SERA - ShakeMap

April 14 2022

John Eidinger

Notices

Agenda

- A Possible Future for ShakeMap - Forecasting Power Outages - with David Wald of USGS
- SERA ShakeMap ShakeCast Pager
- Who Pays? CEC, NSF, USGS, Utility Contributions
- Questions and Comments

ShakeMap and ShakeCast

- ShakeMap gives you “near real time” ground motions after earthquakes
- ShakeCast reads in ShakeMaps, adds in inventory, and produces various forecasts
- What is the difference between SERA and ShakeCast?
- Can ShakeCast be updated to produce forecasts of power outages?

☆ **USGS ENS**

USGS ENS March 30, 2022 at 7:13 PM

2022-03-31 02:05:26 UPDATED: (M4.0) California-Nevada border region 37.4 -118.6 (8c4b7)

To: Earthlink Eidinger,

Reply-To: ens@ens.usgs.gov

M4.0 Earthquake - California-Nevada border region

Preliminary Report

Magnitude	4.0
Date-Time	31 Mar 2022 02:05:27 UTC 30 Mar 2022 19:05:27 near epicenter 30 Mar 2022 18:05:27 standard time in your timezone
Location	37.410N 118.606W
Depth	9 km
Distances	1.9 km (1.2 mi) WSW of Round Valley, California 115.0 km (71.3 mi) NE of Sanger, California 117.2 km (72.6 mi) ENE of Clovis, California 117.5 km (72.9 mi) NE of Reedley, California 219.6 km (136.1 mi) SSE of Carson City, Nevada
Location Uncertainty	Horizontal: 0.4 km; Vertical 1.0 km
Parameters	Nph = 23; Dmin = 7.4 km; Rmss = 0.06 seconds; Gp = 66° Version = 3
Event ID	nc 73712486 ****This event has been revised.*

USGS science for a changing world

CISN

Earthquake Hazards Program

↩ Latest Earthquakes

Overview

Interactive Map

Regional Information

Impact

Felt Report - Tell Us!

Did You Feel It?

ShakeMap

PAGER

Technical

Origin

Moment Tensor

Focal Mechanism

Waveforms

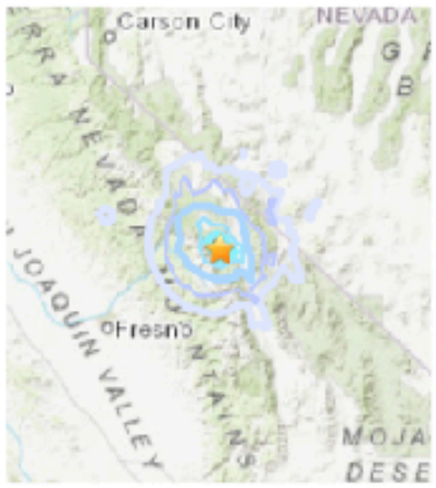
ShakeAlert®

Download Event KML

M 3.9 – 1km SW of Round Valley, CA

2022-03-31 02:05:26 (UTC) | 37.409°N 118.603°W | 10.5 km depth

Interactive Map



Contributed by NC [3]

Regional Information

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Felt Report - Tell Us!

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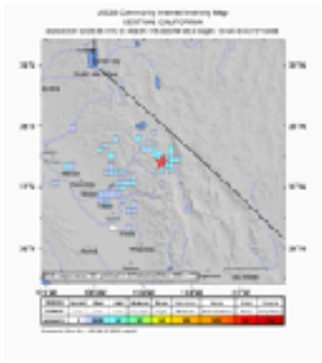
Responses

Contribute to citizen science. Please tell us about your experience.

Citizen Scientist Contributions

Did You Feel It? IV



Community Internet Intensity Map

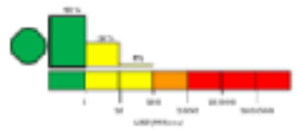
Contributed by US [5]

ShakeMap IV

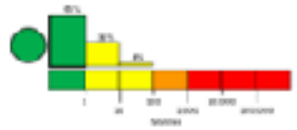
Estimated Intensity Map

Contributed by NC [3]

PAGER GREEN



Estimated Economic Losses



Estimated Fatalities

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USGS science for a changing world | CISN California Integrated Seismic Network

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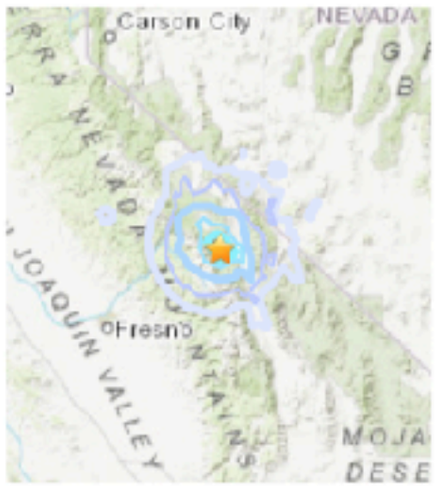

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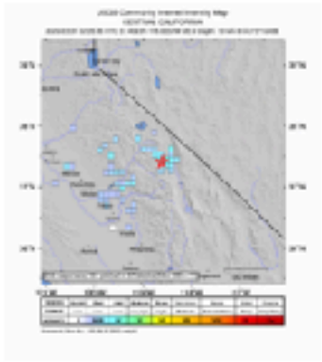

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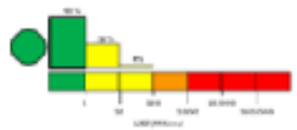

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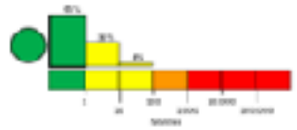

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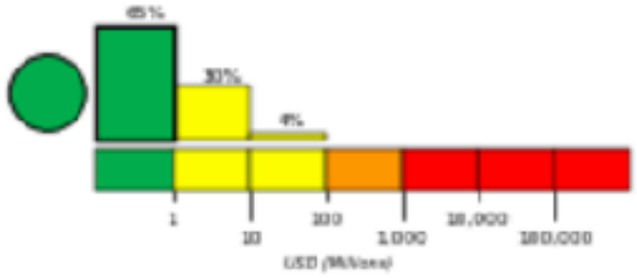
Future SERA - ShakeCast - ShakeMap Tool

PAGER

GREEN



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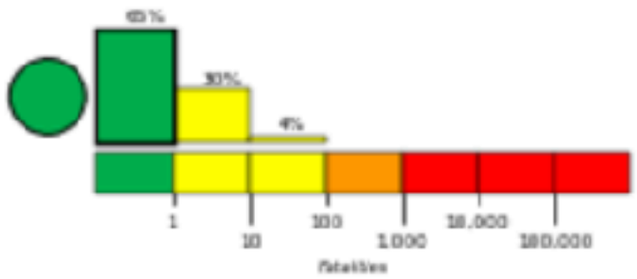

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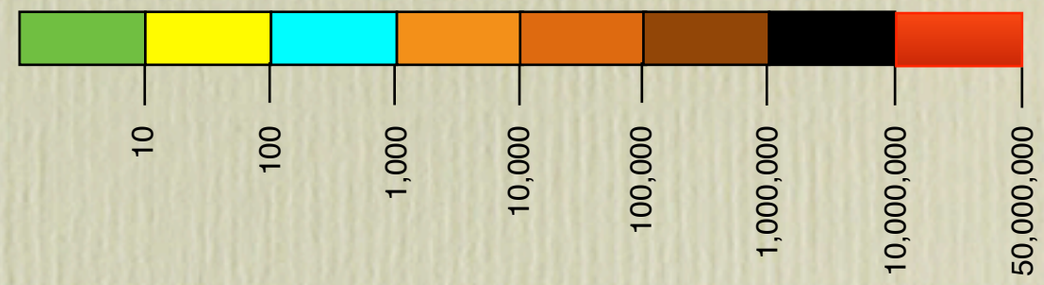
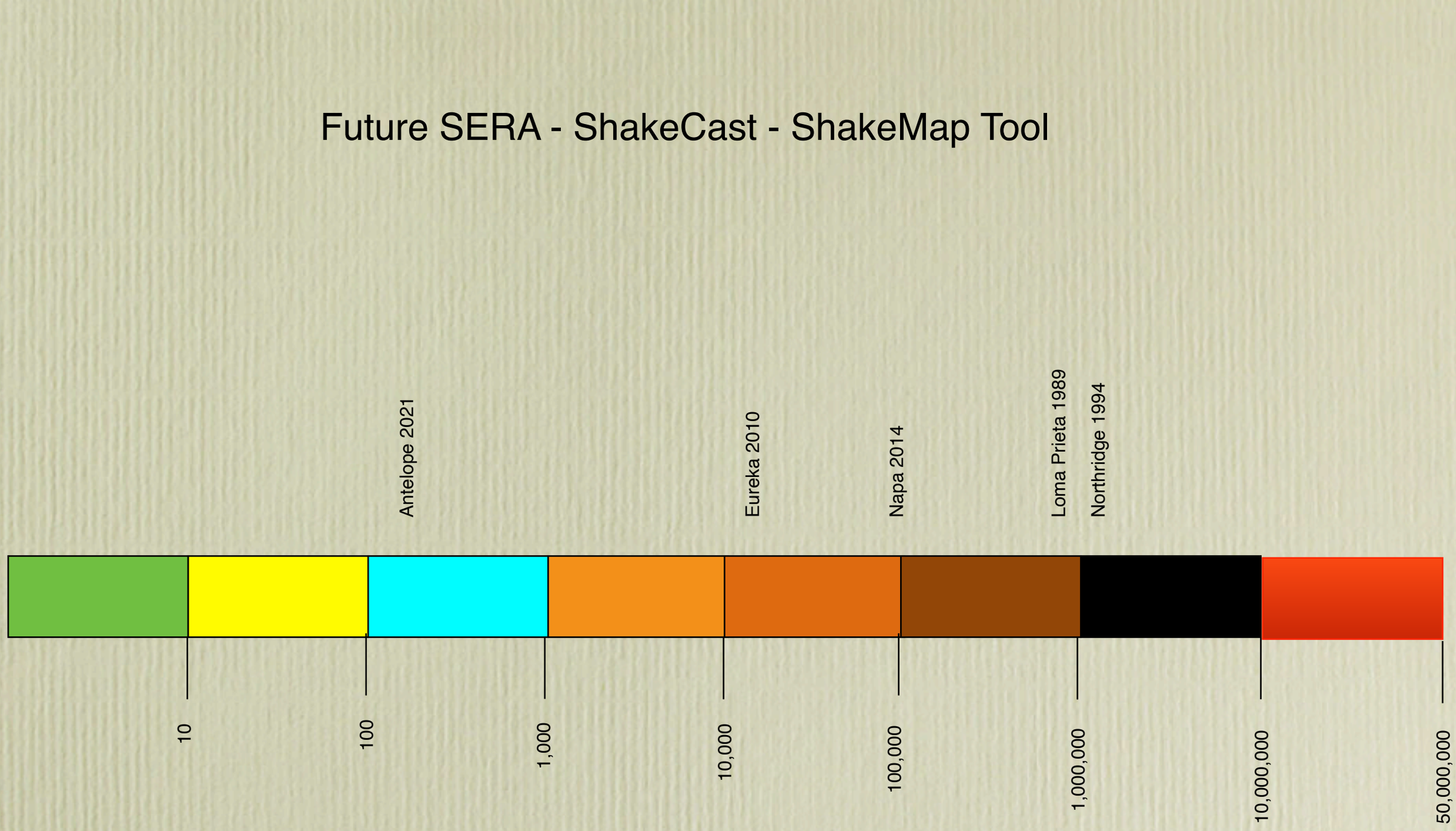


Estimated Customers with Power Outages

Estimated Customer-Minutes of Power Outages

Future SERA - ShakeCast - ShakeMap Tool



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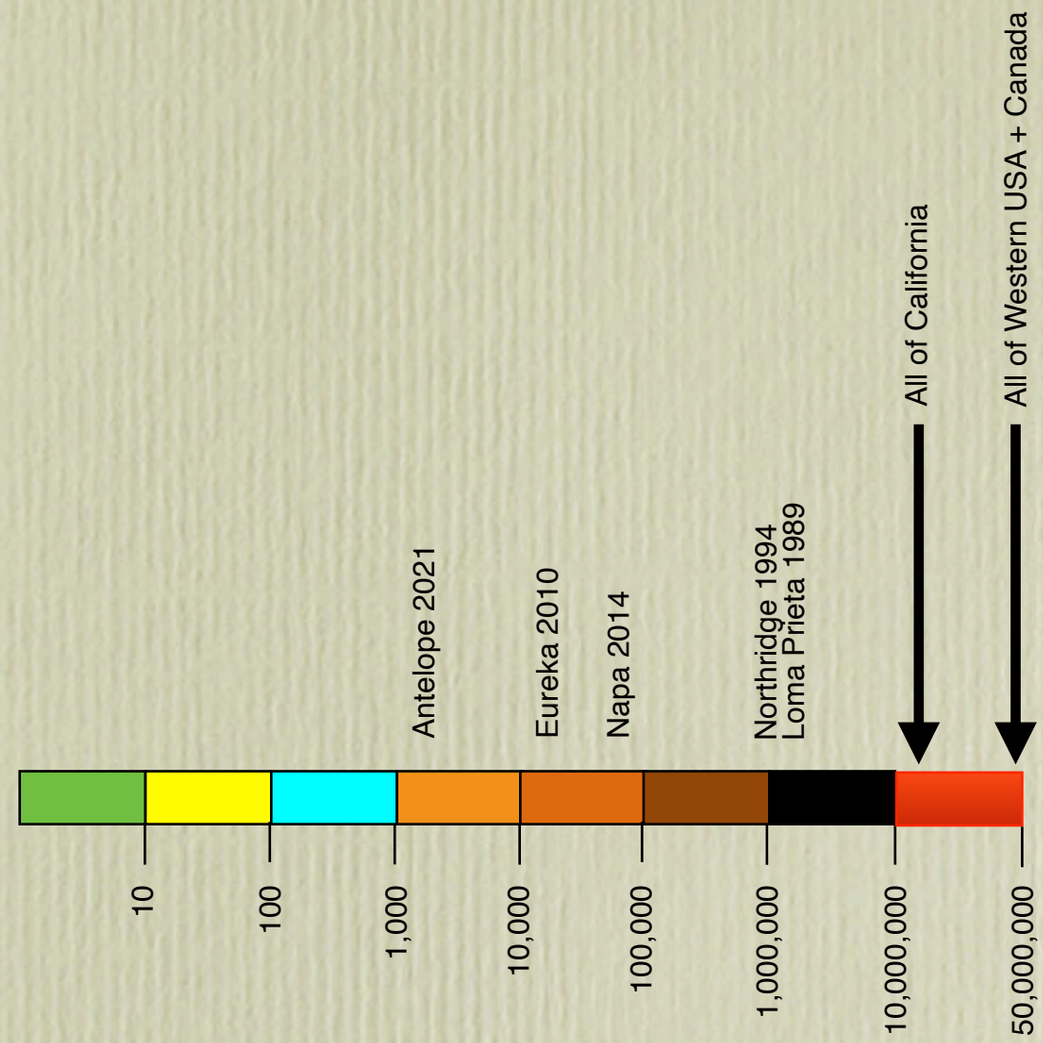

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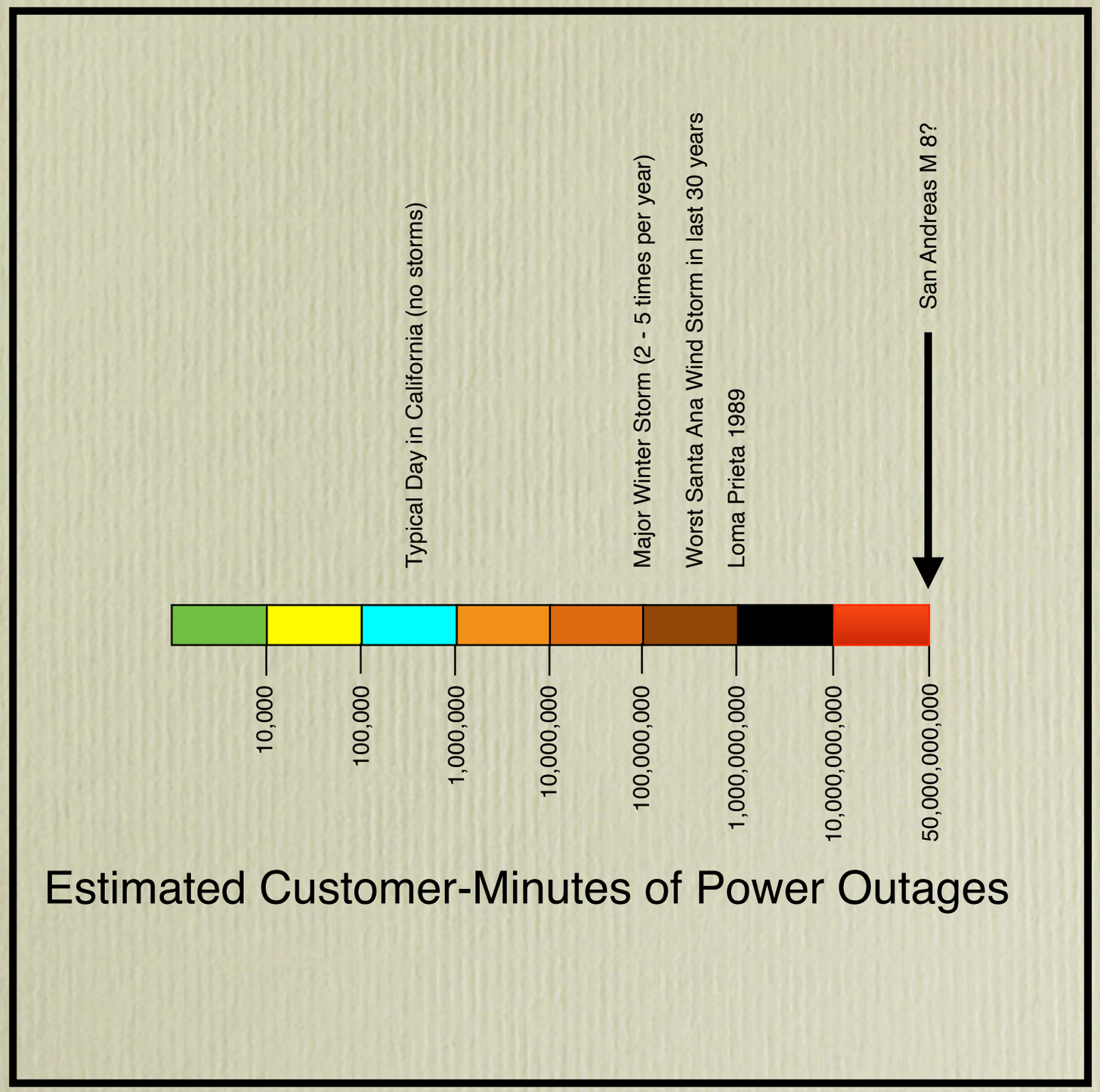


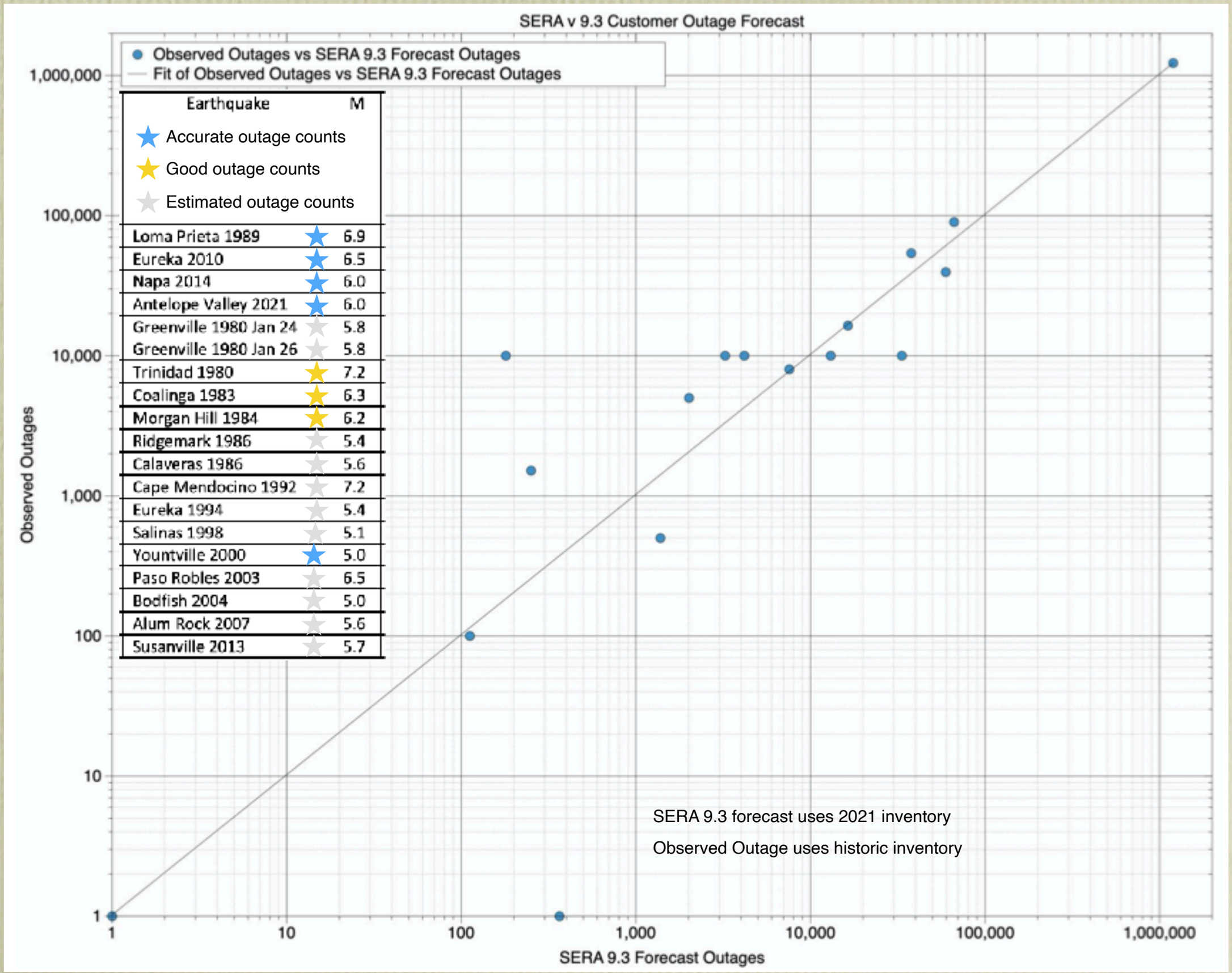
OK, This is a Cool Tool

- Start with Earthquakes
- Extend to Winter Storms, Hurricanes, Fires, Heat Waves, Cold Snaps, Floods, Tornados
- Gives Emergency Response Panners, Public some really useful information
- Add a “what -if” capability, and it becomes a great planning tool for Utilities
- Educate the Regulators (CPUC, Boards of Directors, City Councils, etc.)

Can this be Reliable?

- SERA: Yes, If you put in a huge amount of inventory, fragility information, geohazards
- SERA: Yes, AND you calibrate, calibrate, calibrate over many earthquakes, many systems

SERA v 9.3 Capability



How does this Tool Work?

- Method 1. No inventory (say, North Carolina)
- Method 2. With inventory (say northern California)

Method 1

- Compute PGA, PGV, Spectra, PGD, etc.
- Create a default inventory base on population (Census Tract) and location (zones with 2022-vintage seismic details, zones with limited seismic details, zones with no seismic details
- Use fragility models that are based on default inventory.
- Calibrate against west coast utilities

Method 2

- Compute PGA, PGV, Spectra, PGD, etc.
- Run SERA (inside ShakeMap)
- Issue results to utility owners (alerts, etc.)
- All this issues with who owns the data, access, etc. would need to be developed jointly with utilities who sign up.
- Conceptually, the same results as produced by SERA (damage by component, circuit reliability, maps, etc.)

Inventory, Fragility, Hazard

- SERA Model for a large electric utility
  - > 10 GB of data
  - > 2,000 fragility models
  - > 100,000 lines of code

Who Needs this Tool?

- PG&E, SCE, SDG&E, BPA, BCH, PacifiCorp: “I got mine, it runs on my PC”
- LADWP, SCL, PGE, WAPA: I’m interested. Some University types took a crack at this. I perceive a lot of risk. I’ve done something already.
- TVA, MLG&W. Hmmm. I perceive some risk.
- Palo Alto, Silicon Valley Power, Alameda, Glendale. I’m too small to worry about this… I’ve got a utility to run…. I’ll deal with it after the fact.

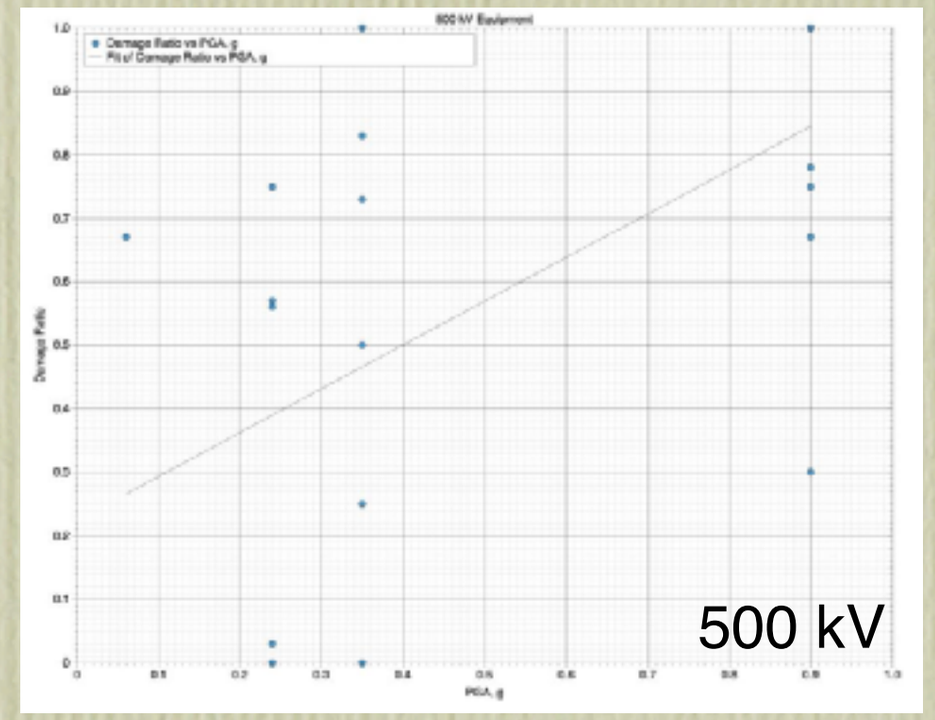
Who Needs this Tool?

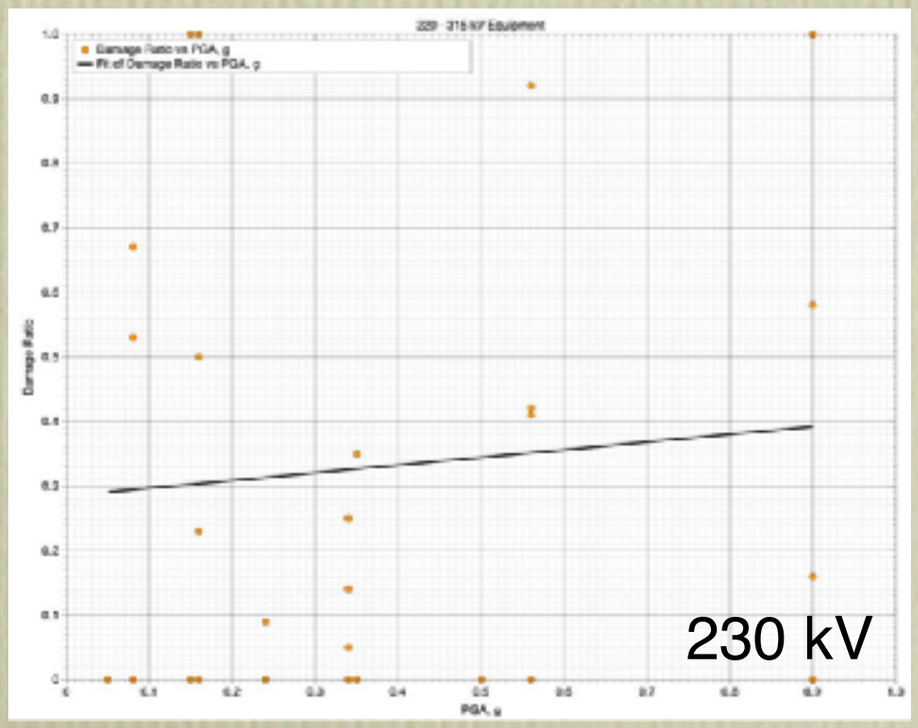
- IID, SMUD, Turlock Irrigation District, Liberty Energy
- Burbank, Glendale, Pasadena, Anaheim
- 80 Small “mom and pops” in Oregon and Washington States
- And > 1,000 utilities in other seismic zones (Quebec, British Columbia, South Carolina, Illinois, Yukon, Hawaii, Alaska, etc.)
- Japan, New Zealand, Turkey, Taiwan, India, Italy, Greece, China, Indonesia, Chile, Peru.....

So, What are the Issues to Make This Happen?

- 1994 HAZUS. John and Dennis wrote the Electric Power Module. Free. Simple default inventory.
- 1999. Thalia Agnanos report on substation fragility.
- We have learned a lot since then!

HAZUS 1994 (Dennis and John)

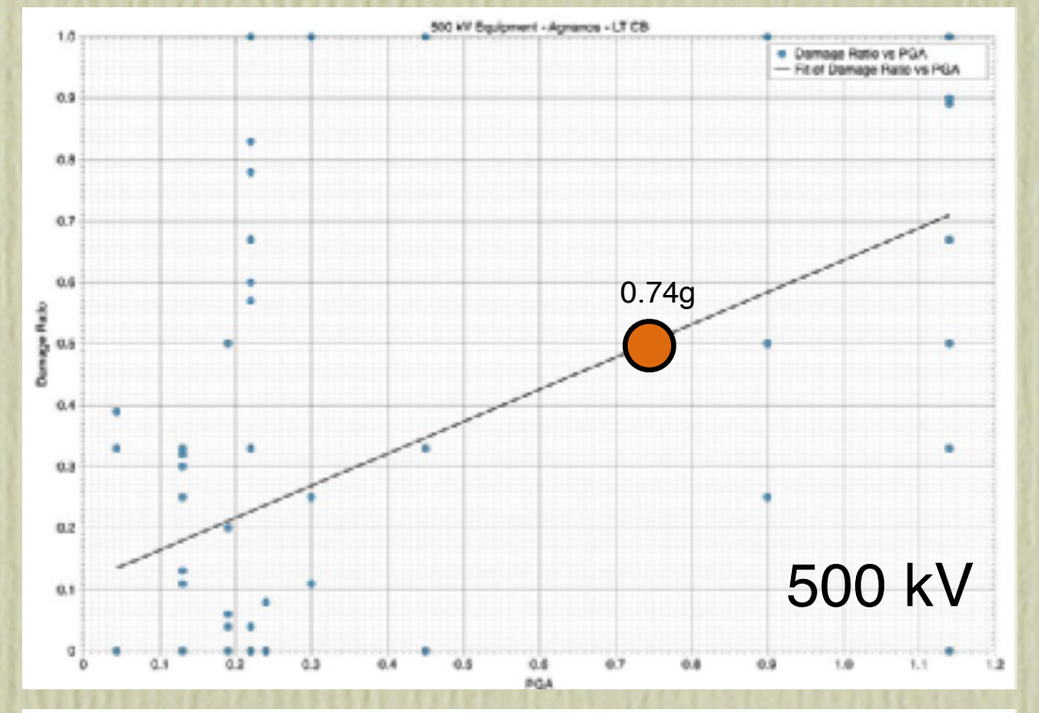


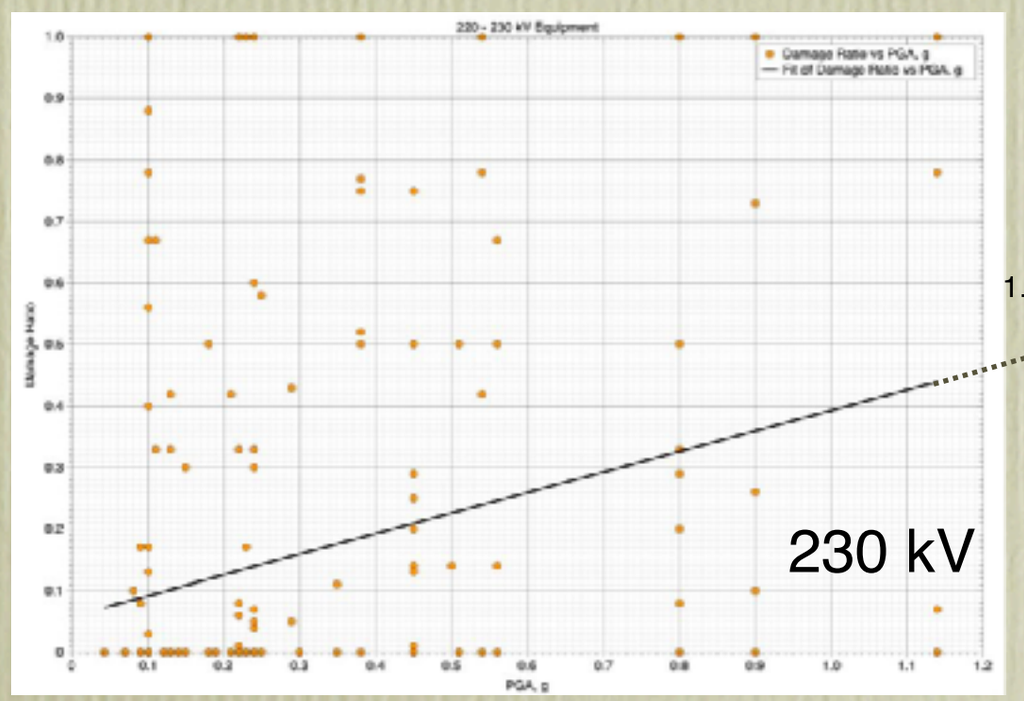


Item	500 kV Median (PGA, g)	230 kV Median (PGA, g)	115 kV Median (PGA, g)	β_c
TR 500 kV Anchored	0.40	0.60	0.75	0.70
TR 500 kV Unanchored	0.25	0.30	0.50	0.70
CB Live Tank, Standard	0.30	0.50	0.60	0.70
CB Live Tank, Seismic	0.40	0.70	1.00	0.70
CB Dead Tank	0.70	1.60	2.00	0.70
DS - Rigid Bus	0.40	0.50	0.90	0.70
DS - Flex Bus	0.60	0.75	1.20	0.70
SA	0.40	0.60	1.00	0.70
CCVT - post supported	0.90	0.60	1.00	0.70
CCVT - suspended	0.30	0.60		0.70
CT - gasketed	0.30	0.50	0.75	0.70
CT - flanged	0.80			0.70
WT - post supported	0.50	0.60	1.00	0.70
WT - suspended	1.30	1.40	1.60	0.60

Table 5-2. HAZUS 500 kV F Models

Thalia 1999 (HAZUS + Anshel)





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CT - flanged	0.80			0.70
WT - post supported	0.50	0.60	1.00	0.70
WT - suspended	1.30	1.40	1.60	0.60

Table 5-2. HAZUS / Thalia Fragility Models

HAZUS + Agnanos

- What Did Dennis, John, Thalia, Anshel Miss in 1994 and 1999?
- We drew fragility models using RAW data.
- We did not distinguish between damage due to inertial motions and adverse bus interactions
- 2022: Today, we see that perhaps **half of all past damage** was due to adverse bus interactions
- 2022: Today, we see that the MAJORITY of power outages are due to damage in the Distribution System

What about the millions of small stuff?

Bus Issues
Pardee Substation
1994 Northridge
PGA = 0.56g

What is the Fragility Level for this 220 kV DS?

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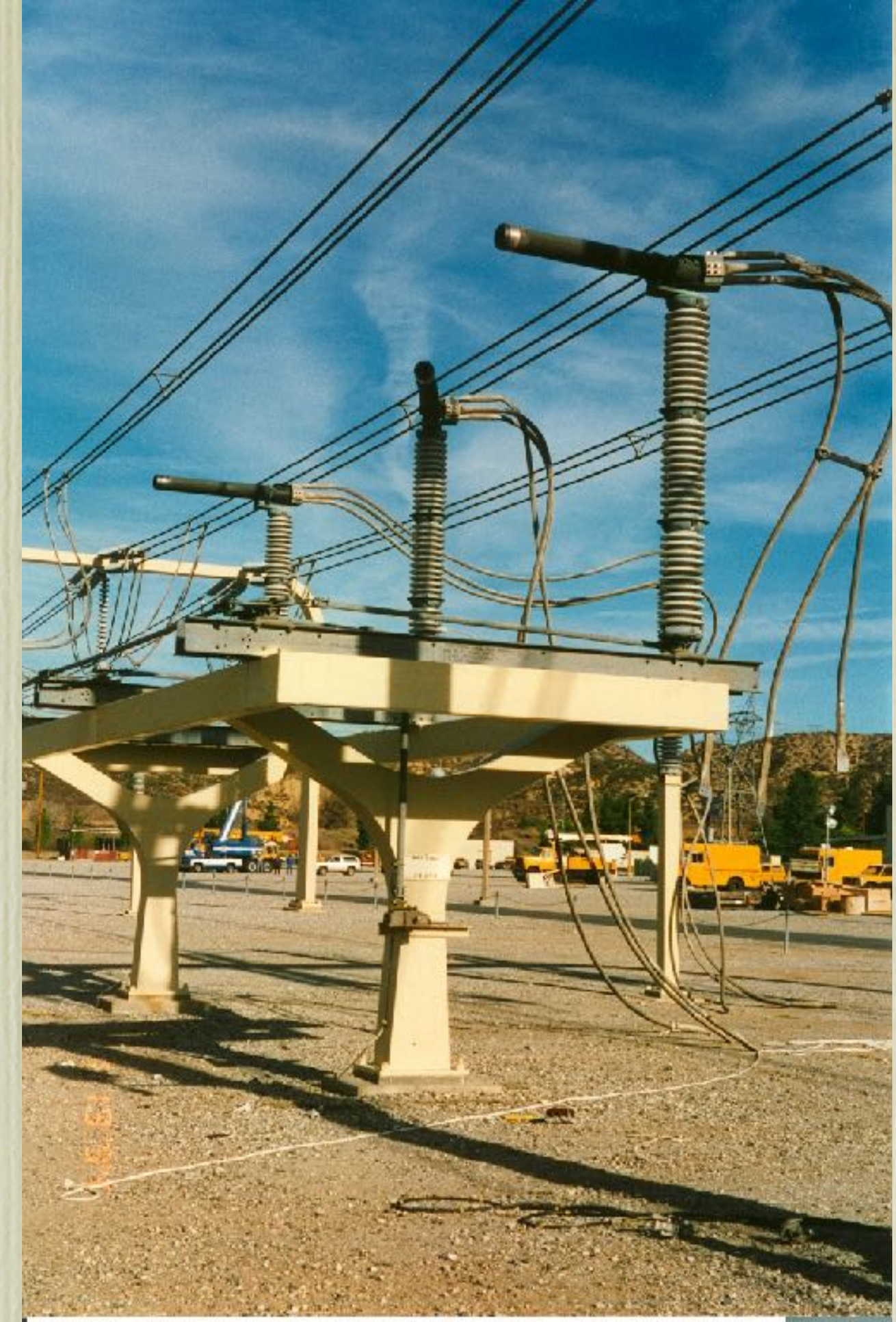


What is the Fragility Level for this 220 kV DS?

Bus Issues
Pardee Substation
1994 Northridge
PGA = 0.56g

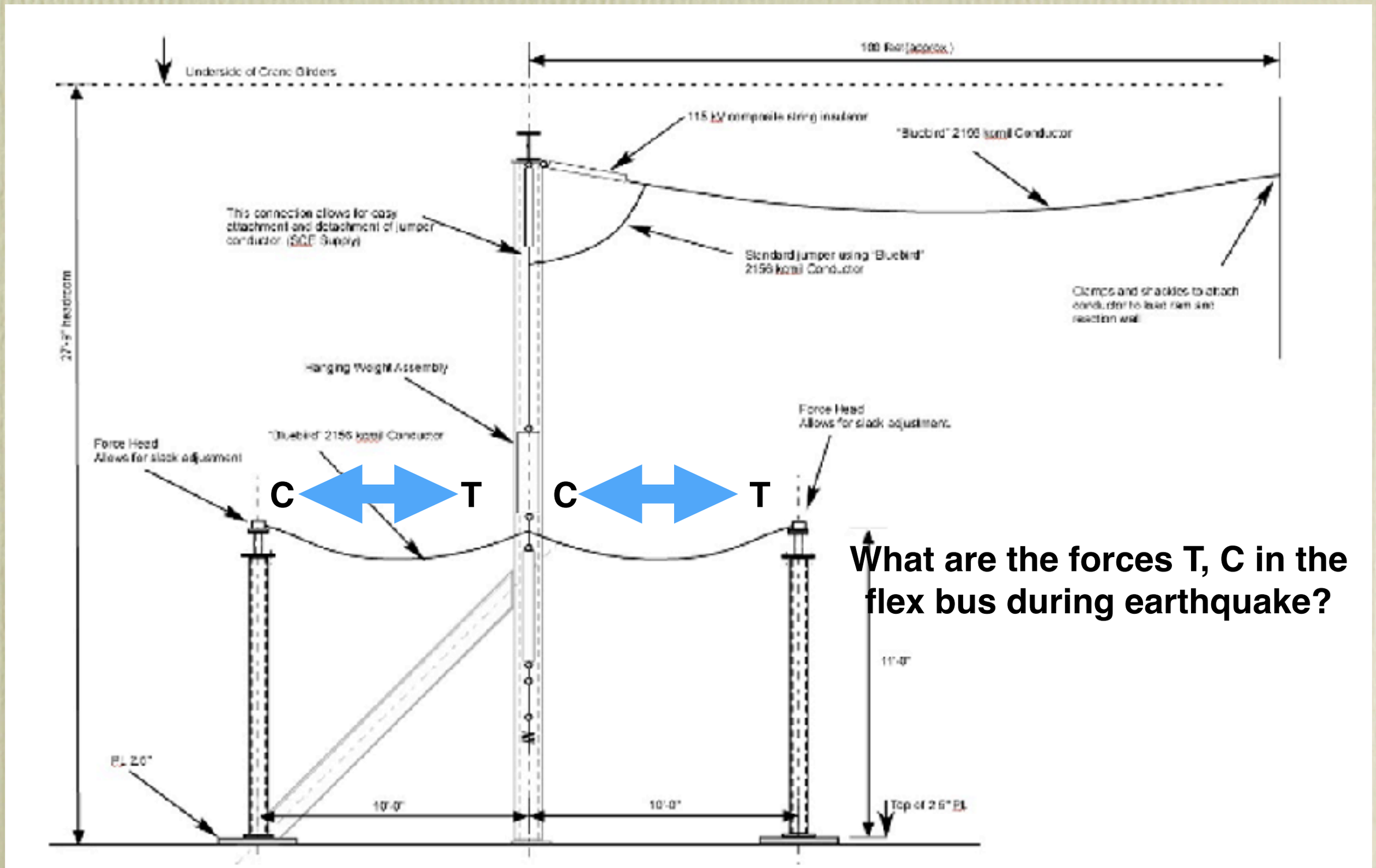
Row # / Component (all 220 kV)	Not Damaged	Damaged	Comment
1. Disconnect Switches (Horizontal)	79	56	41.4%
2. Potential Transformers	6	0	0%
3. CCVTs	26	19	42.2%
4. Circuit Breakers Dead Tank / SF6	45	0	0%
5. Circuit Breakers (all types) Live Tank	2	23	92%
6. Wave Traps	13	0	0%
7. GE ATB Live Tank Breaker	0	6	100%
8. Other Live Tank Breaker	5	4	44%
9. DS next to damaged GE ATB LT CB	1	11	91.7%
10. DS next to undamaged W SF6 CB	43	17	28.3%
11. DS next to swinging WT	7	11	61.1%
12. DS next to swinging CCVT	25	23	47.9%
13. DS not next to sides of damaged CB or swinging WT or swinging CCVT	57	12	17.3%
14. DS posts not next to damaged CB or swinging WT or swinging CCVT	125	13	9.4%
15. DS next to sides of damaged CB or swinging WT or swinging CCVT	10	23	69.7%
16. DS posts next to damaged CB or swinging WT or swinging CCVT	39	27	48.2%

Observed Damage Data, Pardee Substation

Component (all 220 kV)	Combined Inertial + Interaction PGA, g	Inertial Only PGA, g	Sample Size
1. DS, Horizontal Break, Flex Stand	0.598	0.831	135
2. Potential Transformers		0.917	6
3. CCVTs			45
4. CB Westinghouse Dead Tank / SF6		1.037	45
5. CB Live Tank	0.367		25
6. WT Hanging	1.008		13
7. CB GE ATB Live Tank	0.342		6
8. CB Other Live Tank Breaker	0.586		9

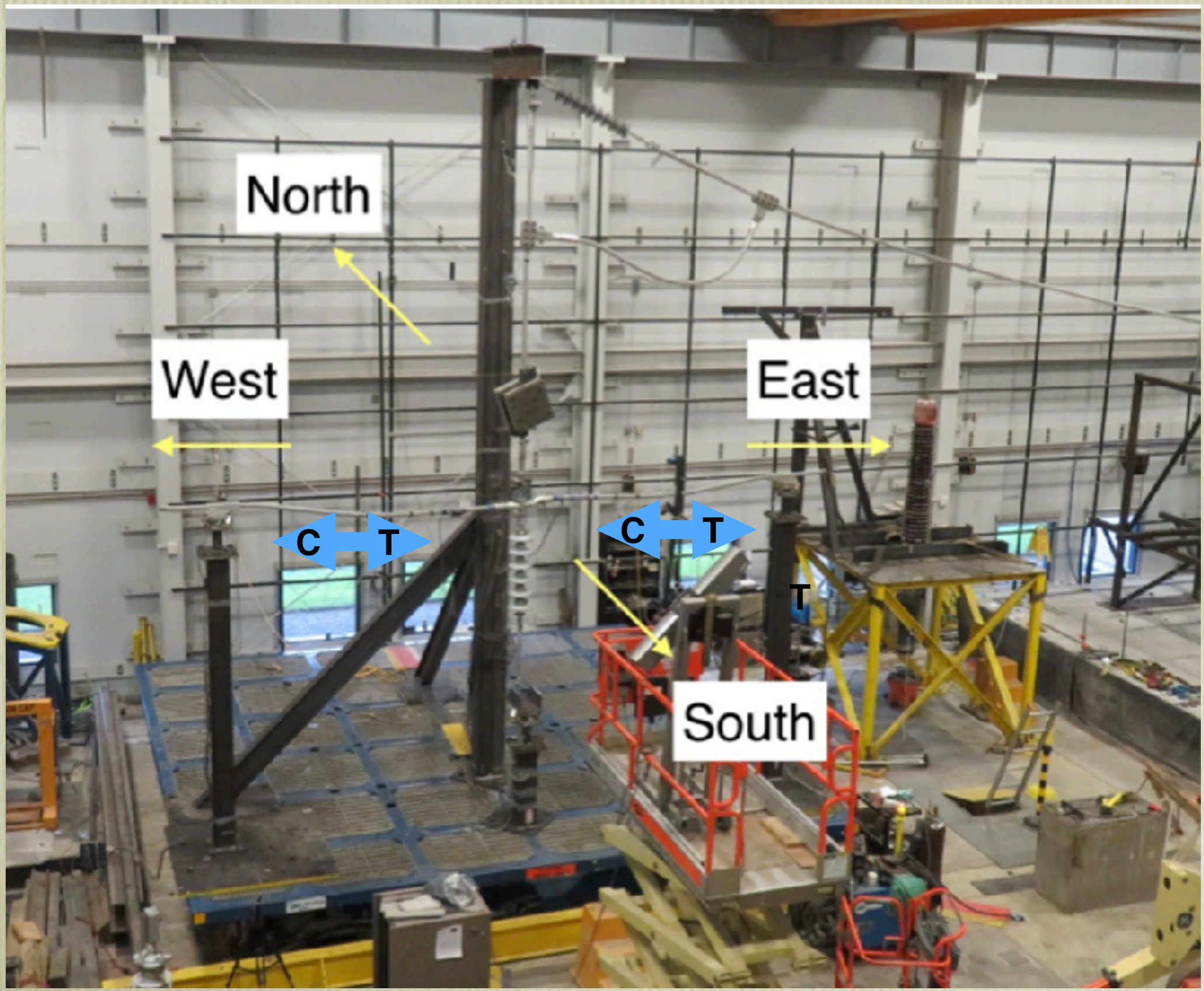
Fragility Models, Pardee Substation Beta = 0.30

Quantifying Bus Forces

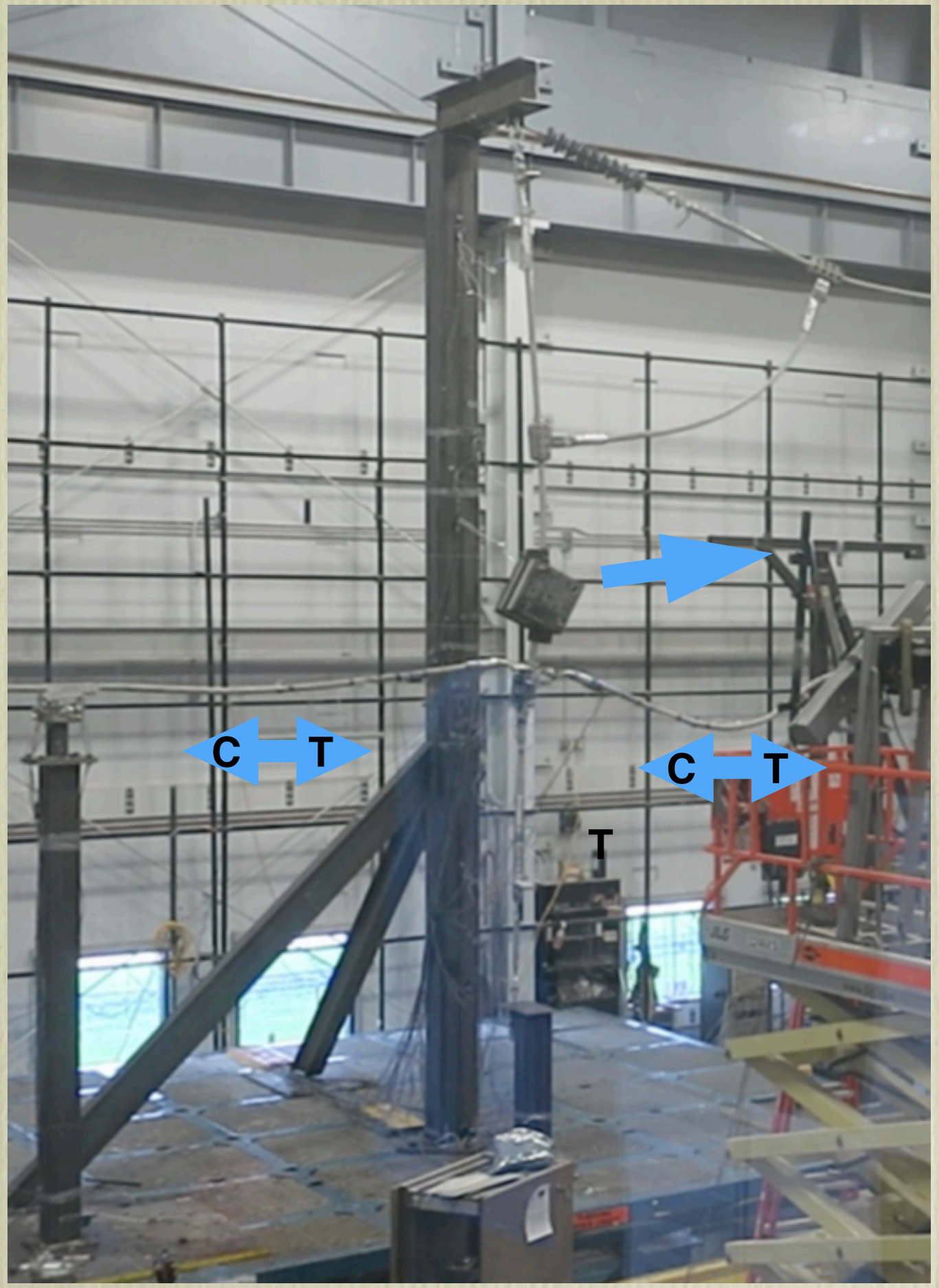


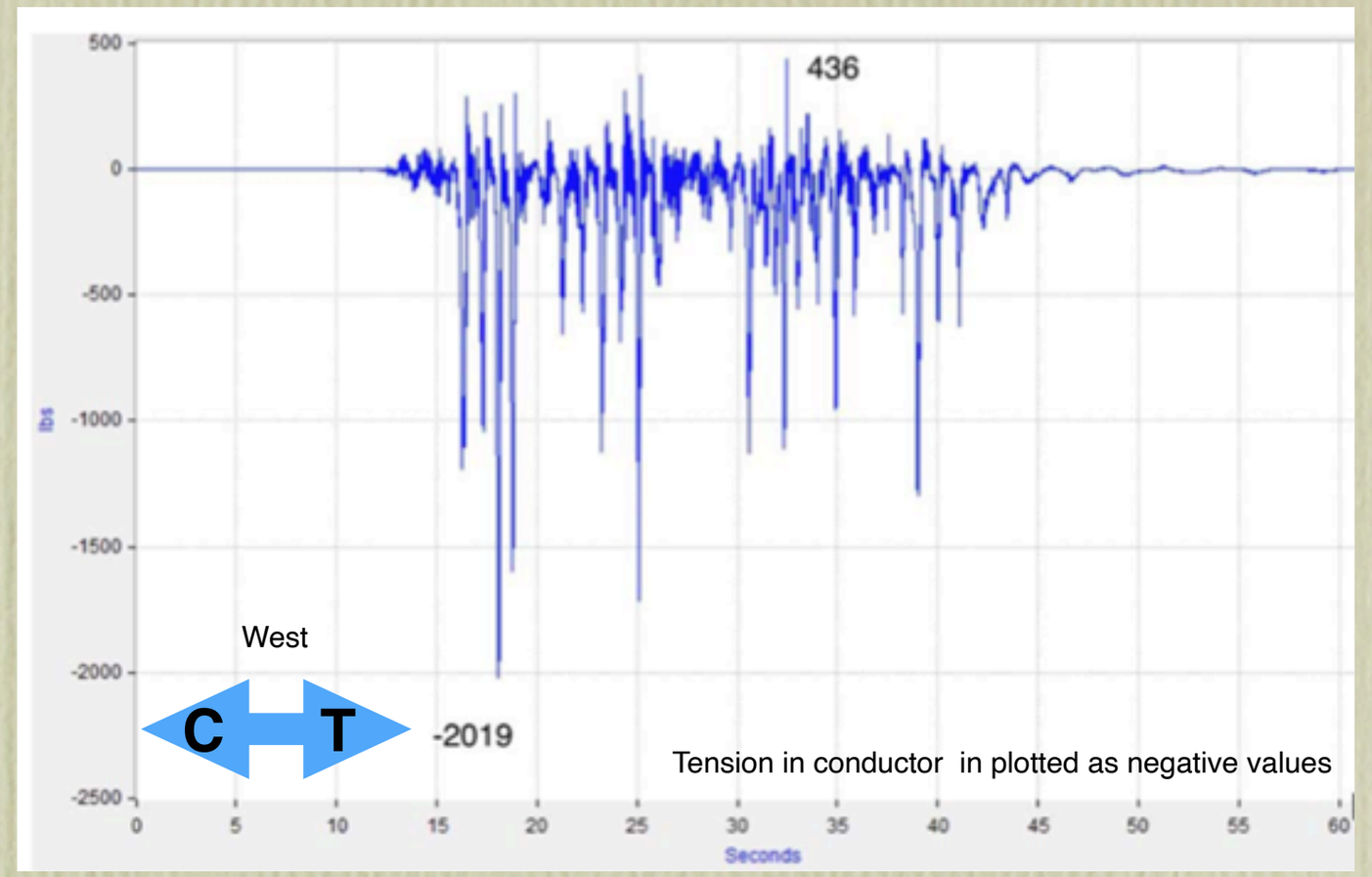
What are the forces T, C in the flex bus during earthquake?

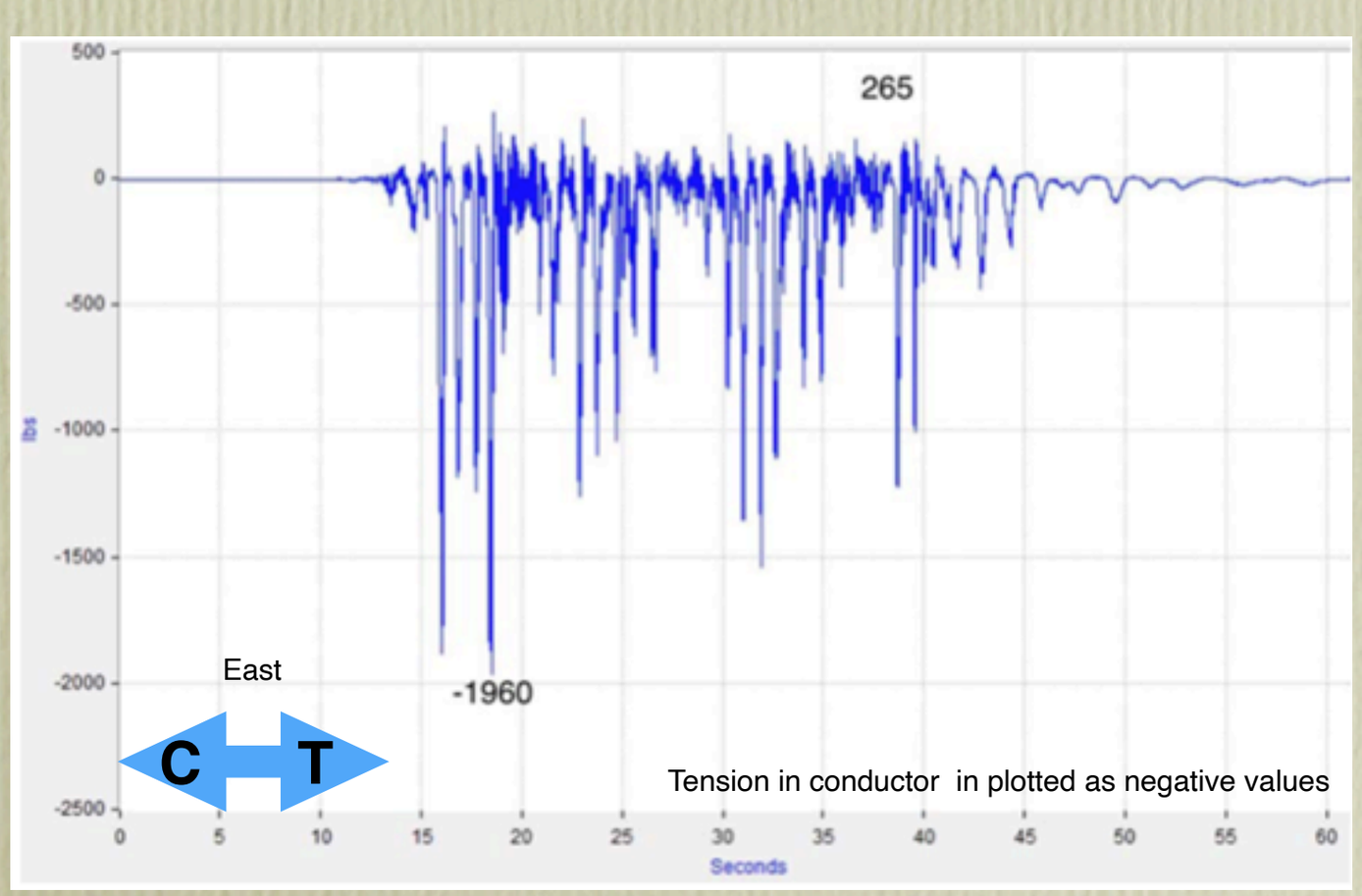
Quantifying Bus Forces

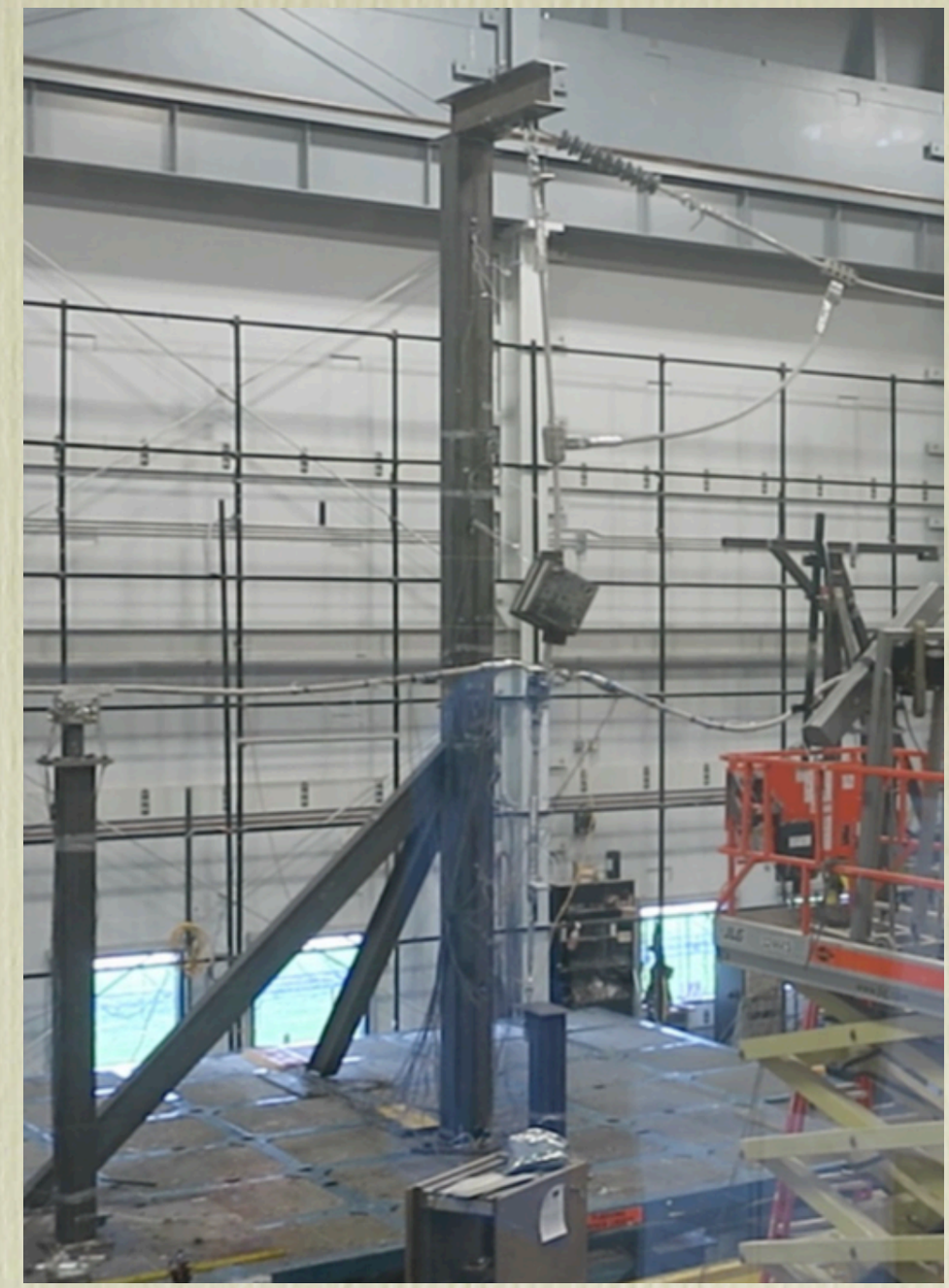


Snapshot during Test









Conductor: Bluebird 2156 kcmil
Steel core
Aluminum strands

Key Points

- Substations: We have "nearly solved" the seismic vulnerability. Some utilities are well on their way to implementation. Some utilities are like Dinosaurs.
- Distribution Systems: The Elephant on the room
- How much to complete the job? Brute force = $300,000,000,000 for California.
- SERA and ShakeMaps: tools to quantify, evaluate, and make smart decisions. Maybe find a $40 B mitigation plan that does 95% of the $300 B brute force plan.

Key Findings

- Modern Seismic-Qualified Substations: a WHOLE LOT BETTER than what was built in the 1960s and 1970s
- Old, vulnerable equipment had Fragility levels PGA = 0.2g to 0.5g
- New, qualified equipment has Fragility levels commonly PGA = 1.3g+

Key Findings

- To Forecast outages, we need:
- Substation issues (0-25% of issue in California, 50%± in Memphis, Eugene, Salt Lake City)
- Distribution issues (75-100% of issue in California, 50±% in Memphis, Eugene, Salt Lake City)
- Power Plants, Grid Frequency: 2nd order
- Locally: Landslides (liquefaction) for Towers, Jumpers, etc.

Summary

- SERA - ShakeMap. These tools can predict power outages. All you need is inventory, fragility, hazards.
- Substations. The problem is largely "solved". Some utilities implement. Others are waiting for that 66 million year event.
- $300 Billion will reduce power outages by 90%. Maybe SERA - ShakeMap tools can do this “smarter".

Possible Actions

- USGS - ShakeMap + SERA
- ~1 man-year effort. Uncle Sam. Many will be involved.
- ~20,000 lines of new code
- 6 months to get it working “Alpha”
- 3 months of calibration “Beta”
- Low data -> High uncertainty, Red, Yellow, Green Maps
- High data -> Increased confidence, better tool for planning

Thank you