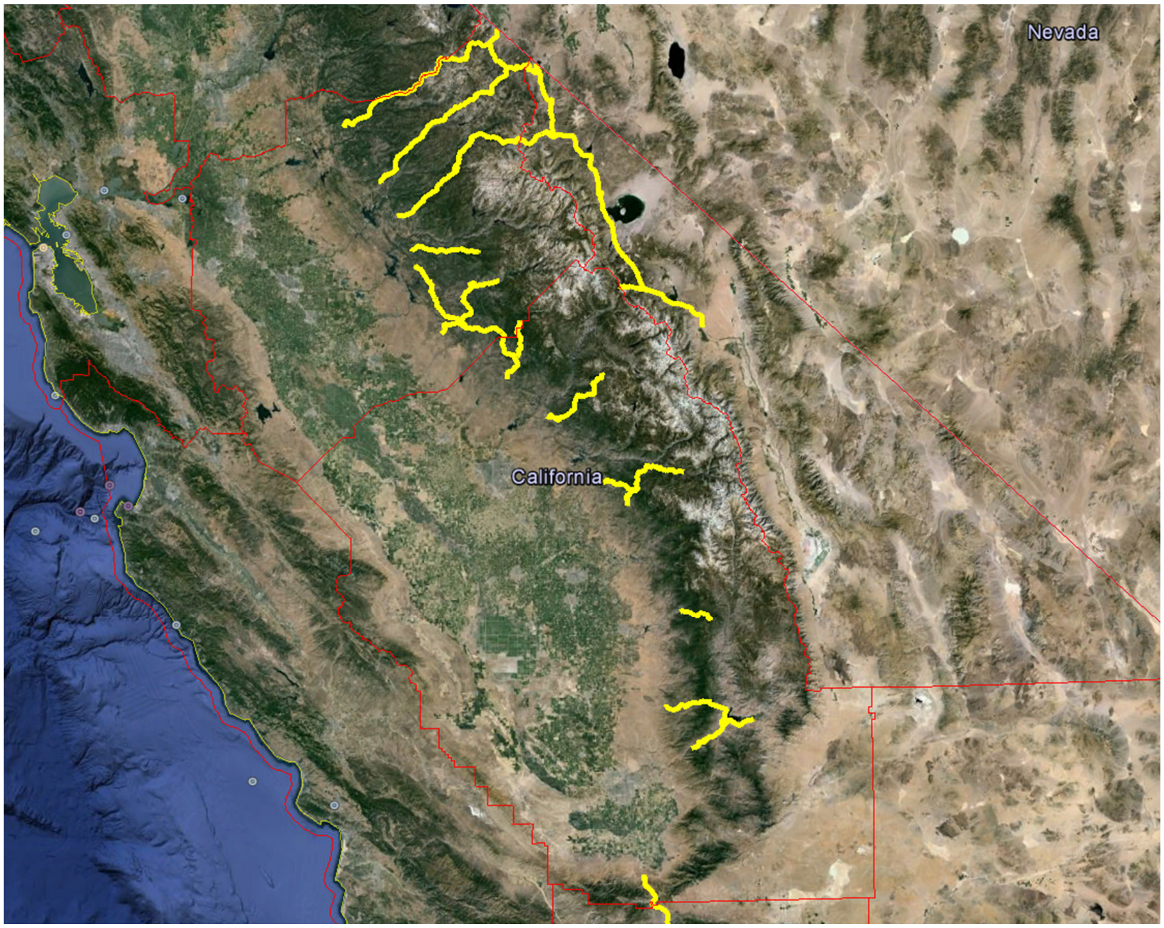


Figure D.3: Snow-affected routes (yellow) for central California. Red boundaries represent Caltrans districts.

To determine cellular coverage and signal strength for multiple cellular providers, AHMCT developed a survey strategy, cellular data collection hardware, and an Android application to sample and record signal strength. The data collection hardware and software, and detailed survey results are presented in [1]. Examples that are relevant for Responder are provided in Figures C.5 and C.6 (State Route 299 (SR 299) in northeast District 2), Figures C.7 – C.9 (SR 395 in District 9), and Figures C.10 – C.12 (SR 88 in District 10). The data was collected using an AHMCT research vehicle. The process consisted of driving each snow-affected route while capturing the providers' (T-Mobile, AT&T, and Verizon) signal strength as measured by the AHMCT's PowerMeter application. Location coordinates were also recorded using the smartphone's built-in GPS receiver. To perform the full survey, AHMCT spent three full working weeks on the road, logging a total of approximately 5000 miles.

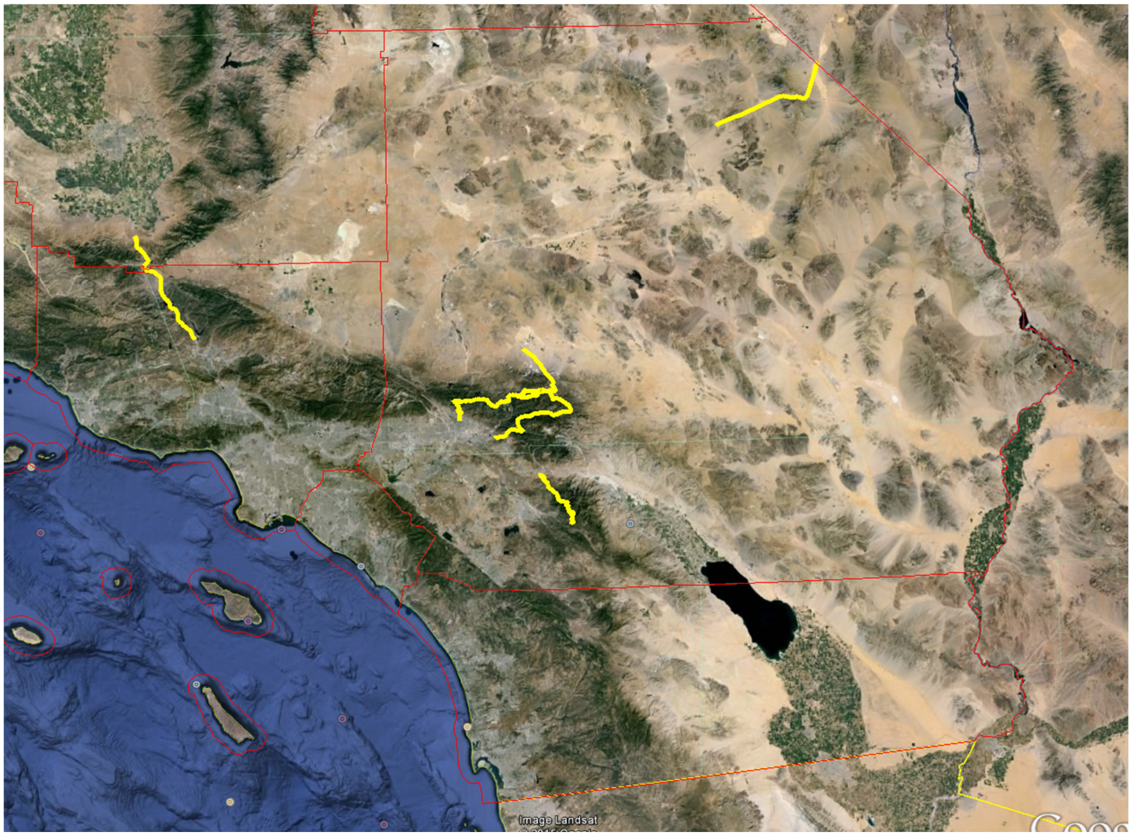


Figure D.4: Snow-affected routes (yellow) for southern California. Red boundaries represent Caltrans districts.

Figures C.5 and C.6 show the signal strength for AT&T and Verizon, respectively, on SR 299 from west of Nubieber to state line. Verizon provides better coverage and signal strength than AT&T in this rural area. Throughout the results, red areas represent the highest signal strength ("hot"), while orange, yellow, green, turquoise, and blue represent decreasing ("cooler") signal strength. If an area is not colored, no signal was detected for that carrier in that particular area. Table C.1 provides a key mapping color to strength.

Table D.1: Heat map key relating color to signal strength

Color	Signal Strength
Red	-75 dBm
Orange	-81 dBm
Yellow	-87 dBm
Green	-93 dBm
Turqoise	-99 dBm
Blue	-105 dBm
None	No signal detected

ATT Signal Strength (nexus4)

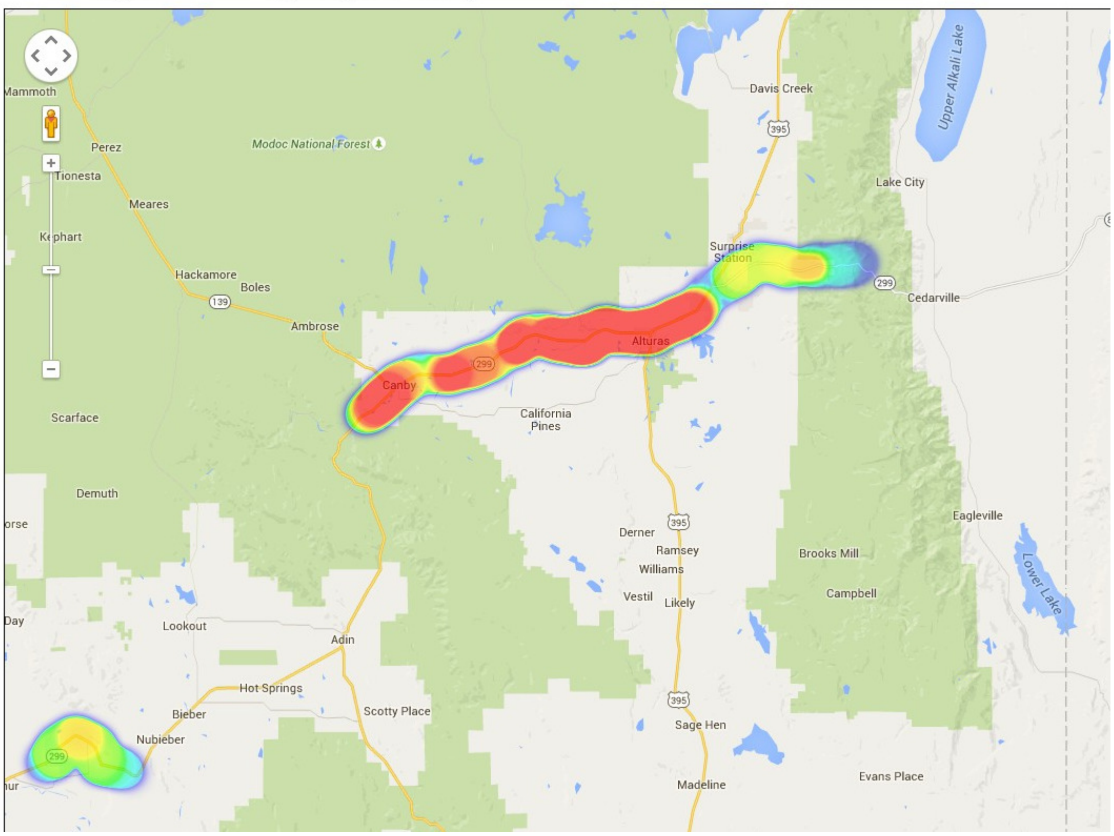


Figure D.5: AT&T signal strength for SR 299 from west of Nubieber to state line in Caltrans District 2 (survey: July 27, 2013 from 9:25 – 11:09)

Verizon Signal Strength (s4)

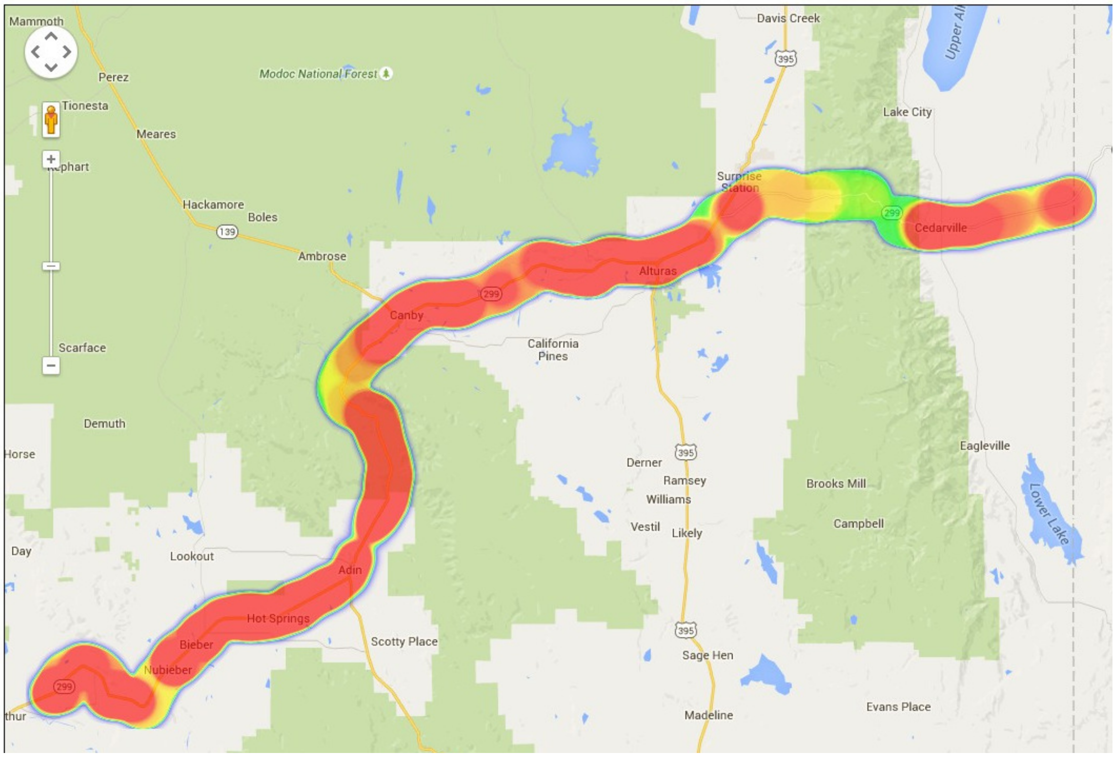


Figure D.6: Verizon signal strength for SR 299 from west of Nubieber to state line in Caltrans District 2 (survey: July 27, 2013 from 9:25 – 11:09)

Figures C.7 – C.9 show the signal strength for T-Mobile, AT&T, and Verizon, respectively, on SR 395 from Round Valley to state line. Here again, in much of this rural area, Verizon provides the better coverage. Note that between Bridgeport and Walker, Verizon does have a significant coverage gap. For any operations in this area, AT&T would be a much better choice. However, Verizon has better signal strength and coverage near Walker and Coleville. As such, for District 9 Responder implementation, inclusion of two cellular modems is well-justified. The best choice for dual-modem service would be AT&T and Verizon.

T-Mobile Signal Strength (galaxynexus)

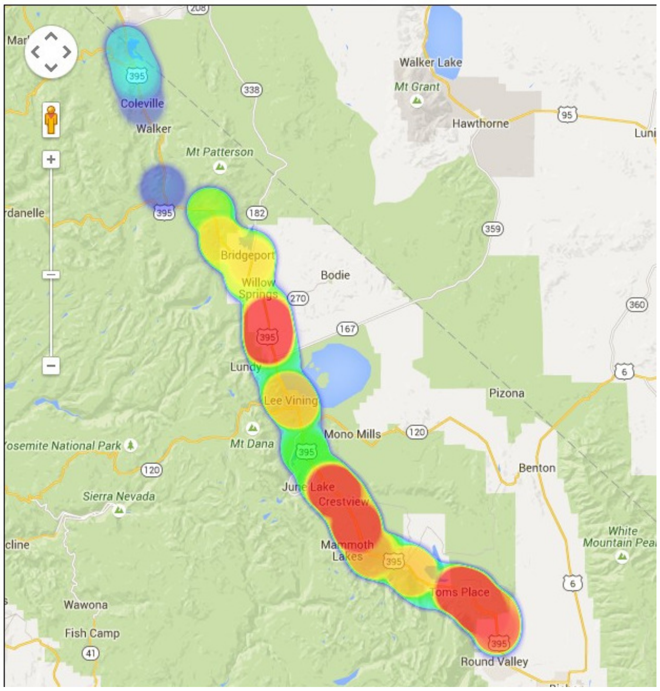


Figure D.7: T-Mobile signal strength for SR 395 from Round Valley to state line in Caltrans District 9 (survey: August 24, 2013 from 11:04 – 14:04)

ATT Signal Strength (nexus4)

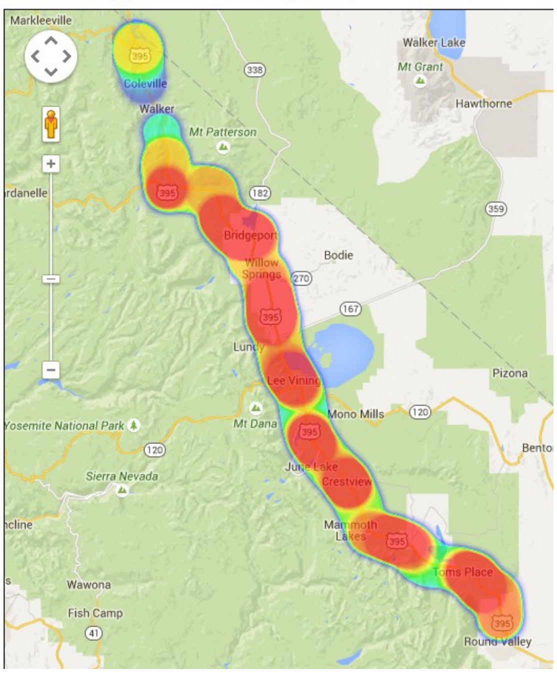


Figure D.8: AT&T signal strength for SR 395 from Round Valley to state line in Caltrans District 9 (survey: August 24, 2013 from 11:04 – 14:04)

Verizon Signal Strength (s4)

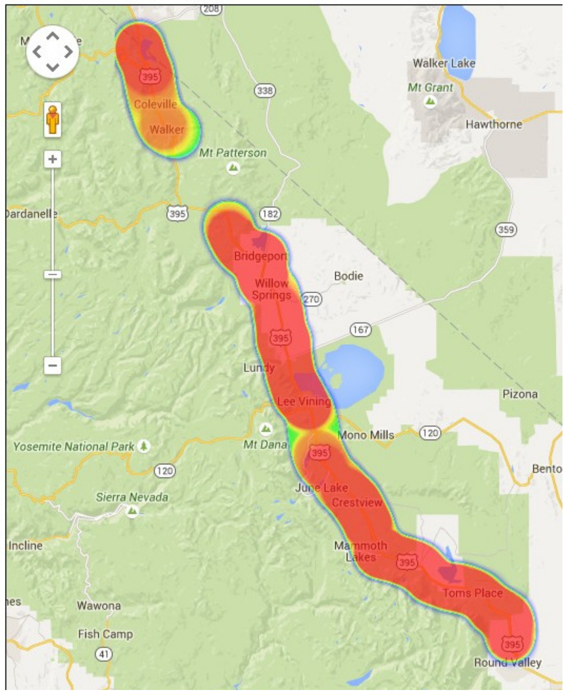


Figure D.9: Verizon signal strength for SR 395 from Round Valley to state line in Caltrans District 9 (survey: August 24, 2013 from 11:04 – 14:04)

As a final rural example, Figures C.10, C.11, and C.12 show the signal strength for T-Mobile, AT&T, and Verizon, respectively, on SR 88 from west of Pioneer to the state line. Again, Verizon provides better coverage and signal strength than T-Mobile or AT&T in this rural area. This general pattern was repeated in essentially all of the California snow-affected roadways, which again strongly correlate with rural areas. For semi-rural to rural areas, Verizon would be a good vendor for cellular data transmission. As noted in the District 9 example, inclusion of a second cellular modem with AT&T service could be justified in some areas.

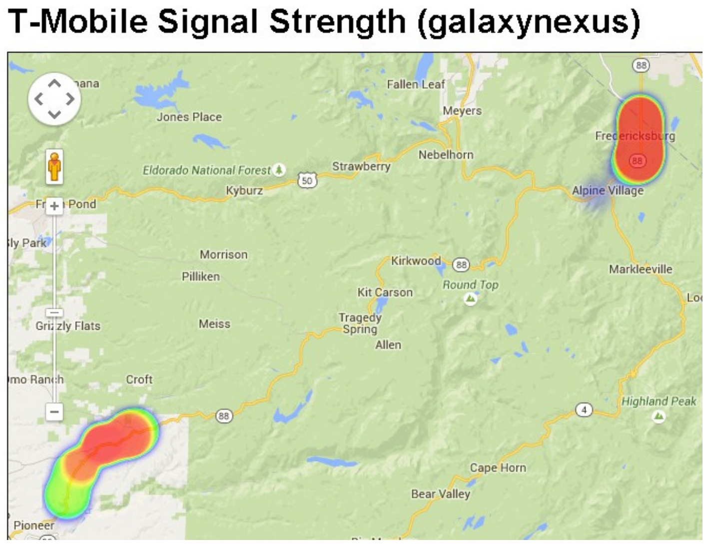


Figure D.10: T-Mobile signal strength for SR 88 from west of Pioneer to the state line in Caltrans District 10 (survey: August 3, 2013 from 12:25 – 13:52)

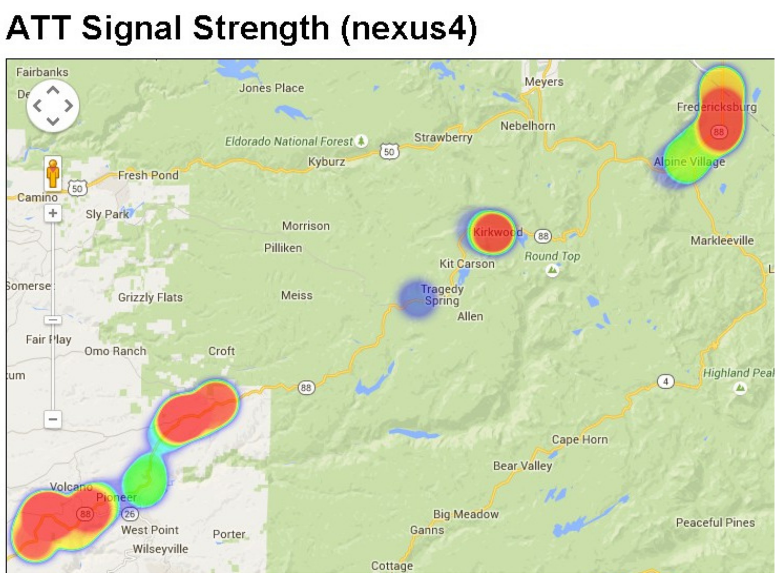


Figure D.11: AT&T signal strength for SR 88 from west of Pioneer to the state line in Caltrans District 10 (survey: August 3, 2013 from 12:25 – 13:52)

Verizon Signal Strength (s4)

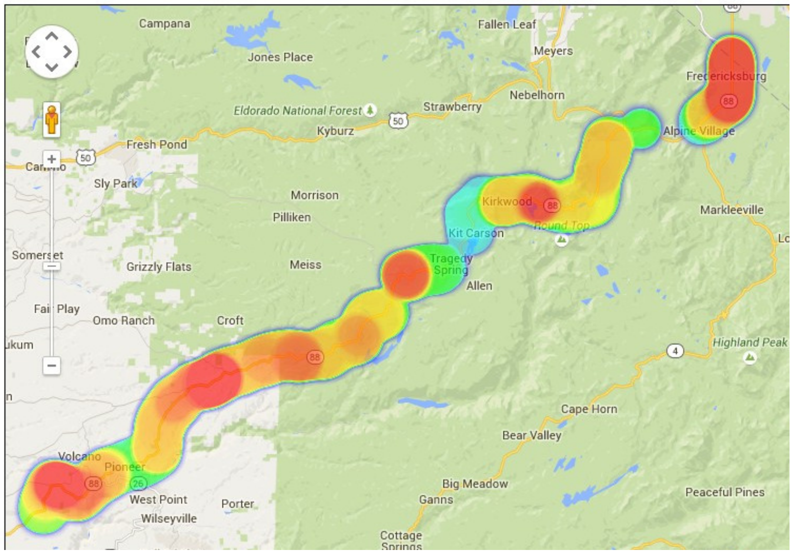


Figure D.12: Verizon signal strength for SR 88 from west of Pioneer to the state line in Caltrans District 10 (survey: August 3, 2013 from 12:25 – 13:52)

Beyond concluding which provider is the better choice in rural areas, the cellular coverage results clearly demonstrate that there are significant rural areas with either low signal strength or no coverage, for any cellular provider. This matches Caltrans and others intuitive or experience-based expectation, but clearly quantifies the issue. This conclusion provides a scientific basis for the decision to include additional means of communication, specifically satellite-based, for Responder. As satellite communication is also subject to blockage, e.g. in deep canyons or valleys, this also emphasizes the importance of Responder's use of a store-and-forward architecture. This architecture is discussed in Chapter 4. With this architecture, Responder can bridge areas of no communications, storing all messages and requests. Upon entering an area with cell or satellite coverage, the system then forwards messages and requests, and downloads any feed responses.