The Redding Responder Project: Mobile Data Communication Challenges and Solutions in Remote Rural Areas

Western States Rural Transportation Technology Implementers Forum

Mount Shasta, California

June 6-7

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Abstract:

In cooperation with the California Department of Transportation, Montana State University's Western Transportation Institute has developed a "proof-of-concept" mobile data communication system for use on any roadway, particularly in remote rural locations with little or no communication infrastructure.

Within this study, WTI investigated and evaluated data communication alternatives including satellite, cellular and land-mobile radio for use in Northern California.

This presentation will provide a detailed summary of our analysis techniques, our findings and their consequences, and resulting implementation decisions.

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A "Responder" Problem

Question:

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

Problem:

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

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"A Picture is Worth a Thousand Words"

Photograph - Topanga Canyon Boulder

Source: California Governor's Office of Emergency Services, Photos by Robert Eplett

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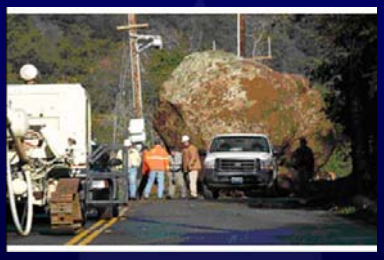
More Photos …



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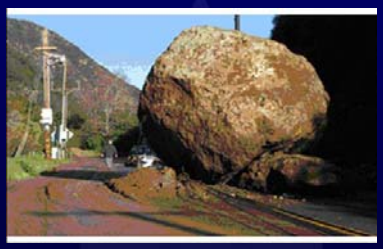

Photograph - Topanga Canyon Boulder

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A District 2 Rockslide
SR-70 Butte County

Source: Caltrans District 2

Incident Background from Press Release

REDDING – The California Department of Transportation (Caltrans) will begin immediate emergency road work to remove **soil and rocks, some measuring more than 15 feet in diameter from State Route (SR) 70 in Butte County**.

The slide **occurred February 25, 2004 at approximately 7:40 p.m. near Lake Oroville, 1.5 mile west of Pulga. The roadway is open to one-way traffic control and it is anticipated that it will reopen to normal traffic at 8 p.m., Friday, February 27, 2004.**

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

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

Source: Caltrans District 2

Additional Information

- The road was cleared on Saturday, February 28th.
- Phone lines at Pulga, 1.5 mi east were out.
- It was estimated that each incident photo would have taken 15-20 minutes to transmit.
- Photos were not transmitted until the maintenance supervisor returned to Quincy, 55 miles to the east, on February 26th.

Additional Information

- Communication challenges were encountered while making arrangements to secure equipment.
- The maintenance supervisor had to drive to Concow, 6 mi to the southwest, for cellular coverage.
- An estimated 4-6 hours were lost due to back and forth trips to call blasting companies.
- Attempts to use dispatch as an intermediary were dismissed due to reluctance on the part of the blasting companies. They wanted to communicate directly with the maintenance supervisor.
- Under ideal circumstances the incident could have been cleared by noon on the 27th as opposed to the 28th.
- The transmission of incident photos may have helped to achieve this.

System Concept

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

Communication

- Interesting, Challenging, Important
- Two means analyzed: cellular, satellite.
- Viewed as complementary.
- No attempt to compare providers.
- Other possibilities: 800 MHz.

Preliminary Testing in Montana

- Tests of both cellular and satellite.
- "Interesting" observations for satellite when used in rugged terrain.
- Used OTC equipment.
- Developed testing methodologies.

Satellite Observations

- Calls were dropped in the shadow of tall mountains.
- Signal strength fluctuated dramatically.
- Data connections required multiple attempts for download and upload.
- With a relatively clear view of the sky, signal strength is high and steady.

Impact

- Dropped voice calls are a nuisance. Redial is necessary.
- Dropped data calls can be disastrous. Must redial and start over.

Communication Options and Pricing

- Globalstar Satellite
  - $0.49 to $0.99 per minute
  - They report rates as low as $0.20 per minute, but not shown on website.
- Verizon Wireless
  - $79.99 / mo, unlimited usage
  - (now $59.99 / mo)
- Government discounts are available.

Communication Coverage

- Globalstar
  - Anywhere in the continental U.S. with a "clear view of the sky."
- Verizon
  - Available nationwide, primarily along roadways and in urban areas.
  - There are still un-serviced areas, particularly for data service.

Data Rates

- Globalstar
  - 9.6 Kbps max
- Verizon
  - Quick2Net: 14.4Kbps
  - NationalAccess (1xRTT): 60-80Kbps avg, 144Kbps bursts
  - BroadbandAccess (EV-DO): 400-700Kbps, 2Mbps theoretical max.

Propagation Analyses for Land-Mobile Radio and Cellular

- Analysis was conducted for several study areas in the RIME region.
- Tower Sites were selected from FCC database.
- Not meant to show actual coverage.
- Meant to show the impact of terrain on prospective coverage.

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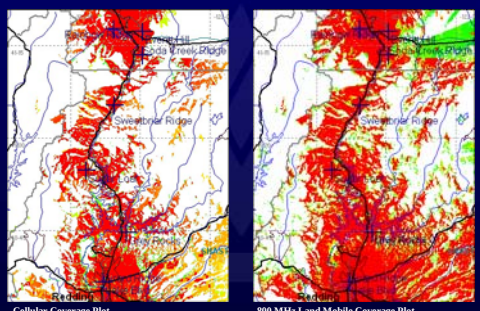
Modeled Cellular and 800 MHz Coverage: Redding to Mt. Shasta



Cellular Coverage Plot

30 dBu – Roughly equivalent to 5 level bar
20 dBu – Roughly equivalent to 3 level bar
10 dBu – Roughly equivalent to 1 level bar

800 MHz Land Mobile Coverage Plot

20 dBu - Excellent land mobile coverage
10 dBu -Good land mobile coverage
0 dBu -Acceptable land mobile coverage

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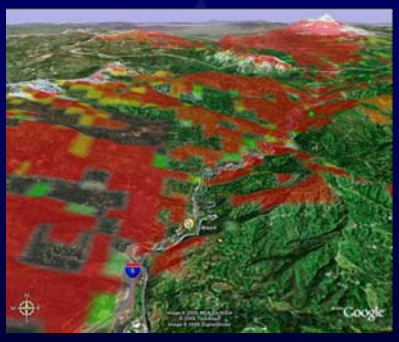
Modeled Cellular Coverage Gibson area, North to Mt. Shasta



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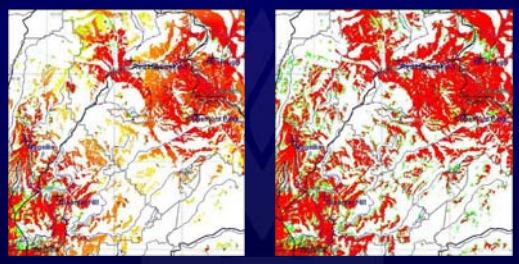
Modeled Cellular and 800 MHz Coverage: Oroville to Quincy



SR-70 Cellular Coverage Plot

30 dBu – Roughly equivalent to 5 level bar
20 dBu – Roughly equivalent to 3 level bar
10 dBu – Roughly equivalent to 1 level bar

SR-70 800 MHz Land Mobile Coverage Plot

20 dBu - Excellent land mobile coverage
10 dBu -Good land mobile coverage
0 dBu -Acceptable land mobile coverage

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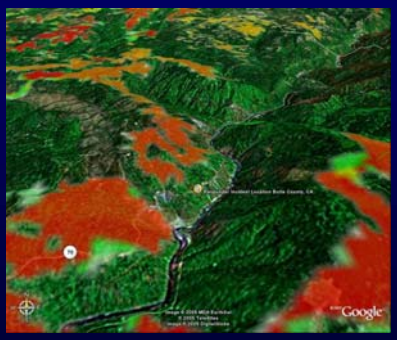
Modeled Cellular Coverage Near SR-70 Incident Location



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Northern California Cellular Signal Strength Drive Tests

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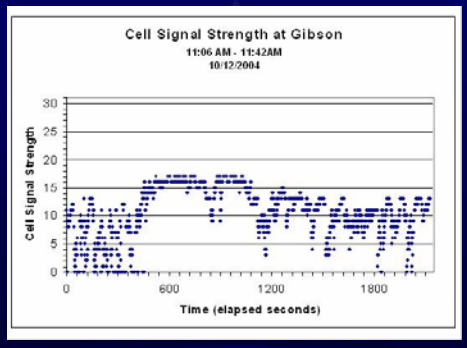
Northern California Cellular Signal Strength Drive Tests

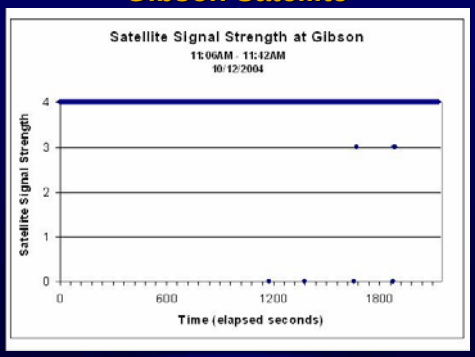
Excellent Signal
Good Signal
Poor Signal or No Signal

Site Tests: Gibson

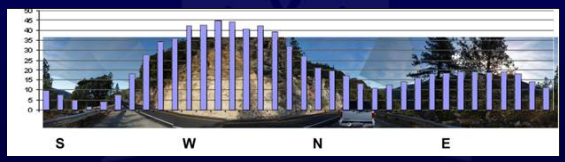
Gibson Cellular



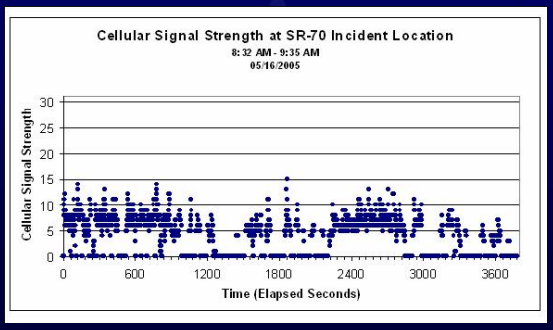
Gibson Satellite



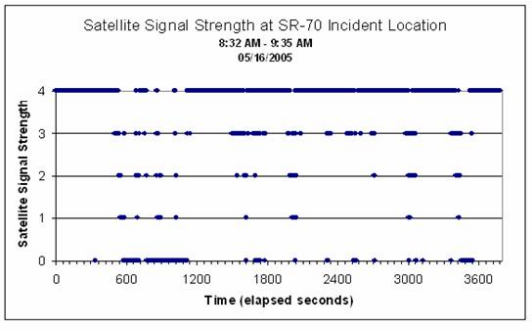
Site Tests: SR-70 Butte



SR-70 Butte Cellular



SR-70 Butte Satellite



SR-70 Butte Satellite Available / Unavailable Intervals

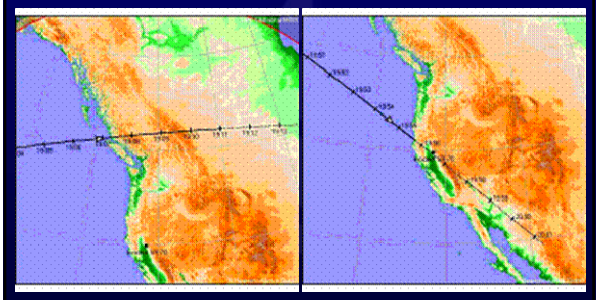
signal available	duration (min)	elapsed (min)	elapsed (sec)
yes	5.57	5.57	334
no	0.18	5.75	345
yes	3.82	9.57	574
no	2.05	11.62	697
yes	1.08	12.70	762
no	5.75	18.45	1107
yes	19.80	38.25	2295
no	0.25	38.50	2310
yes	3.75	42.25	2535
no	0.23	42.48	2549
yes	8.27	50.75	3045
no	0.13	50.88	3053
yes	6.33	57.22	3433
no	1.25	58.47	3508
yes	4.32	62.78	3767

The Globalstar System

- There are 48 total satellites, 6 per orbit plane.
- There are 8 orbit planes, each with a declination of 52 degrees.
- The satellites orbit at approximately 1,410 km above the earth and with a period of approximately 114 minutes.
- The satellite nominal footprint is 5,850 km.
- LEO, not GEO

Globalstar Constellation

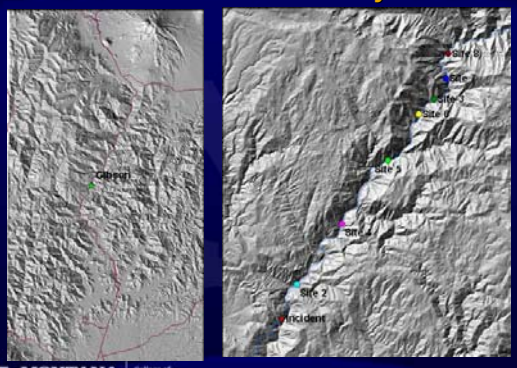
Globalstar Satellite Paths



Test Sites (and Scenarios) for Model of System

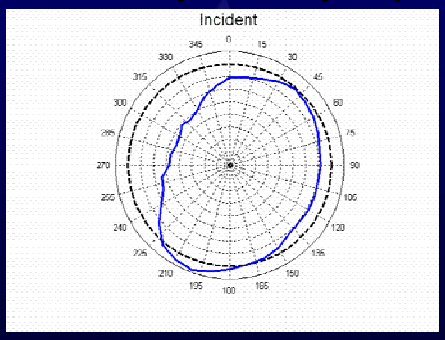
	Latitude	Longitude	Elevation (m)
Gibson	41.02261	-122.39877	496
Incident	39.77616	-121.45572	555
Incident No Elevation	39.77616	-121.45572	555
Incident Bowl 15	39.77616	-121.45572	555
Incident Bowl 30	39.77616	-121.45572	555
Incident Bowl 45	39.77616	-121.45572	555
Incident Vegetation	39.77616	-121.45572	555
Site 2	39.80453	-121.43974	422
Site 3	39.95749	-121.29116	624
Site 4	39.85434	-121.39110	462
Site 5	39.90676	-121.34105	534
Site 6	39.94519	-121.30733	619
Site 7	39.97464	-121.27799	662
Site 8	39.99533	-121.27485	693

Test Sites for Model of System

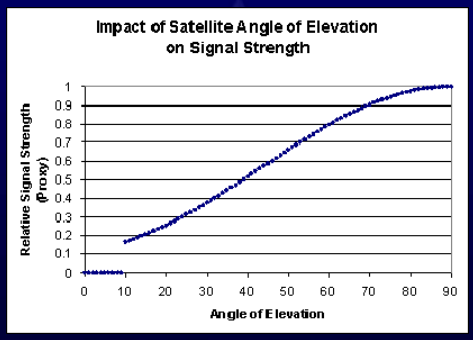


Sites 6, 3, 7 & 8 – Feather River Canyon

SR-70 Sky Visibility Map



Impact of Angle of Elevation on Signal Strength



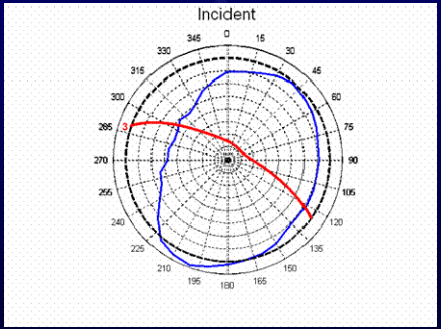
Sites and Sky Blockage Statistics

	Gibson	Incident	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Mean	11.0	21.9	18.1	22.5	26.1	26.0	23.2	27.9	27.6
Std Dev	4.2	12.8	5.8	6.7	9.6	8.9	7.2	7.7	9.0
Min	2.9	1.8	7.3	8.9	8.7	9.8	9.8	12.6	7.8
Max	17.2	45.1	28.8	31.4	41.3	36.8	33.8	40.1	40.7
Block. Sky pct.	0.23	0.41	0.36	0.43	0.49	0.48	0.44	0.52	0.51
Block. Sat. Sky pct.	0.06	0.27	0.19	0.28	0.35	0.35	0.29	0.39	0.38
Block. Sig. Potential pct.	0.02	0.15	0.08	0.14	0.19	0.19	0.15	0.21	0.21

Scenarios and Sky Blockage Statistics

	Incident	Incident No Elevation	Incident Bowl 15	Incident Bowl 30	Incident Bowl 45	Incident Vegetation
Mean	21.9	0.0	15.0	30.0	45.0	26.1
Std Dev	12.8	0.0	0.0	0.0	0.0	12.2
Min	1.8	0.0	15.0	30.0	45.0	7.6
Max	45.1	0.0	15.0	30.0	45.0	45.1
Block. Sky pct.	0.41	0.00	0.31	0.56	0.75	0.48
Block. Sat. Sky pct.	0.27	0.00	0.12	0.44	0.68	0.34
Block. Sig. Potential pct.	0.15	0.00	0.05	0.23	0.48	0.20

Single Satellite Path – 17 min



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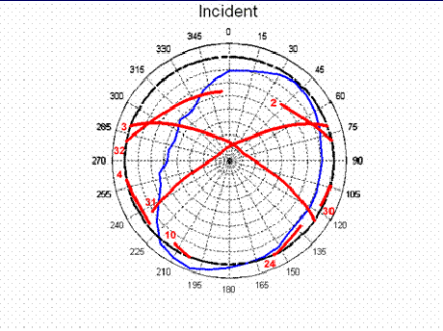
Multiple Satellites – 17 min



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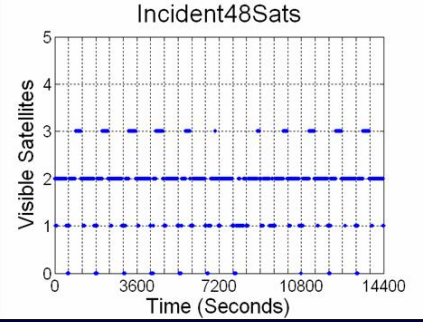
Modeled Visible Satellites



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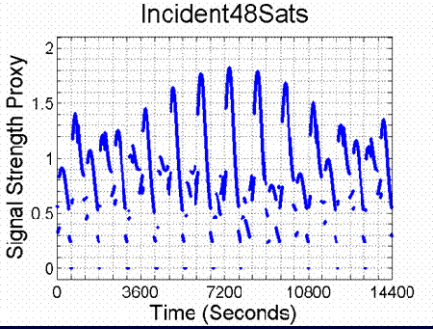
Modeled (Proxy) Signal Strength



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Modeled Visible Satellite Statistics 40 Satellite Constellation

Site	Sats Mean	Sats Min	Sats Max	Sats Std Dev	Sats Percent = 0	Sats Percent = 1	Sats Percent = 2	Sats Percent = 3	Sats Percent = 4	Sats Percent = 5
Gibson 40 Sats	2.40	1	4	0.77	0.00	0.38	0.55	0.28	0.10	0.00
Incident 40 Sats	1.57	0	3	0.67	0.04	0.35	0.61	0.30	0.00	0.00
Incident 40 Sats No Elevation	2.70	1	4	0.79	0.00	0.32	0.44	0.36	0.19	0.00
Incident 40 Sats Bowl 15	2.18	1	4	0.71	0.00	0.13	0.61	0.21	0.05	0.00
Incident 40 Sats Bowl 30	1.12	0	3	0.76	0.23	0.43	0.34	0.00	0.00	0.00
Incident 40 Sats Bowl 45	0.42	0	2	0.69	0.70	0.19	0.11	0.00	0.00	0.00
Incident Vegetation 40 Sats	1.31	0	3	0.66	0.10	0.49	0.42	0.00	0.00	0.00
Site 2 - 40 Sats	1.91	0	4	0.72	0.03	0.23	0.69	0.14	0.02	0.00
Site 3 - 40 Sats	1.77	0	4	0.72	0.03	0.33	0.62	0.13	0.01	0.00
Site 4 - 40 Sats	1.24	0	3	0.74	0.16	0.39	0.43	0.00	0.00	0.00
Site 5 - 40 Sats	1.78	0	4	0.79	0.03	0.40	0.41	0.16	0.02	0.00
Site 6 - 40 Sats	1.46	0	3	0.82	0.07	0.41	0.62	0.00	0.00	0.00
Site 7 - 40 Sats	1.17	0	3	0.76	0.21	0.41	0.38	0.00	0.00	0.00
Site 8 - 40 Sats	1.14	0	3	0.70	0.16	0.49	0.32	0.00	0.00	0.00

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Modeled (Proxy) Signal Strength Statistics 40 Satellite Constellation

Site	Signal Mean	Signal Min	Signal Max	Signal Std Dev	Signal Percent = 0	Signal Percent 0<x<=0.5	Signal Percent 0.5<x<=1.0	Signal Percent 1.0<x<=1.5	Signal Percent 1.5<x<=2
Gibson 40 Sats	0.99	0.37	1.81	0.35	0.00	0.05	0.49	0.37	0.10
Incident 40 Sats	0.73	0.00	1.82	0.45	0.04	0.33	0.38	0.17	0.08
Incident 40 Sats No Elevation	1.03	0.39	1.82	0.34	0.00	0.02	0.48	0.38	0.11
Incident 40 Sats Bowl 15	0.94	0.31	1.82	0.37	0.00	0.13	0.44	0.35	0.08
Incident 40 Sats Bowl 30	0.64	0.00	1.82	0.52	0.23	0.30	0.18	0.21	0.08
Incident 40 Sats Bowl 45	0.31	0.00	1.82	0.53	0.70	0.00	0.19	0.04	0.08
Incident Vegetation 40 Sats	0.66	0.00	1.82	0.46	0.10	0.36	0.30	0.15	0.08
Site 2 - 40 Sats	0.87	0.00	1.82	0.42	0.02	0.26	0.32	0.32	0.08
Site 3 - 40 Sats	0.83	0.00	1.82	0.44	0.02	0.33	0.27	0.30	0.08
Site 4 - 40 Sats	0.66	0.00	1.82	0.50	0.16	0.28	0.29	0.17	0.08
Site 5 - 40 Sats	0.81	0.00	1.82	0.45	0.02	0.35	0.26	0.29	0.08
Site 6 - 40 Sats	0.74	0.00	1.82	0.46	0.07	0.36	0.29	0.21	0.08
Site 7 - 40 Sats	0.65	0.00	1.82	0.51	0.21	0.27	0.27	0.17	0.08
Site 8 - 40 Sats	0.63	0.00	1.82	0.51	0.18	0.34	0.20	0.19	0.08

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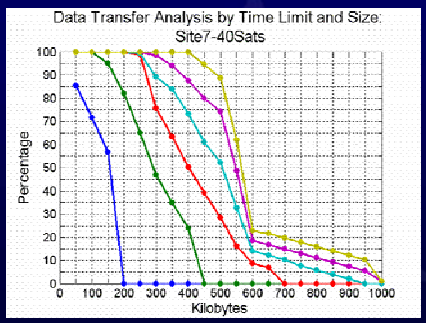
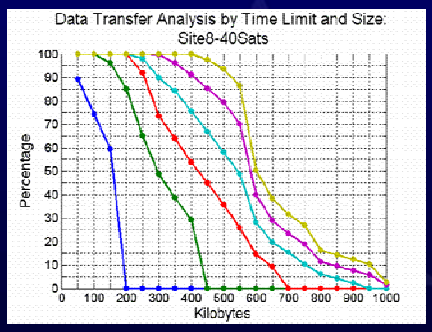
Modeled Data Transfer Analysis

- Data modeled for 1 week at 1 second intervals
- Determine if data could be transferred at given point in time.
- If not, redial and try again.
- Try to complete transmission within time limit.

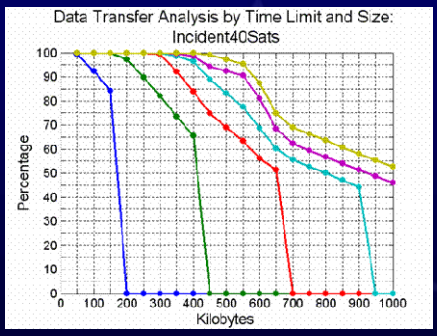
Modeled Data Transfer Analysis – Site 7



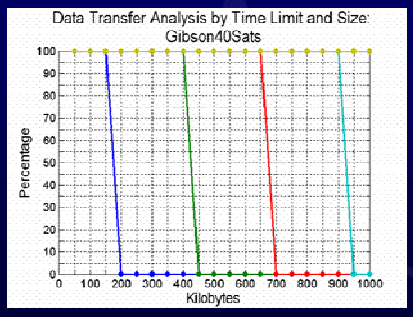
Modeled Data Transfer Analysis – Site 8



Modeled Data Transfer Analysis – SR 70 Butte



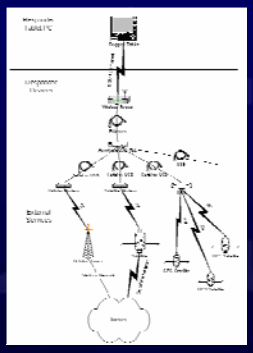
Modeled Data Transfer Analysis – Gibson



Conclusions from Model

- Sky obstruction can have an adverse affect on data transmission.
- Limits need to be set on data size. (500KB or less)
- Re-connects should be implemented, with a time limit.
- May need to consider other options: chunking or connection management software.

Logical Hardware and Communication Framework



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Responder "Proof of Concept" System

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Components

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

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The Responder "Briefcase"

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Inside the Responder "Briefcase"

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Responder Software – The Incident Organizer

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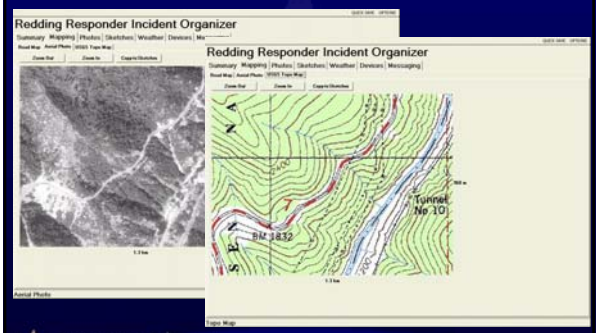
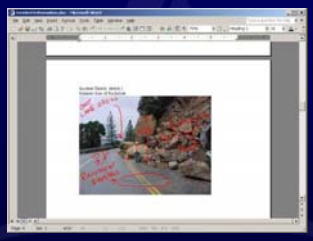
Maps – Preloaded



Digital Photos – Preview and Selection

Weather – "Get Weather"

Incident Information via Microsoft Word Attachment to Email



Evaluation: Survey, Demonstrations, Discussions and Field Testing

Maintenance Staff:

- *"It looks like it's really user friendly. I think with a minimal amount of training I could walk outside and do it right now."*
- *"(It) looks almost fool-proof, there's only one way to go …"*

Evaluation: Survey, Demonstrations, Discussions and Field Testing

Reality Check:

- *"The key for the next phase is just as hard as this, if not harder. That's coming up with a slick, clean, reliable design that will work in the field that's easy enough to use that field guys will use it and that it will be a benefit to them. "*
- *"He's right. Especially with my folks. Reliability is everything. You fail once, especially in the beginning, it'll sit and collect dust."*

Evaluation: Survey, Demonstrations, Discussions and Field Testing

After limited Caltrans' field testing:

I had couple moments when it was flaky but the way I look at it (is that) in a couple places I was standing in the middle of nowhere (with) no other form of communication. ... it was still pretty neat to actually get out and pass on some information from the middle of nowhere.

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

We have:

- A working, proof-of-concept system.
- Detailed requirements.
- An evaluation of communication alternatives.