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

National Rural ITS Conference 2006
Big Sky Montana
Monday, August 14th, 2006
9:45 AM
Session A4: Innovative Communication Solutions

Doug Galarus
Senior Research Associate,
Program Manager (Systems Engineering, Development & Integration)

Dr. Bill Jameson
Senior Research Scientist

Western Transportation Institute

Jeff Kiser
Field Region Manager, Maintenance Operations
Project Champion
Caltrans District 2

MONTANA STATE UNIVERSITY | College of ENGINEERING

Mountains & Minds

Related Sessions:

The Redding Responder Project: Computing and Communication in the Middle of No-Where

Session H2: Innovative Data Collection and Sharing

Wednesday, August 16th, 8:30 am

The Application of Systems and Software Engineering Process Models for Development on Small to Moderate-Sized ITS Projects: WeatherShare and the Redding Responder Projects

Session G2: Using Existing Technology in New Ways

Tuesday, August 15th, 2:45 pm

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 summary of our analysis techniques, our findings and their consequences, and resulting implementation decisions.

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?

“A Picture is Worth a Thousand Words”

A Caltrans 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 (Northern California) 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.

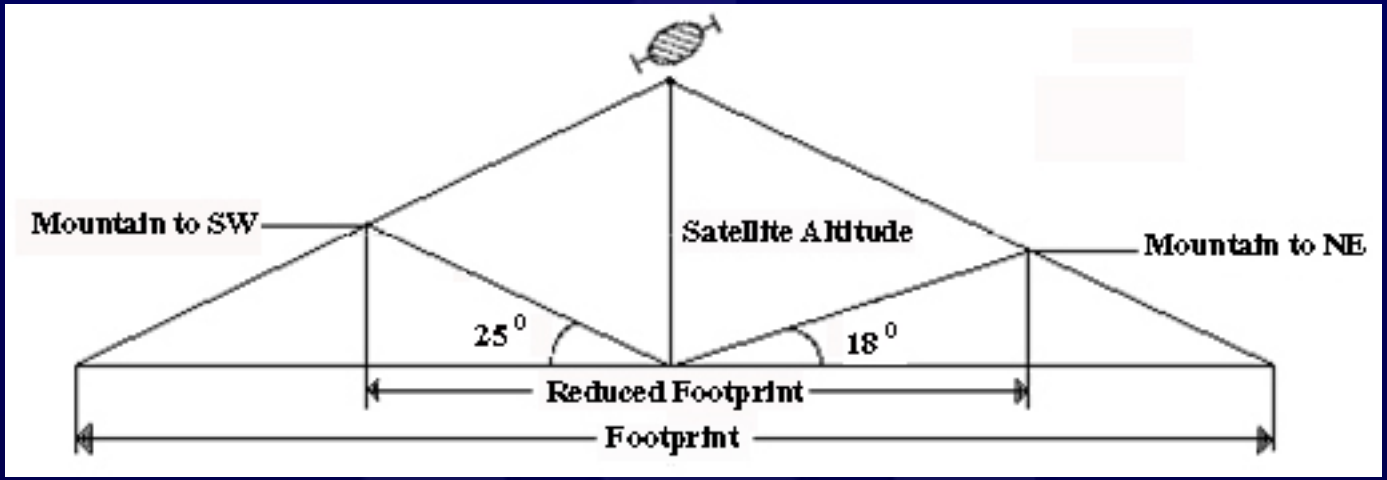
Preliminary Testing in Montana

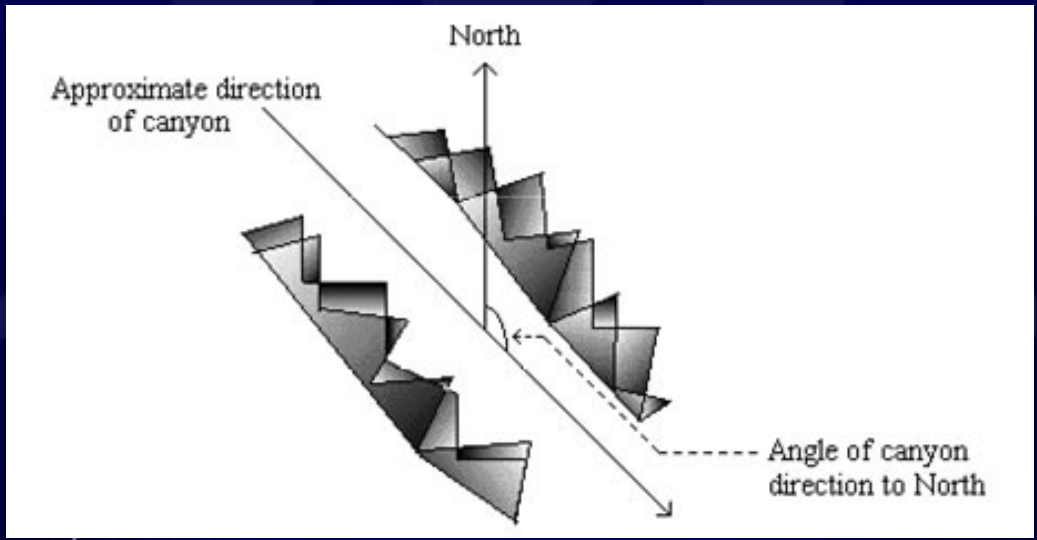
- Tests of both cellular and satellite.
- “Interesting” observations for satellite when used in rugged terrain.
- Used OTC equipment.
- Developed testing methodologies.

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.

Satellite Footprint Reduction / Shadowing

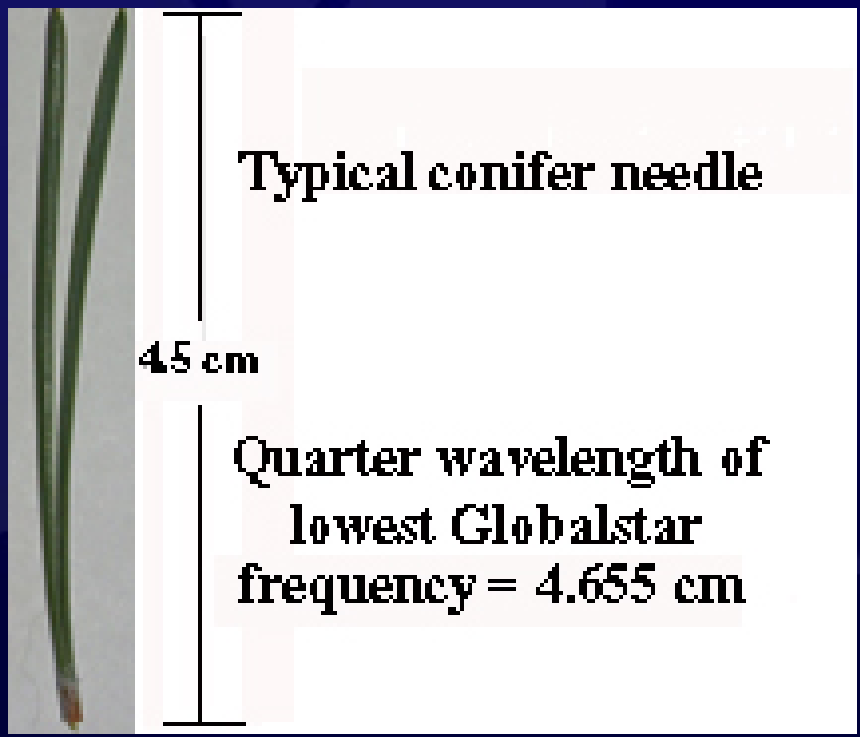




Possible Signal Absorption

- Globalstar operates in L-Band (1610 to 1626.5 MHz) up-link and S-Band (2483.5 to 2500 MHz) downlink.
- 2500 MHz yields a ¼ wavelength of 2.99 cm; 1610 MHz yields a ¼ wavelength of 4.66 cm.

- Several typical conifers have needles in the 1.18” to 1.833” (2.997 to 4.66 cm) range – most common problem with pines – needles act like antennae and can absorb signal energy



Impact

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

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.

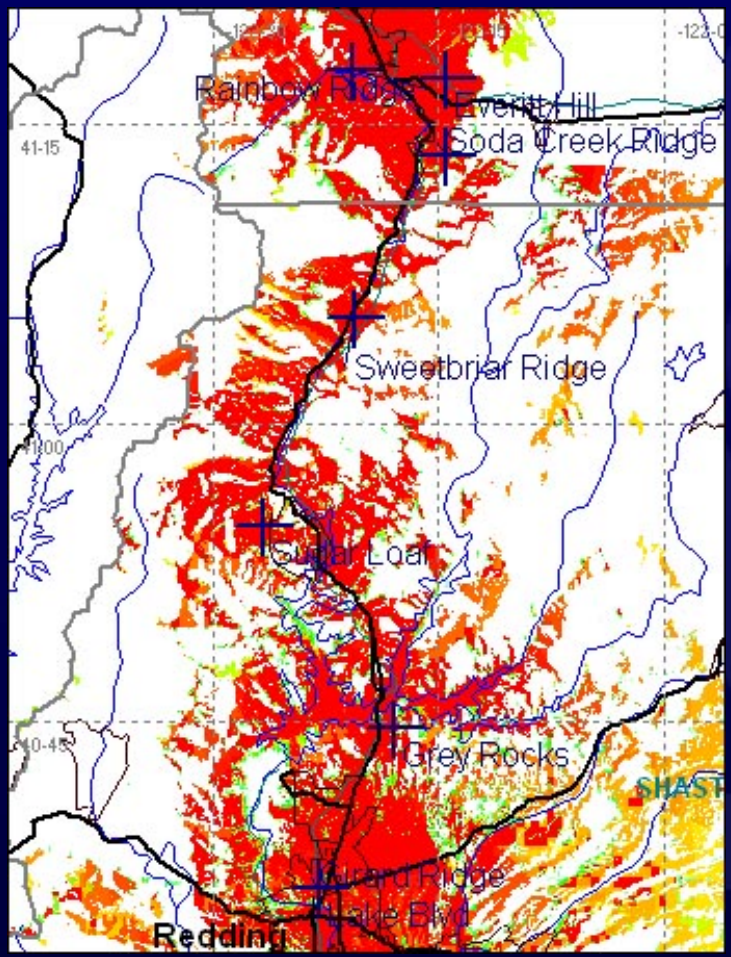
Data Rates

- 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

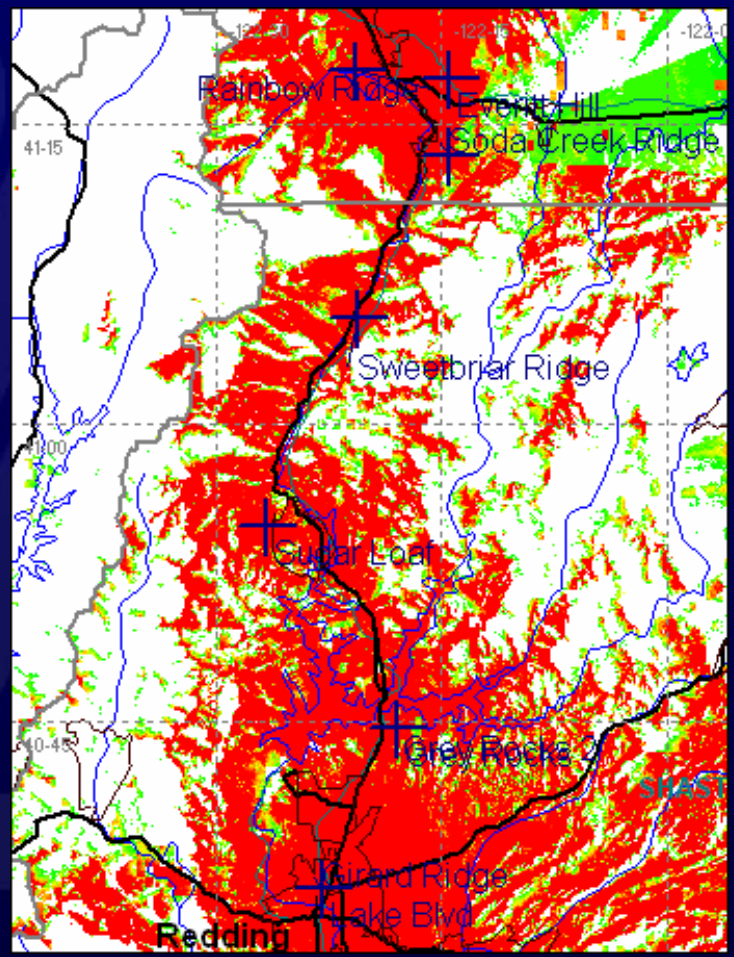
- Analysis was conducted for several study areas in the RIME region (Northern California).
- Tower Sites were selected from FCC database.
- Not meant to show actual coverage.
- Meant to show the impact of terrain on prospective coverage.

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



Cellular Coverage Plot

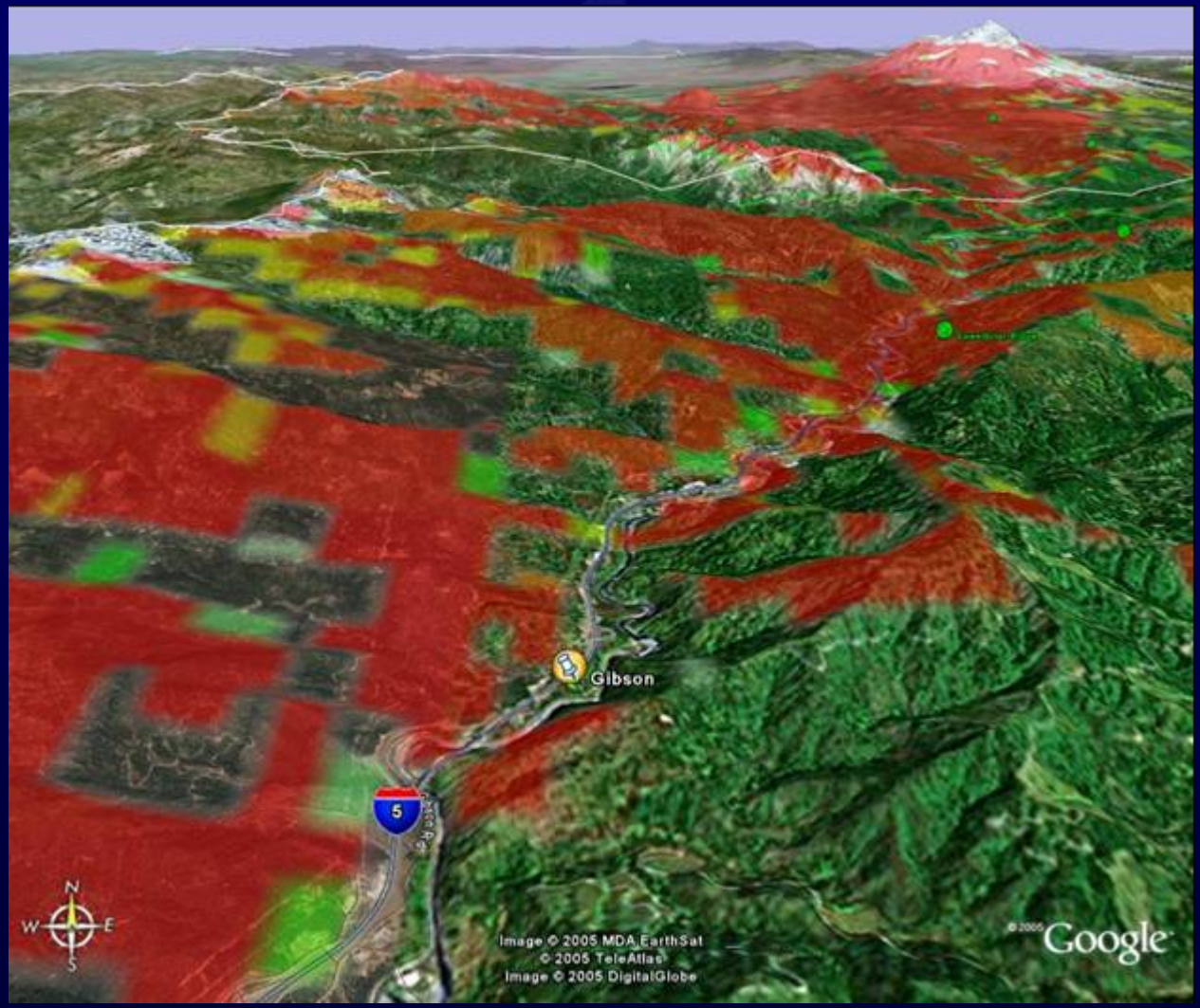
- 30 dBu – Roughly equivalent to 5 level bar
- 20 dBu – Roughly equivalent to 3 level bar
- 10 dBu – Roughly equivalent to 1 level bar



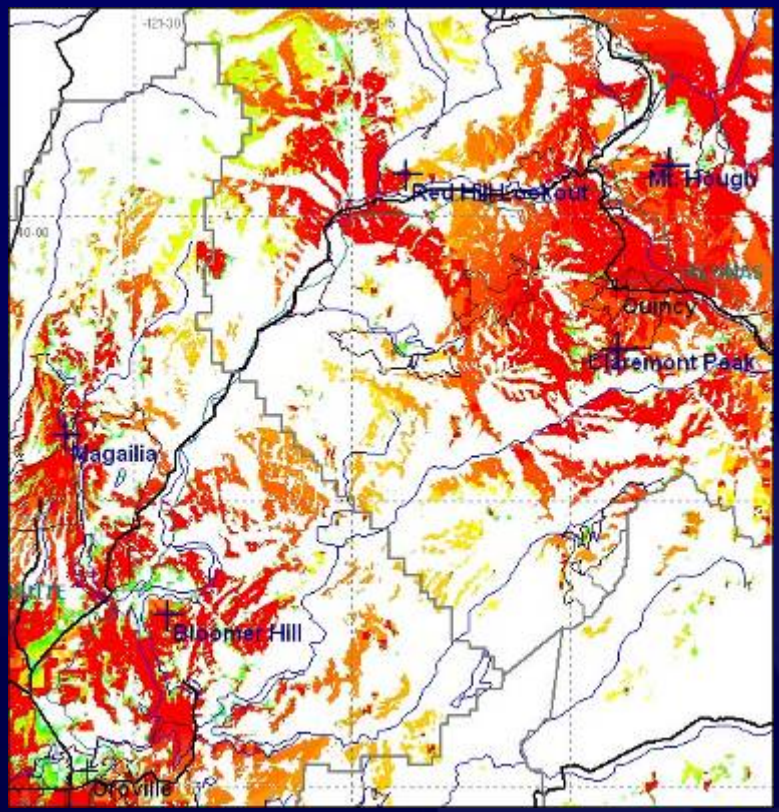
800 MHz Land Mobile Coverage Plot

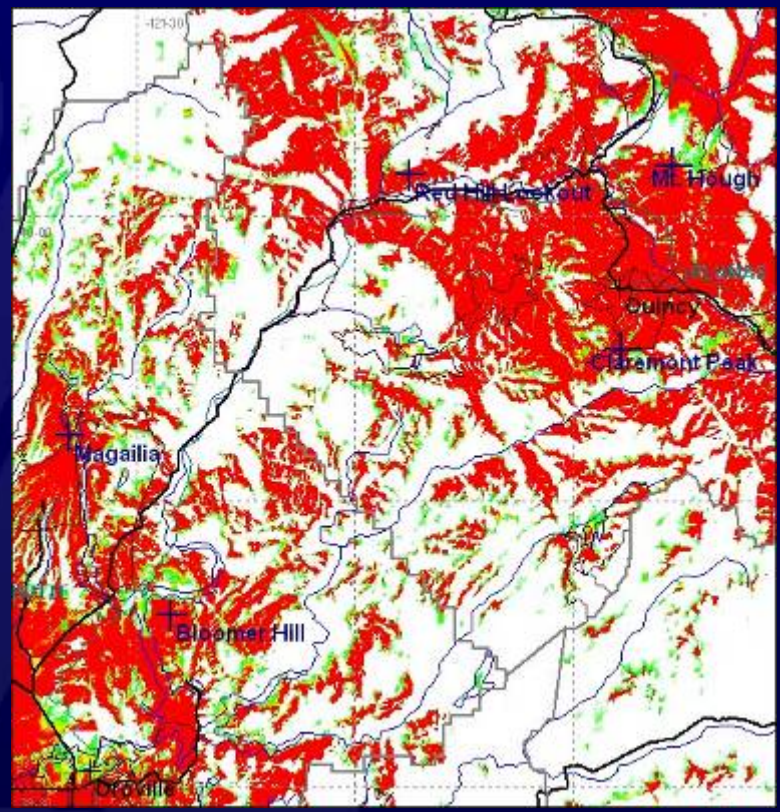
- 20 dBu - Excellent land mobile coverage
- 10 dBu -Good land mobile coverage
- 0 dBu -Acceptable land mobile coverage

Modeled Cellular Coverage Gibson area, North to Mt. Shasta



Modeled Cellular and 800 MHz Coverage: Oroville to Quincy





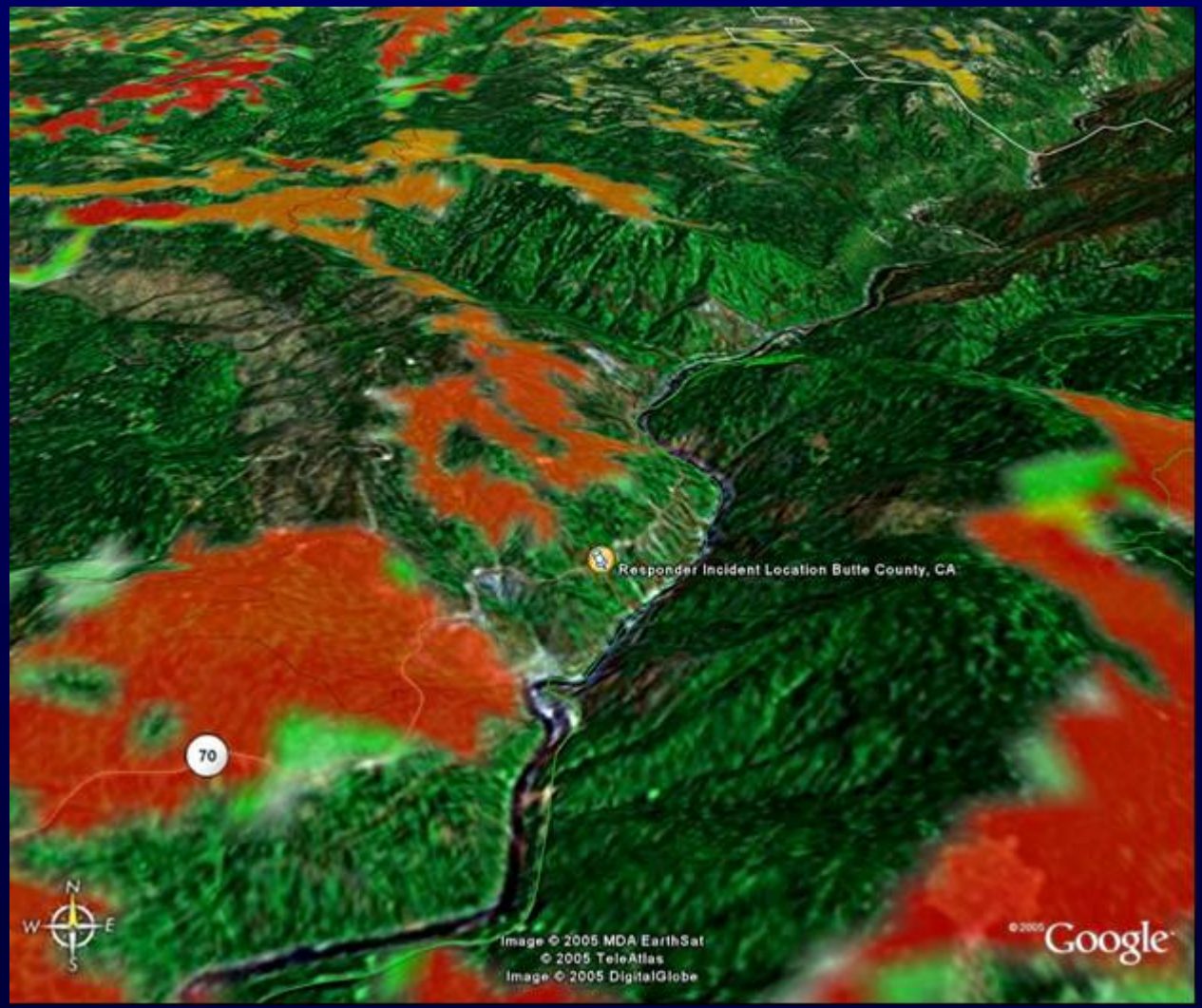
SR-70 Cellular Coverage Plot

- 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

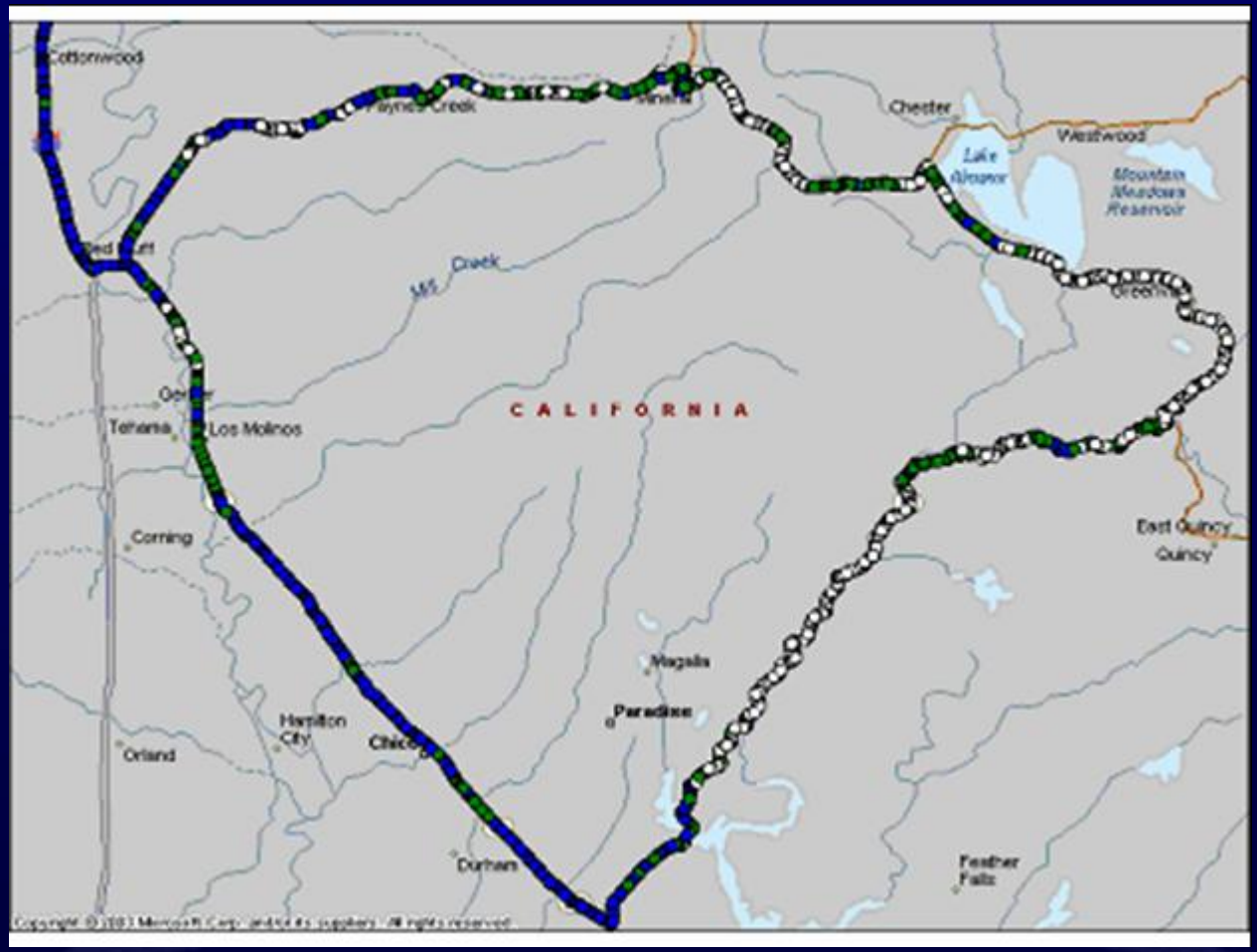
Modeled Cellular Coverage Near SR-70 Incident Location



Northern California Cellular Signal Strength Drive Tests

- Excellent Signal
- Good Signal
- Poor Signal or No Signal

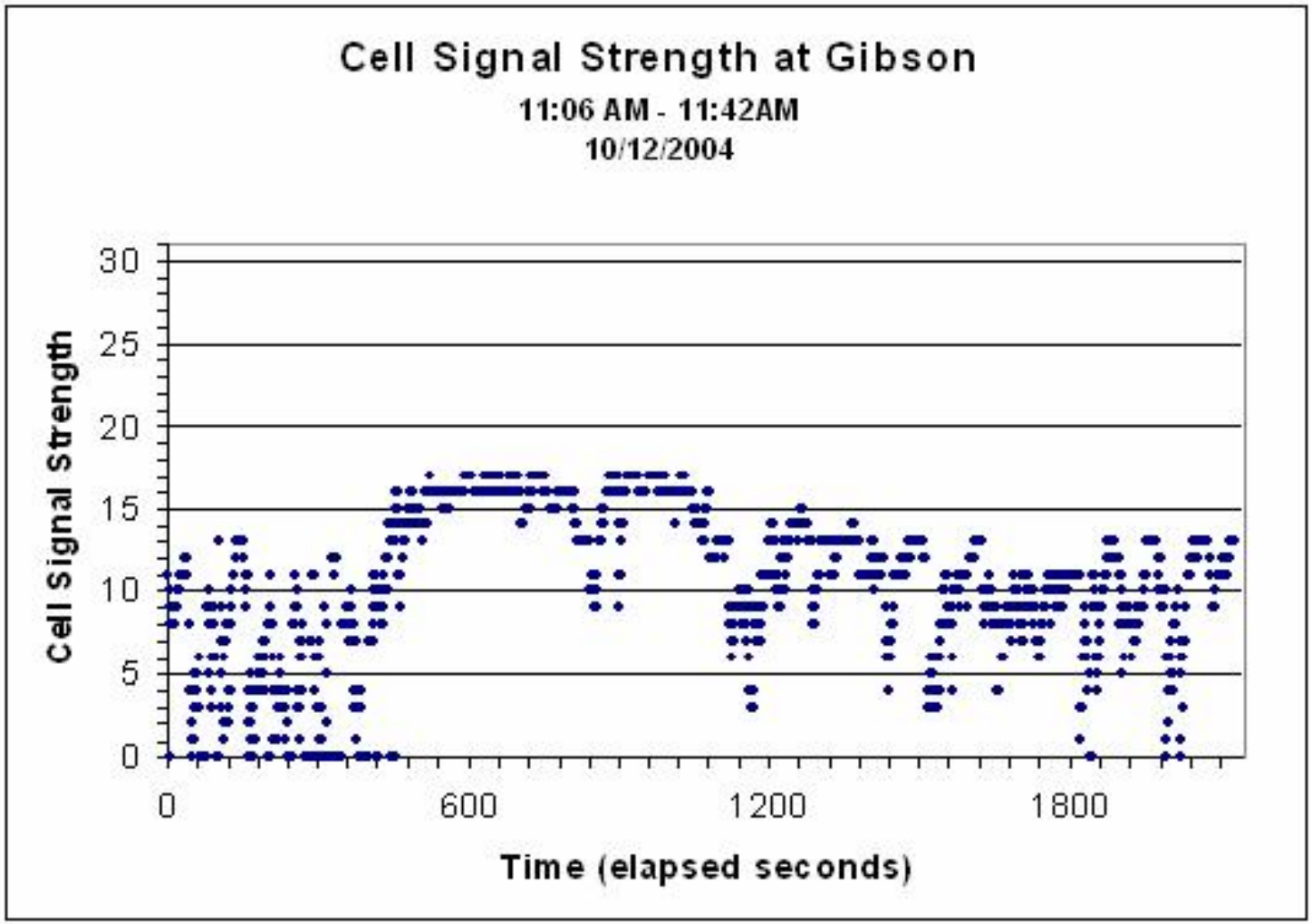
Northern California Cellular Signal Strength Drive Tests



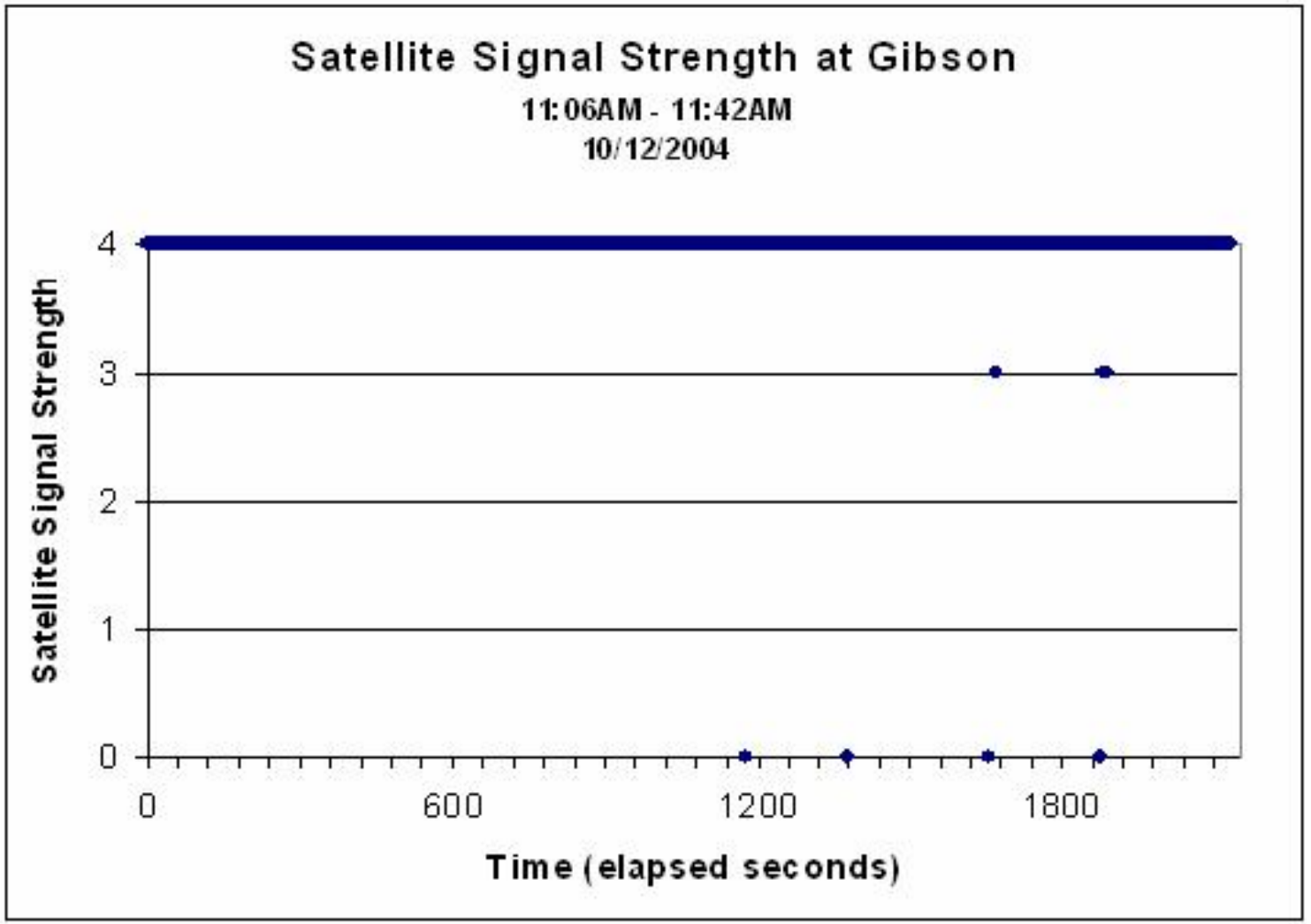
- Excellent Signal
- Good Signal
- Poor Signal or No Signal

Site Tests: Gibson

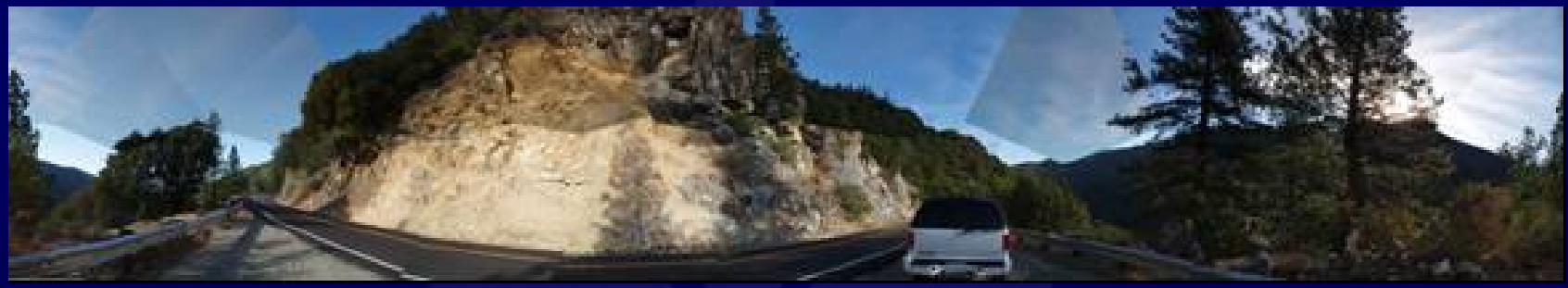
Gibson Cellular

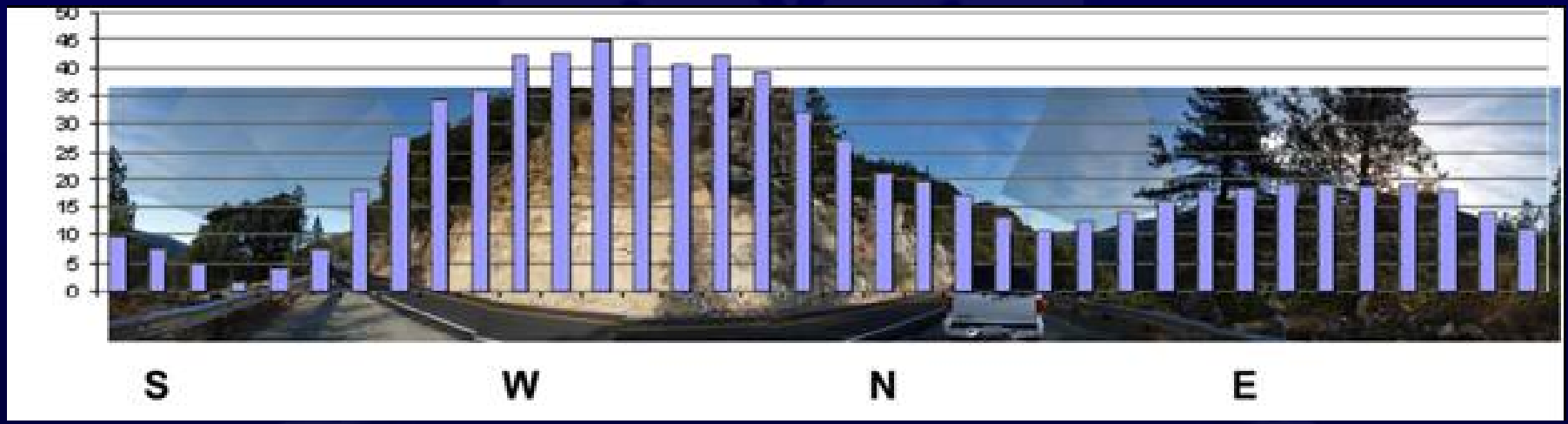


Gibson Satellite

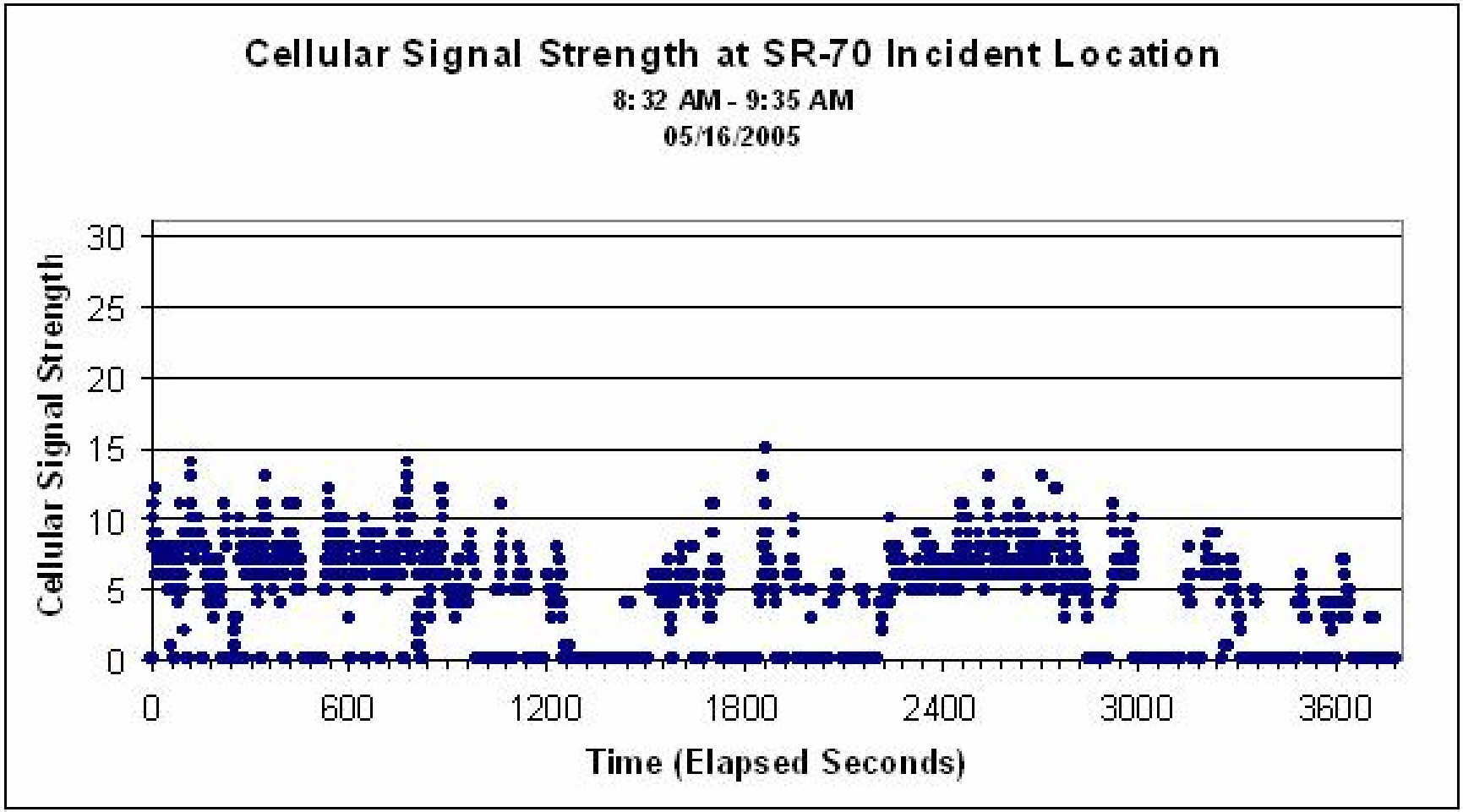


Site Tests: SR-70 Butte

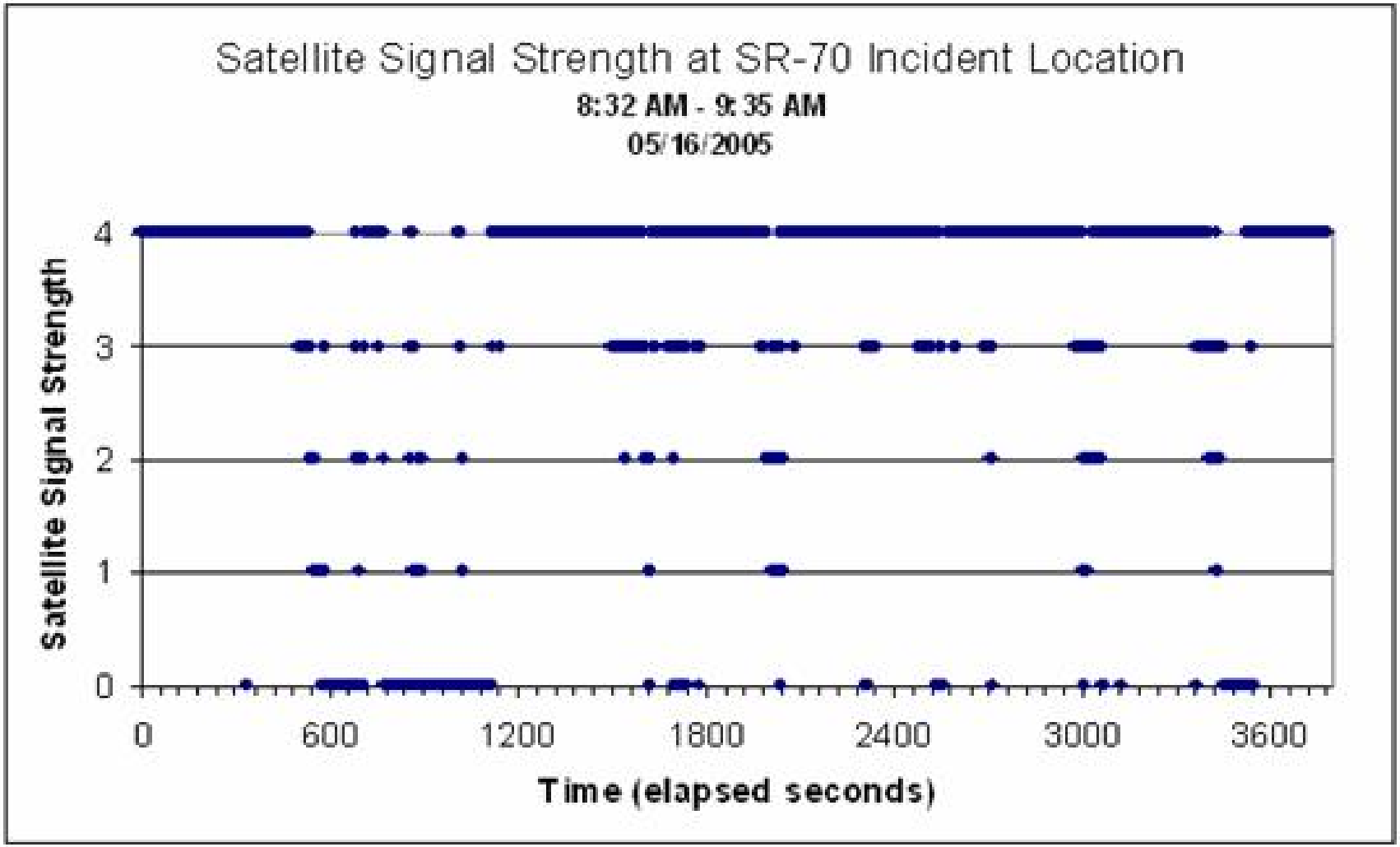




SR-70 Butte Cellular



SR-70 Butte Satellite



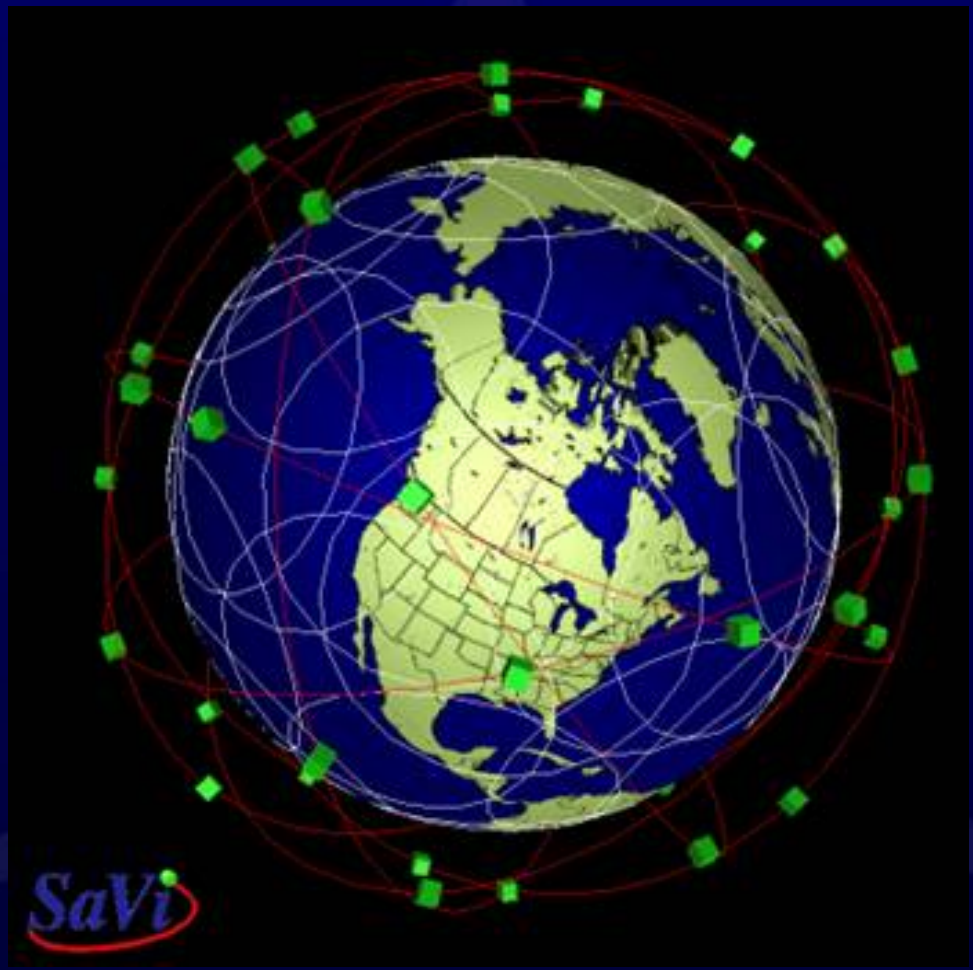
SR-70 Butte Satellite Available / Unavailable Intervals

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**

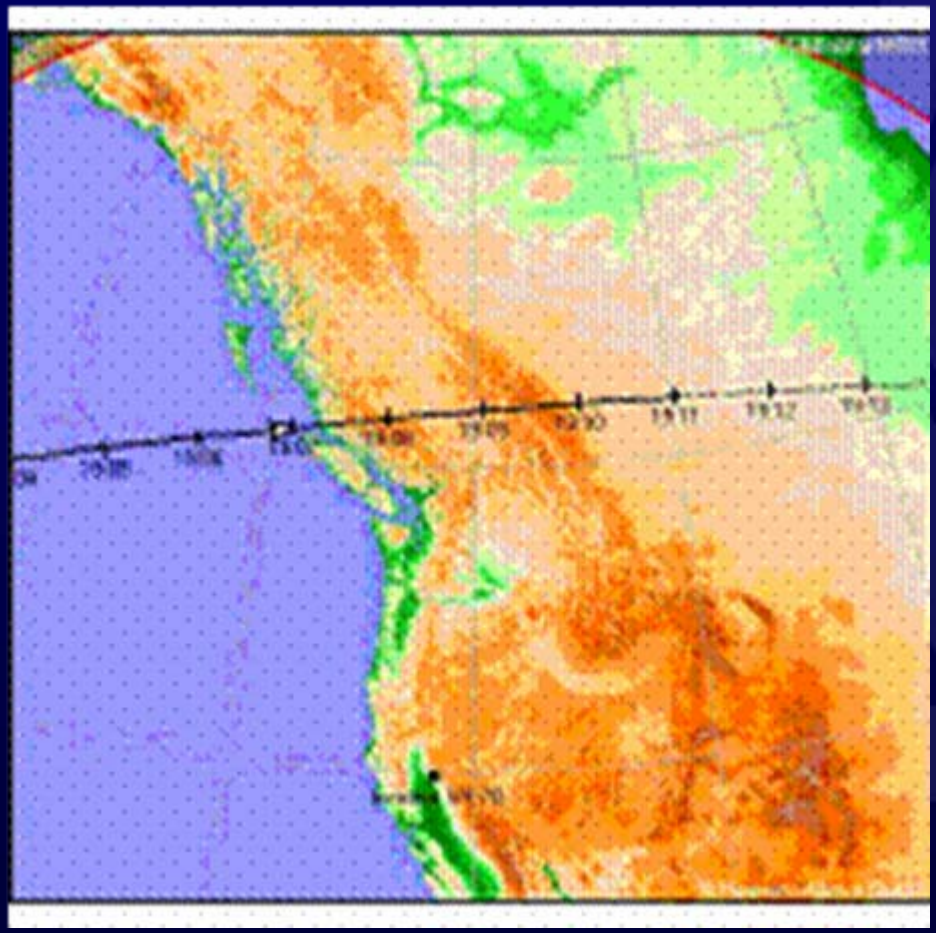
The Globalstar System

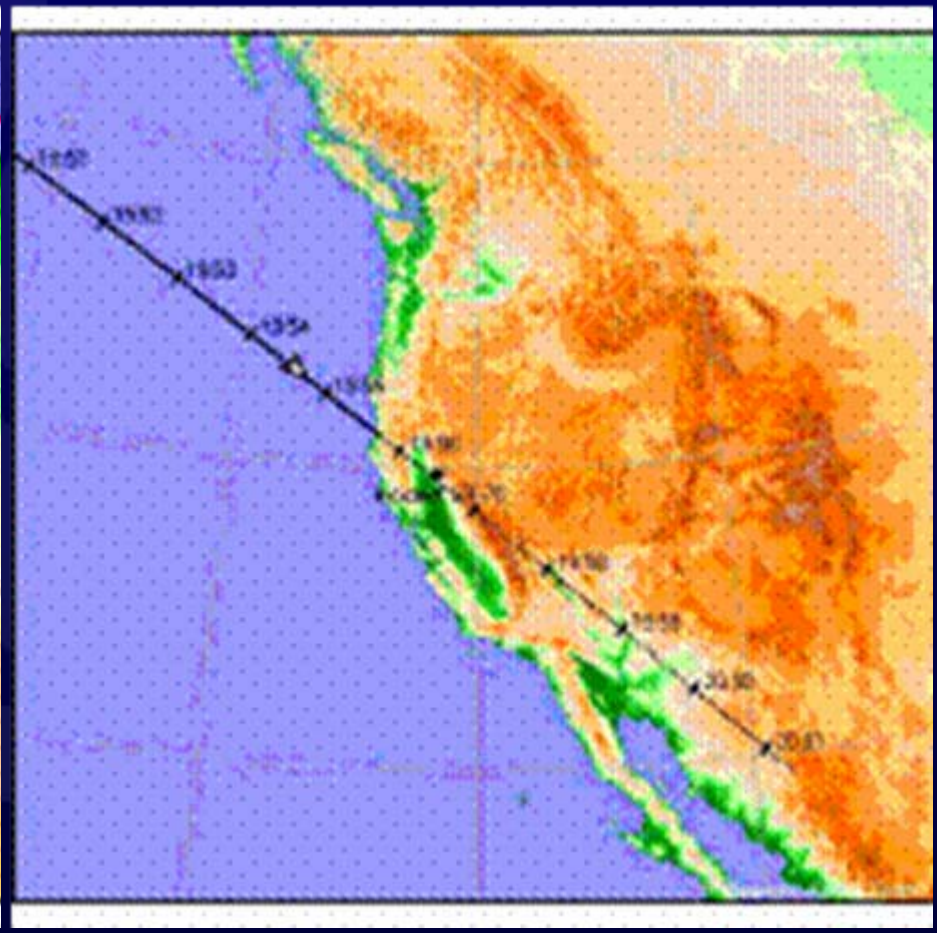
- There are 48 total satellites (currently only 40 in operation), 6 per orbit plane.
- There are 8 orbit planes, each with a declination of 52 degrees.
- The satellites orbit at approximately 1410 km above the earth and with a period of approximately 114 minutes.
- The satellite nominal footprint is 5850 km.
- LEO, not GEO

Globalstar Constellation



Globalstar Satellite Paths

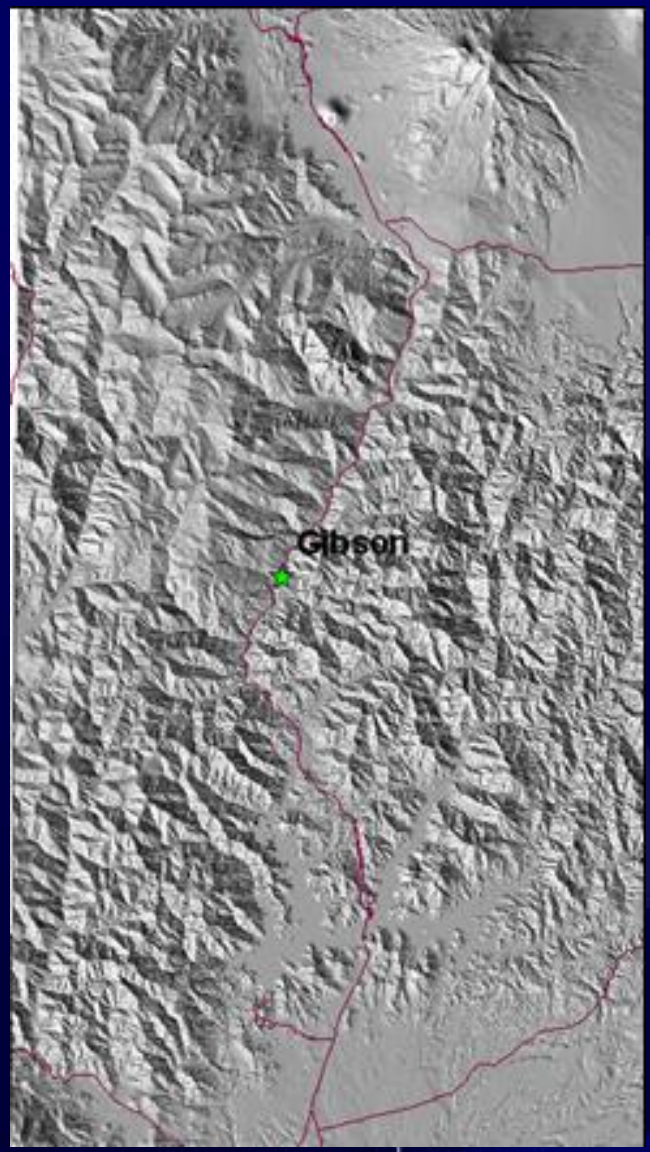


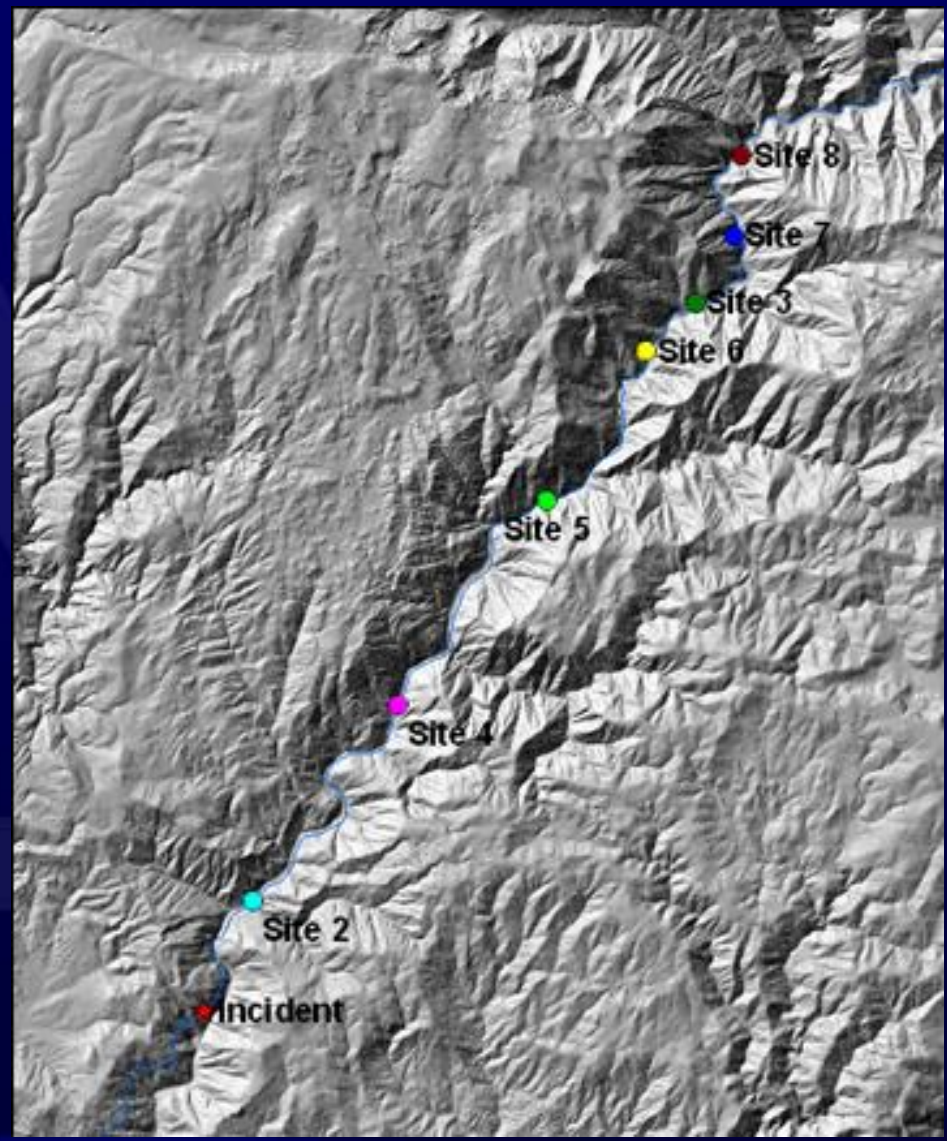


Test Sites (and Scenarios) for Model of System

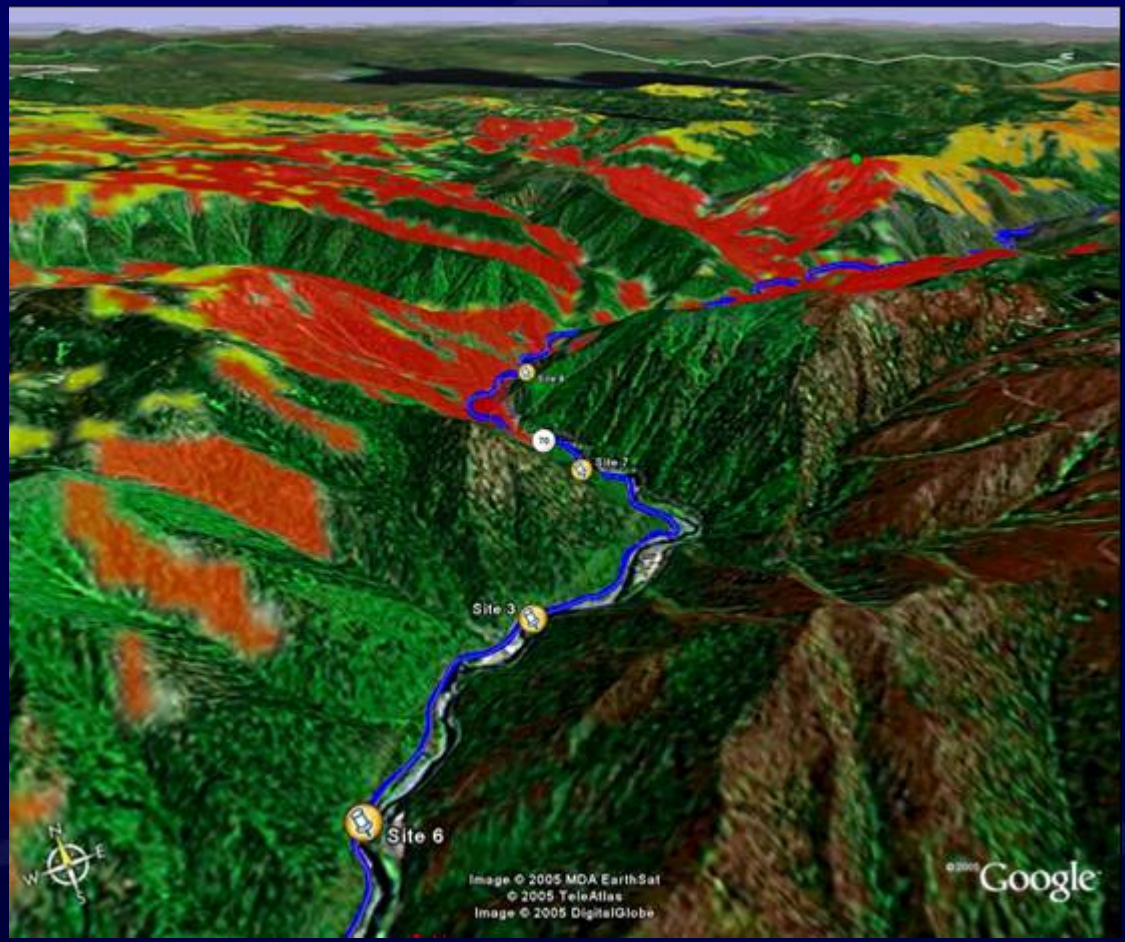
	Latitude	Longitude	Elevation (m)
Gibson	41.02261	-122.39877	496
Incident	39.77616	-121.45572	555
Incident No Elevation	39.77616	-121.45572	555
Incident Bowl 15	39.77616	-121.45572	555
Incident Bowl 30	39.77616	-121.45572	555
Incident Bowl 45	39.77616	-121.45572	555
Incident Vegetation	39.77616	-121.45572	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

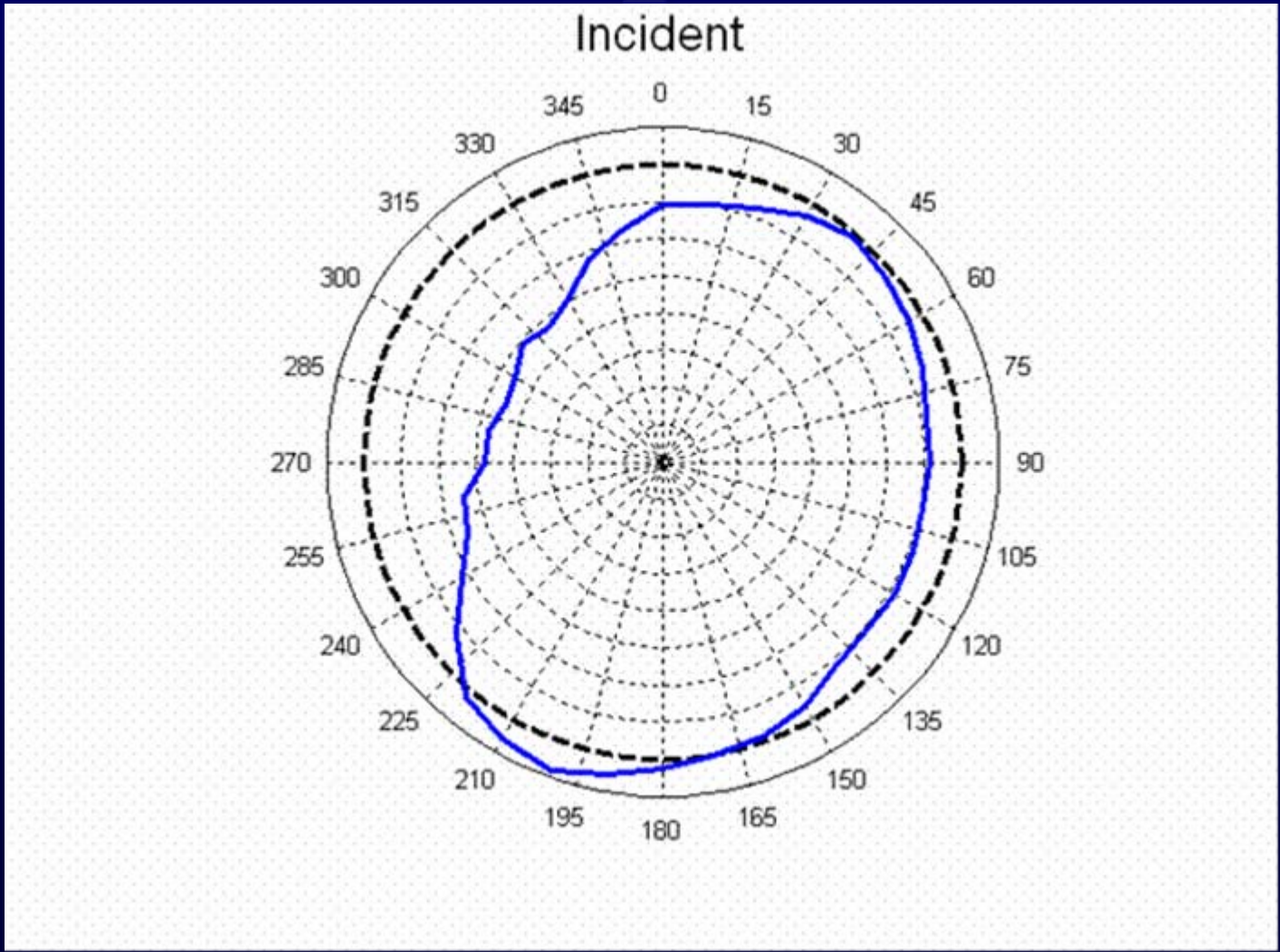




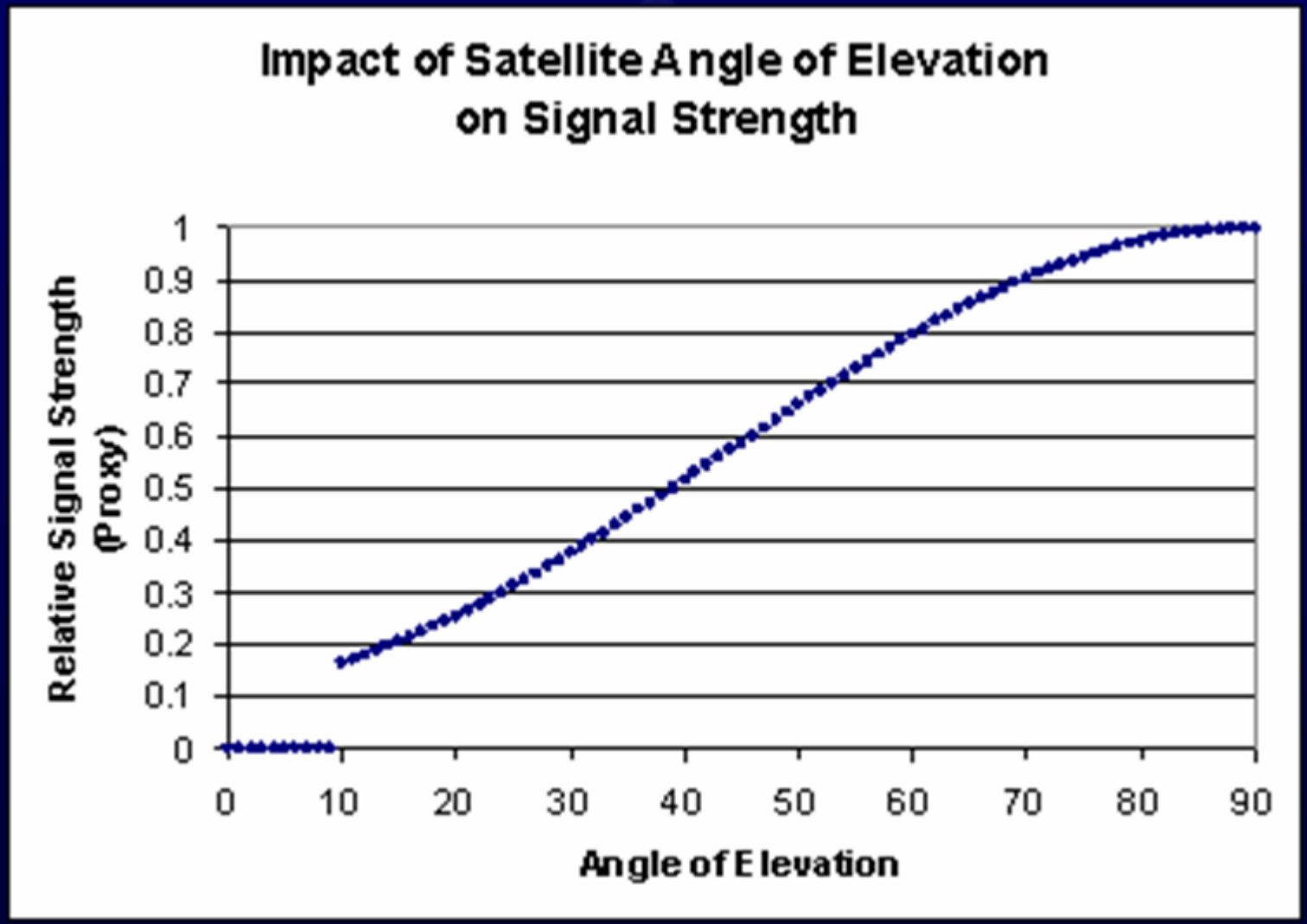
Sites 6, 3, 7 & 8 – Feather River Canyon



SR-70 Sky Visibility Map



Impact of Angle of Elevation on Signal Strength



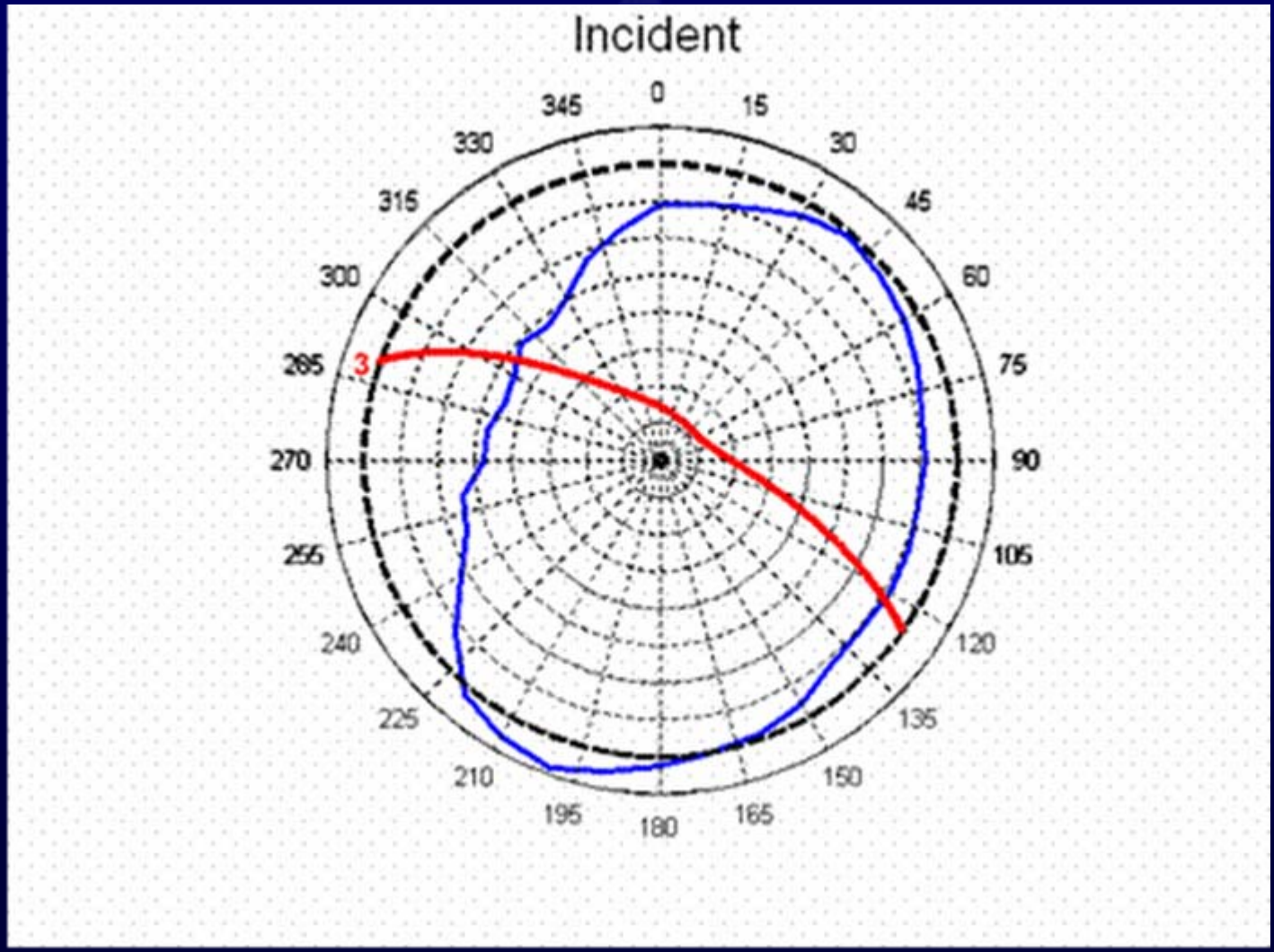
Sites and Sky Blockage Statistics

	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

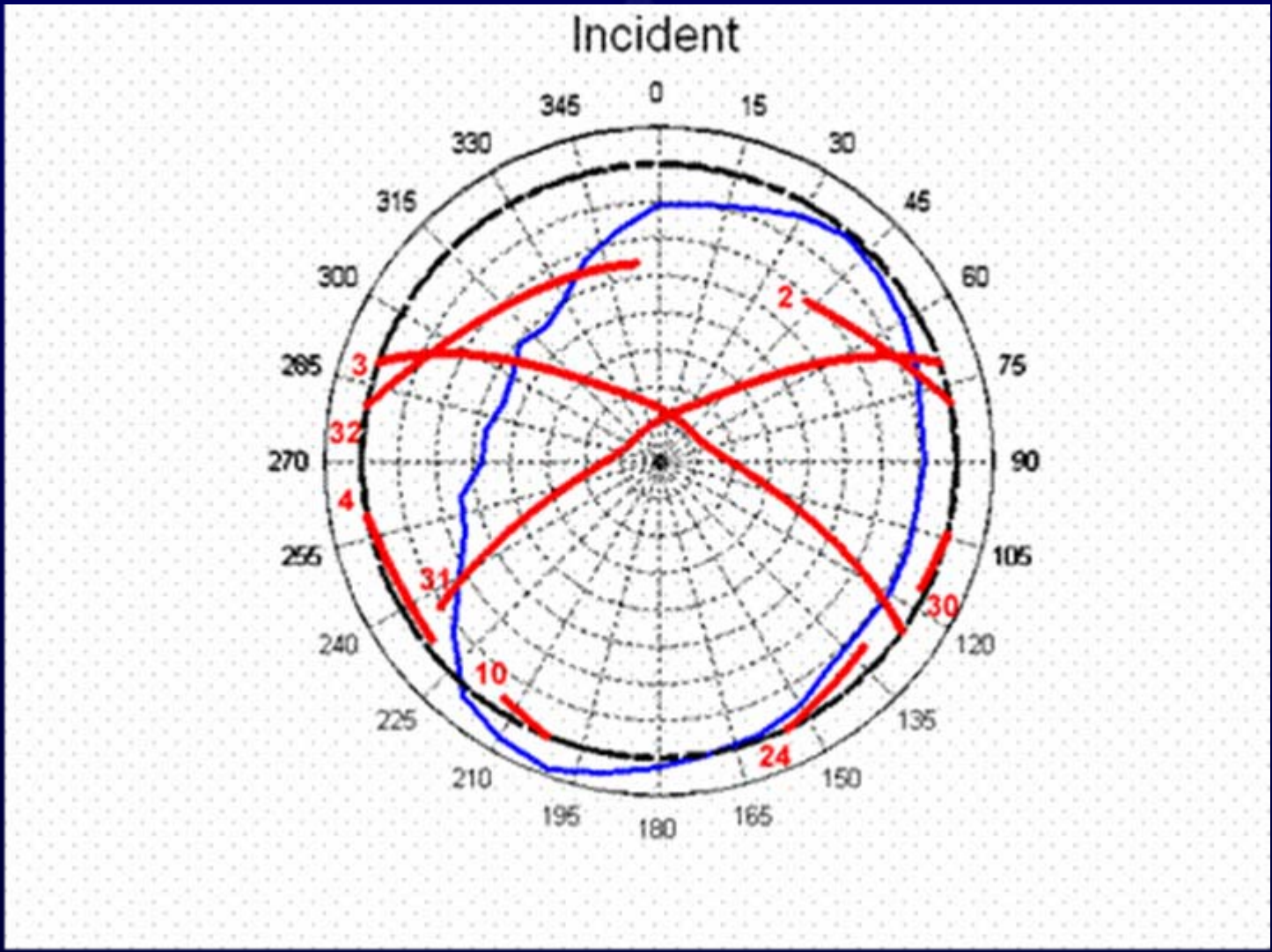
Scenarios and Sky Blockage Statistics

	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

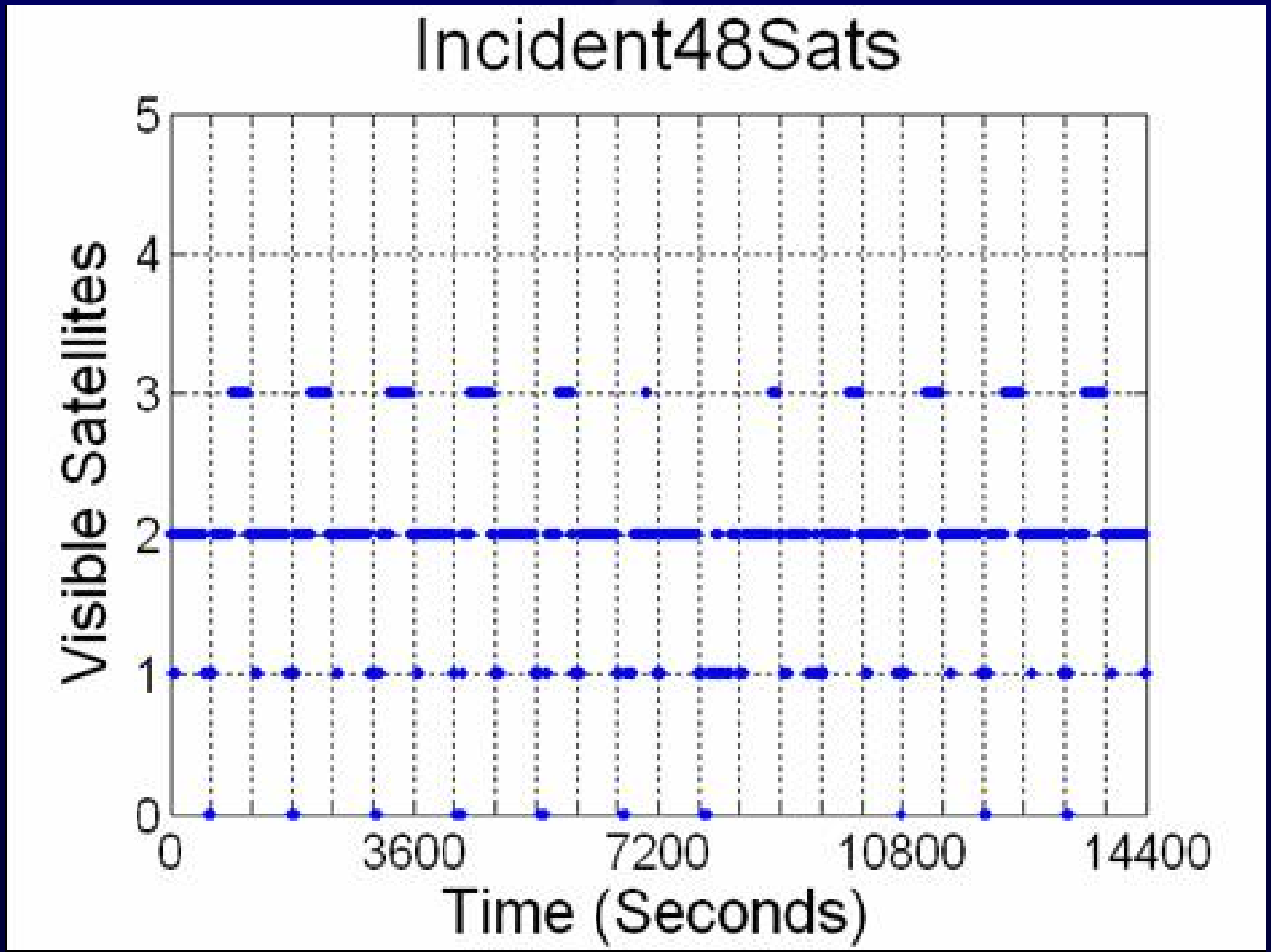
Single Satellite Path – 17 min



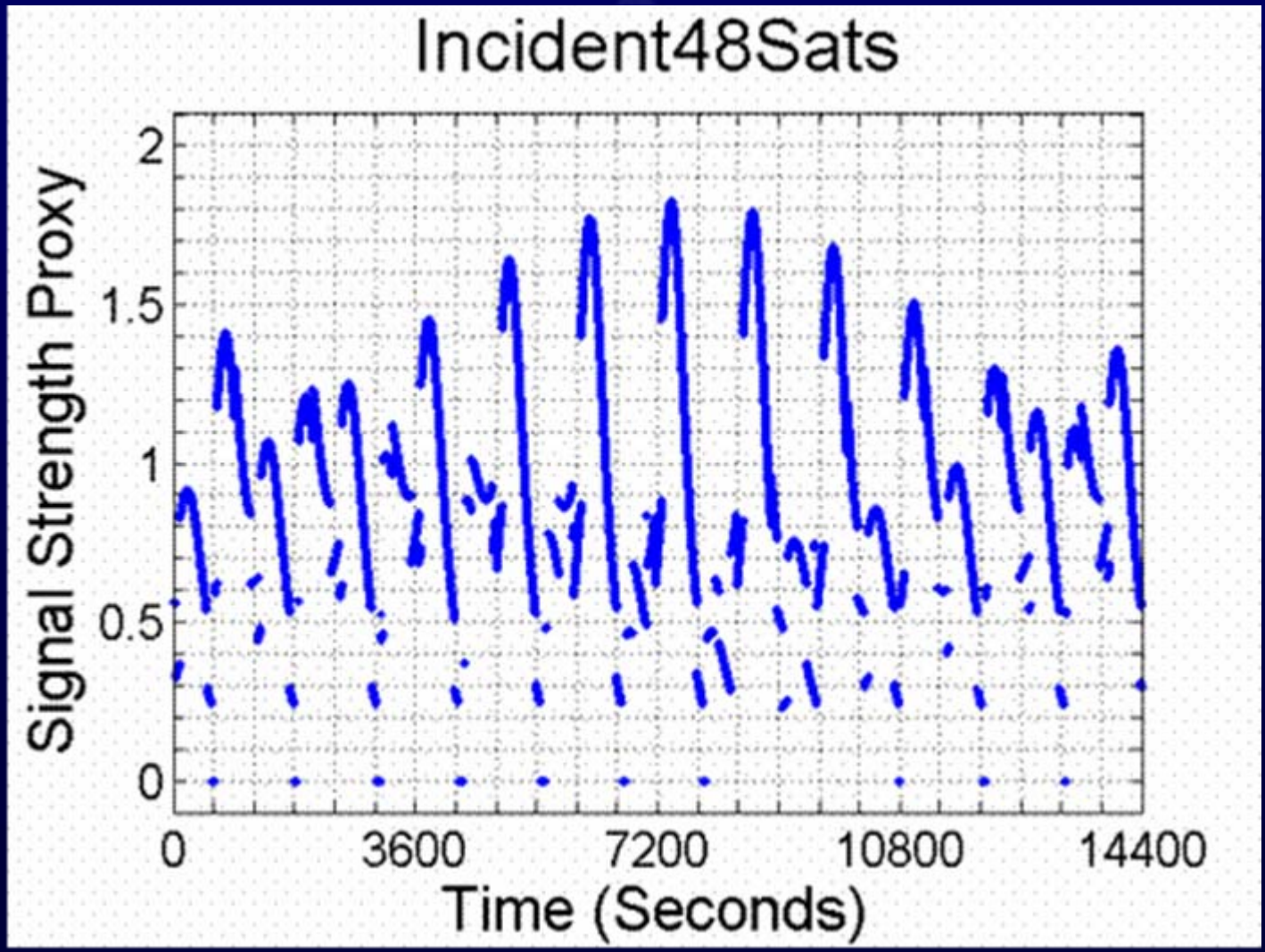
Multiple Satellites – 17 min



Modeled Visible Satellites



Modeled (Proxy) Signal Strength



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	2	0.57	0.04	0.35	0.61	0.00	0.00	0.00
Incident 40 Sats No Elevation	2.70	1	4	0.79	0.00	0.12	0.44	0.35	0.19	0.00
Incident 40 Sats Bowl 15	2.18	1	4	0.71	0.00	0.13	0.61	0.21	0.05	0.00
Incident 40 Sats Bowl 30	1.12	0	2	0.75	0.23	0.43	0.34	0.00	0.00	0.00
Incident 40 Sats Bowl 45	0.42	0	2	0.69	0.70	0.19	0.11	0.00	0.00	0.00
Incident Vegetation 40 Sats	1.3'	0	2	0.65	0.10	0.48	0.42	0.00	0.00	0.00
Site2 40 Sats	1.9'	0	1	0.72	0.02	0.23	0.59	0.14	0.02	0.00
Site3 - 40 Sats	1.77	0	4	0.72	0.02	0.33	0.52	0.13	0.01	0.00
Site4 - 40 Sats	1.24	0	2	0.74	0.18	0.39	0.43	0.00	0.00	0.00
Site5 - 40 Sats	1.76	0	4	0.79	0.02	0.40	0.41	0.16	0.02	0.00
Site6 - 40 Sats	1.45	0	2	0.62	0.07	0.41	0.52	0.00	0.00	0.00
Site7 - 40 Sats	1.17	0	2	0.75	0.21	0.41	0.38	0.00	0.00	0.00
Site8 - 40 Sats	1.14	0	2	0.70	0.18	0.49	0.32	0.00	0.00	0.00

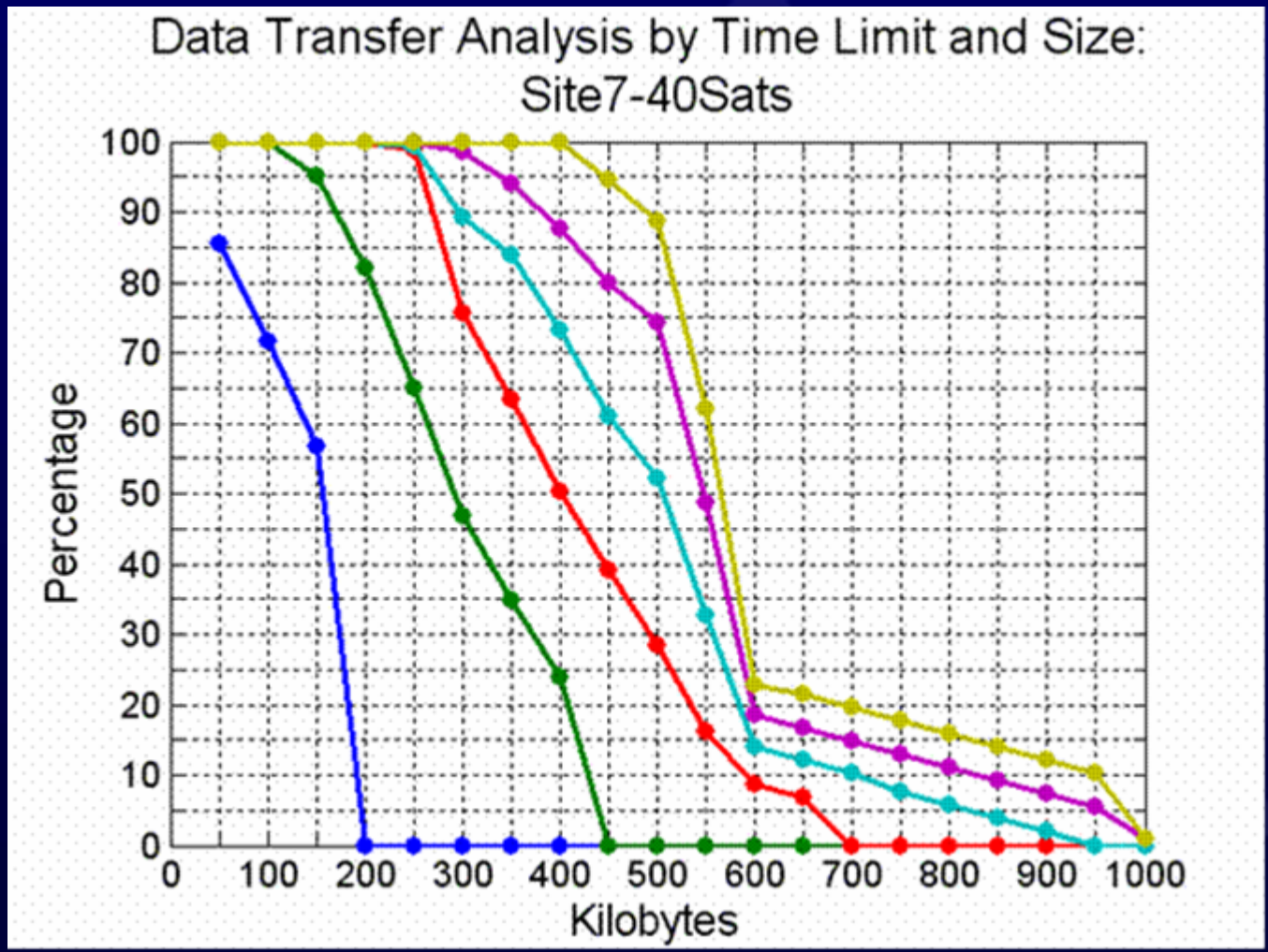
Modeled (Proxy) Signal Strength Statistics
40 Satellite Constellation

	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	0.46	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	0.62	0.23	0.30	0.18	0.21	0.08
Incident 40 Sats Bowl 45		0.31	0.00	1.82	0.63	0.70	0.00	0.19	0.04	0.08
Incident Vegetation 40 Sats		0.86	0.00	1.82	0.48	0.10	0.36	0.30	0.16	0.08
Site 2 - 40 Sats		0.87	0.00	1.82	0.42	0.02	0.28	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		0.86	0.00	1.82	0.60	0.16	0.28	0.29	0.17	0.08
Site 5 - 40 Sats		0.81	0.00	1.82	0.46	0.02	0.36	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		0.86	0.00	1.82	0.61	0.21	0.27	0.27	0.17	0.08
Site 8 - 40 Sats		0.83	0.00	1.82	0.61	0.16	0.34	0.20	0.19	0.08

Modeled Data Transfer Analysis

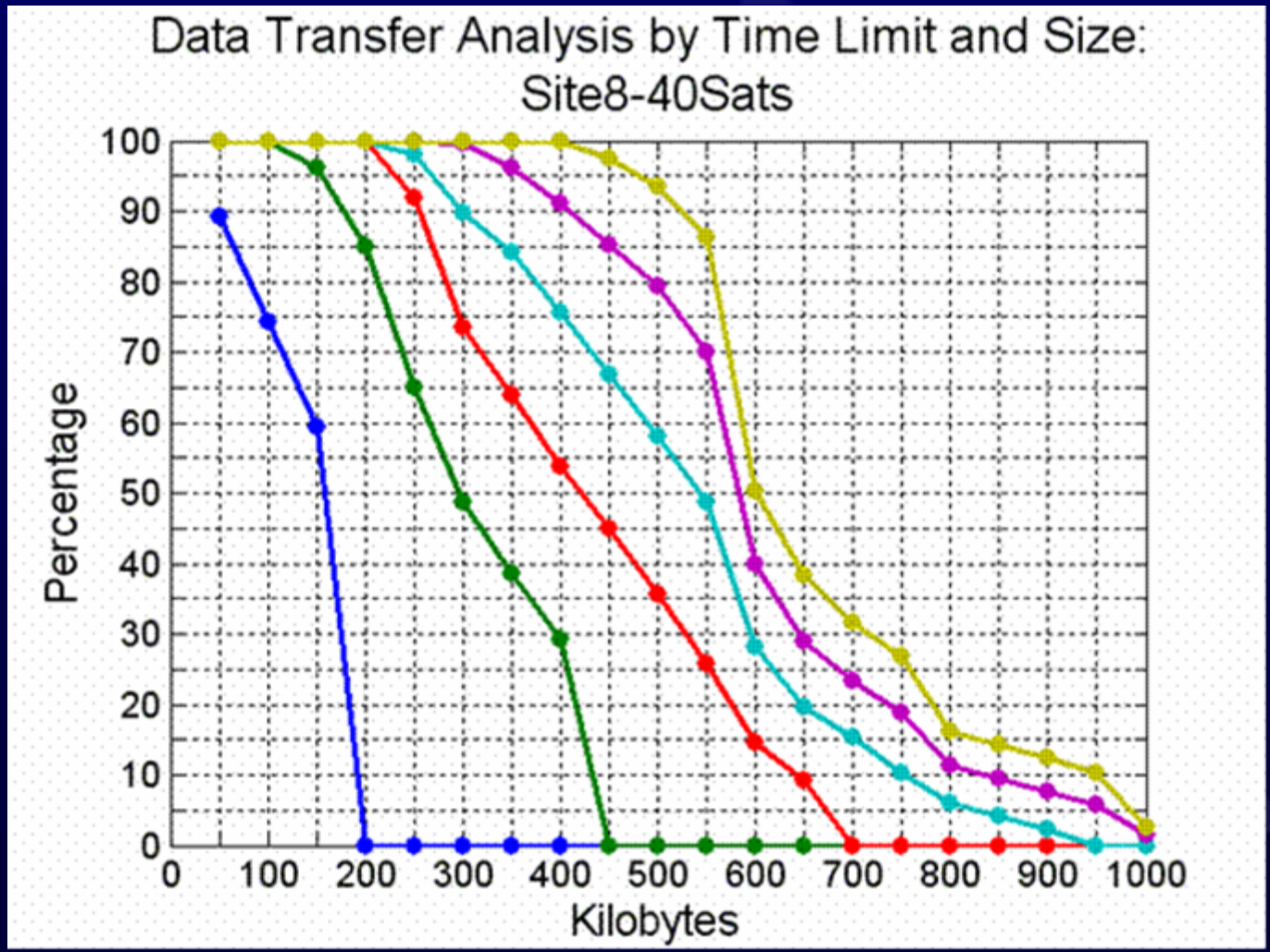
- Satellite movement was modeled for 1 week at 1 second intervals
- Determine if data could be transferred at given point in time.
- If not, redial and try again.
- Try to complete transmission within time limit.

Modeled Data Transfer Analysis – Site 7



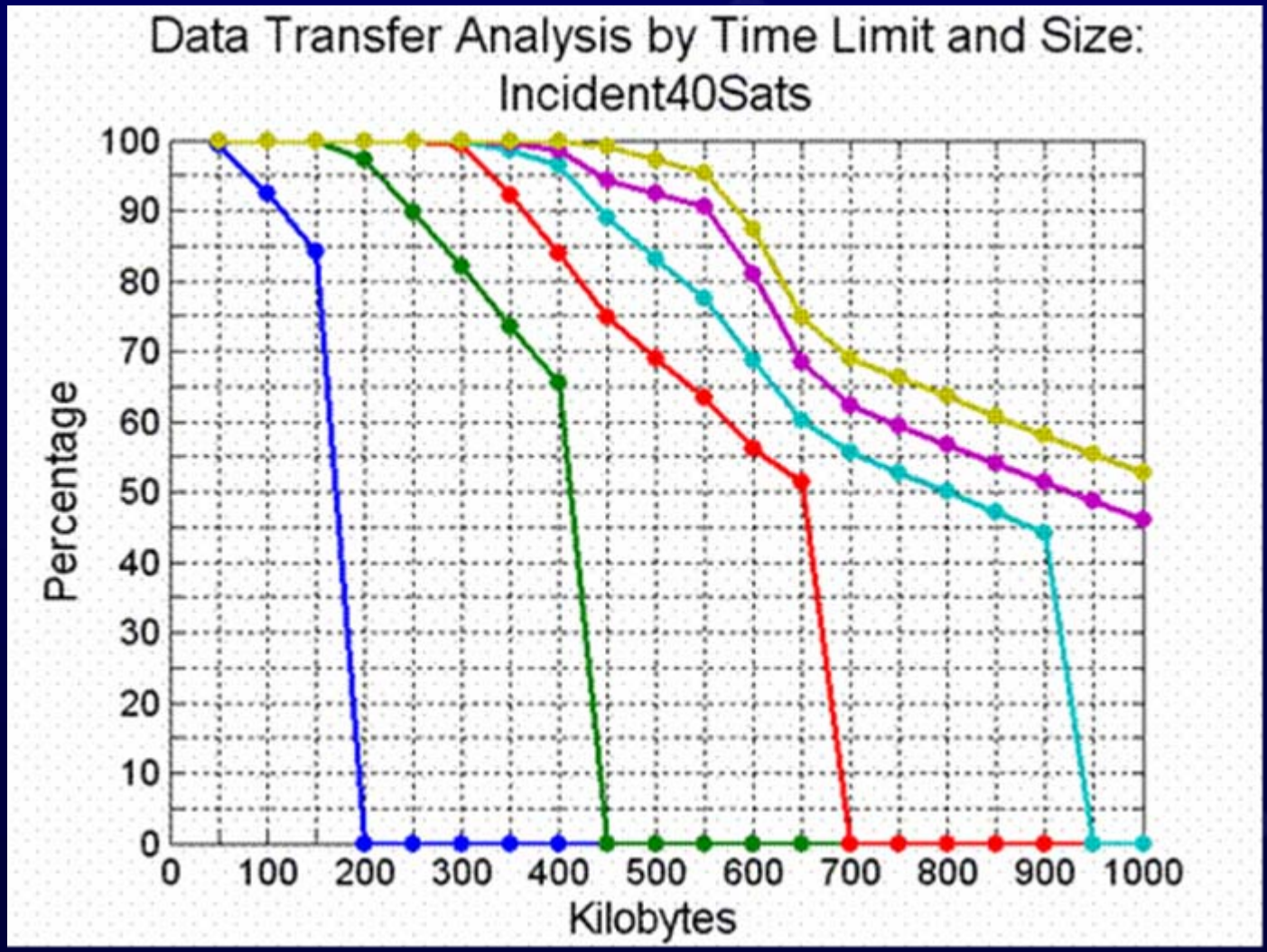
Time Limit	
5 minutes	
10 minutes	
15 minutes	
20 minutes	
25 minutes	
30 minutes	

Modeled Data Transfer Analysis – Site 8



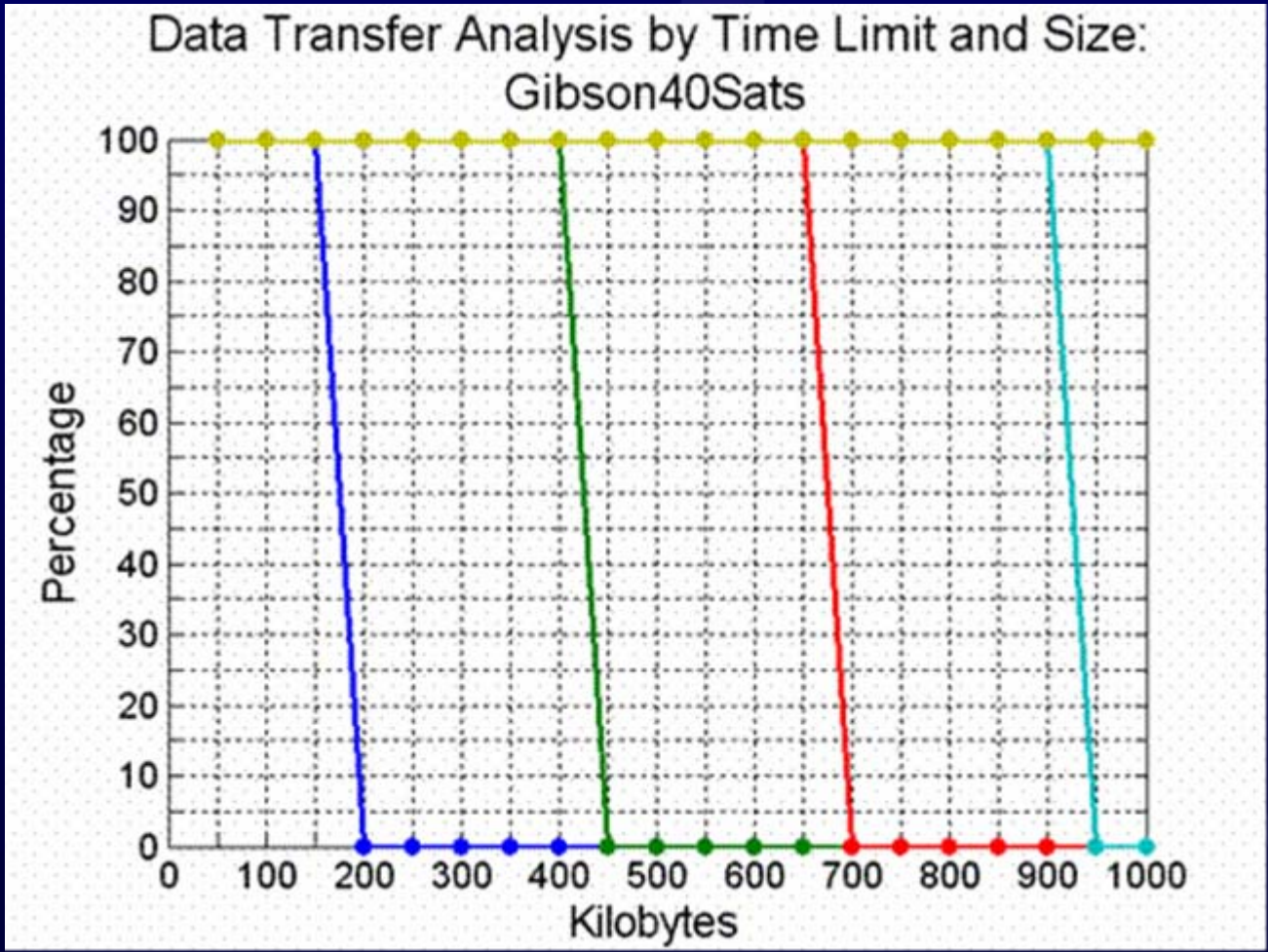
Time Limit
5 minutes
10 minutes
15 minutes
20 minutes
25 minutes
30 minutes

Modeled Data Transfer Analysis – SR 70 Butte



Time Limit	
5 minutes	
10 minutes	
15 minutes	
20 minutes	
25 minutes	
30 minutes	

Modeled Data Transfer Analysis – Gibson

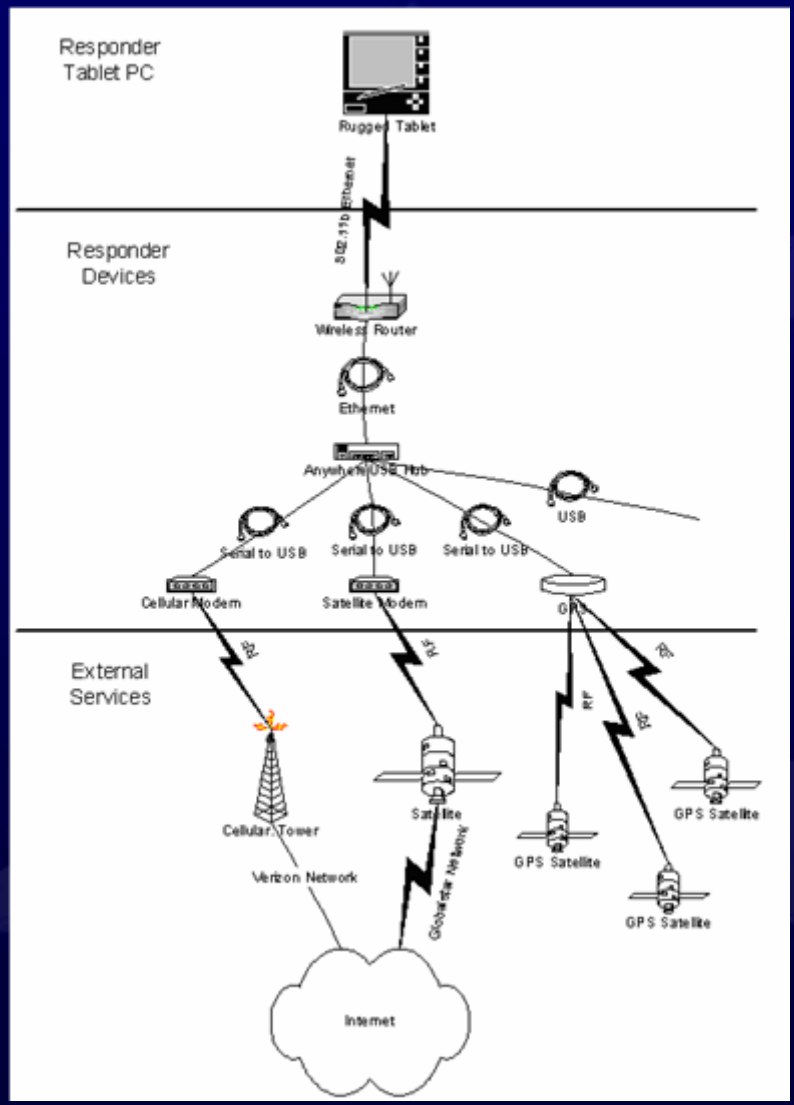


Time Limit	
5 minutes	
10 minutes	
15 minutes	
20 minutes	
25 minutes	
30 minutes	

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



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.

Acknowledgements

- Dr. Bill Jameson
- Caltrans DRI
  - Mandy Chu
  - Sean Campbell
- Caltrans D2
  - Jeff Kiser
  - Ian Turnbull
  - Bill Stein