

“Zipper Arrays” (USGS background) & Earthquake Resiliency for SCE’s Power Grid

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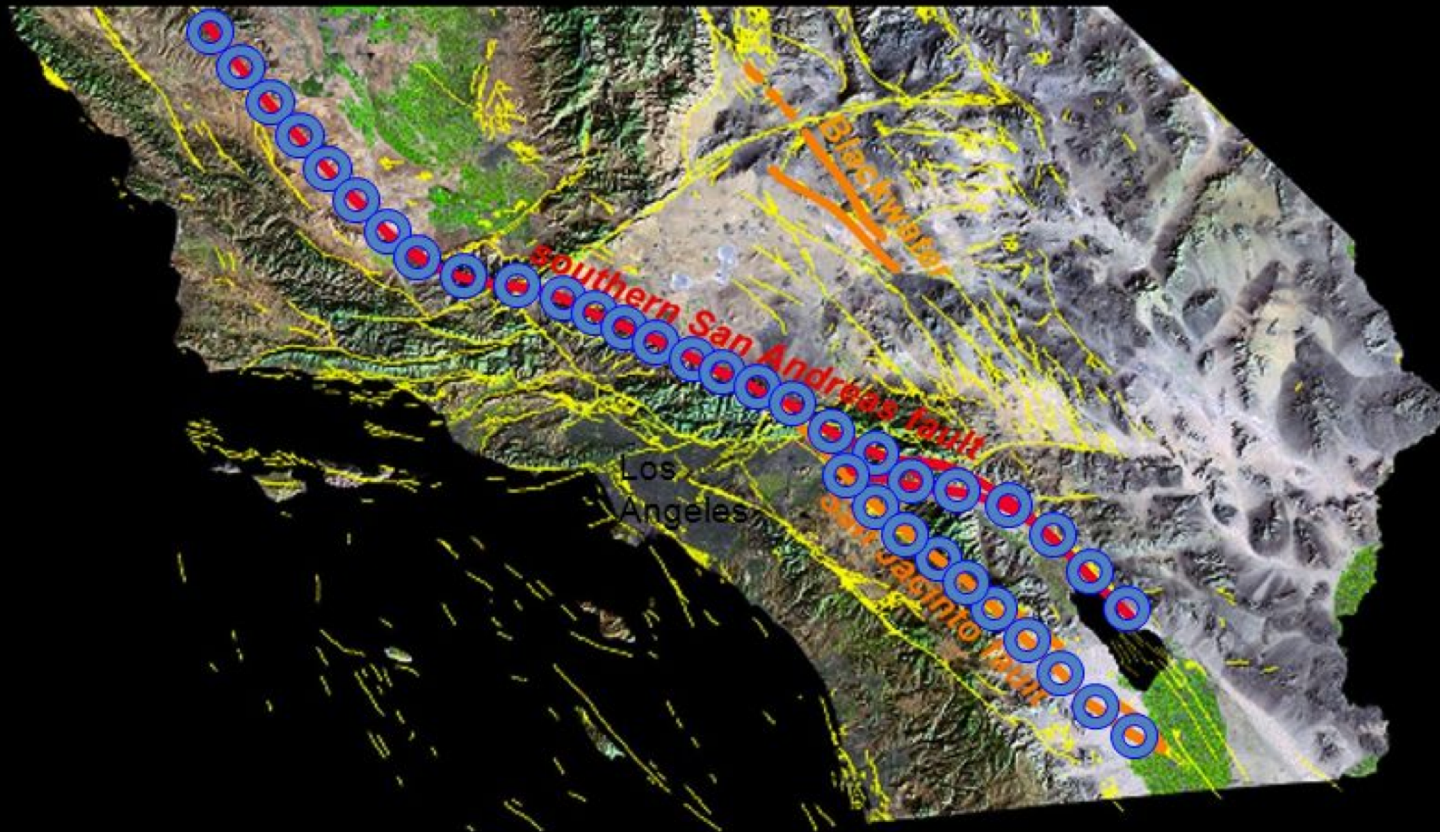
SCEC Near-Fault Observatory Workshop

October 27, 2022

Part 1. “Zipper Arrays” (USGS background)

USGS “Zipper Array” – southern San Andreas Fault (2007)

Proposed a *zipper array* for early warning and immediate finite-fault source for San Andreas and San Jacinto fault ‘Big Ones’

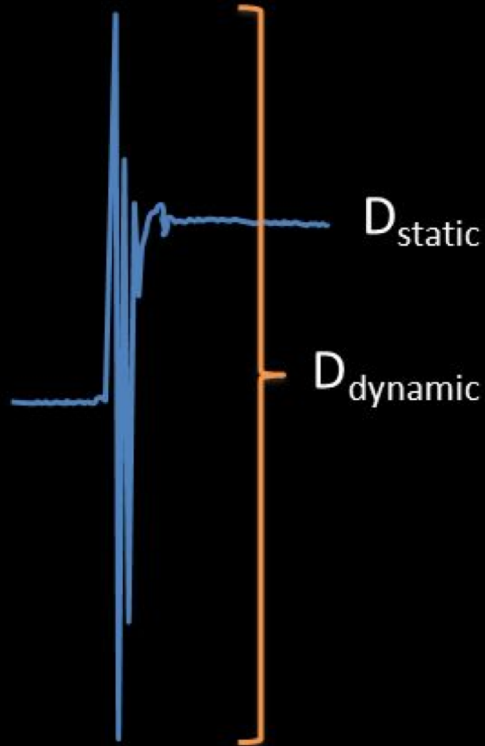


2007

IOC - 36 quadrilaterals shown @ 30 km spacing (shown)
FOC - 100 quads @ 10 km spacing (\$5 M init. + \$1 M/yr)

Observing Near-Fault Large Ground Motions; How Best to Observe?

Observing Static & Dynamic Displacements



In near-field region, $D_{\text{dynamic}} > D_{\text{static}}$

- very useful for EEW algorithms
- e.g., Yamada, Heaton, Aagaard
- FinDer (Böse, Heaton & Hauksson, 2012)

Fault slip means displacements are instantaneous right at the fault, move with rupture front

Direct observation of displacement is **fastest**

Displacements decrease with $1/r^2$

At distances > 50 km, surface wave amplit.'s will exceed displacements and static will travel out at approx. S-wave velocity

Examine rapid post-seismic behavior (friction law?)

Part 2. Earthquake Resiliency for SCE's Power Grid

Energy for What's Ahead®





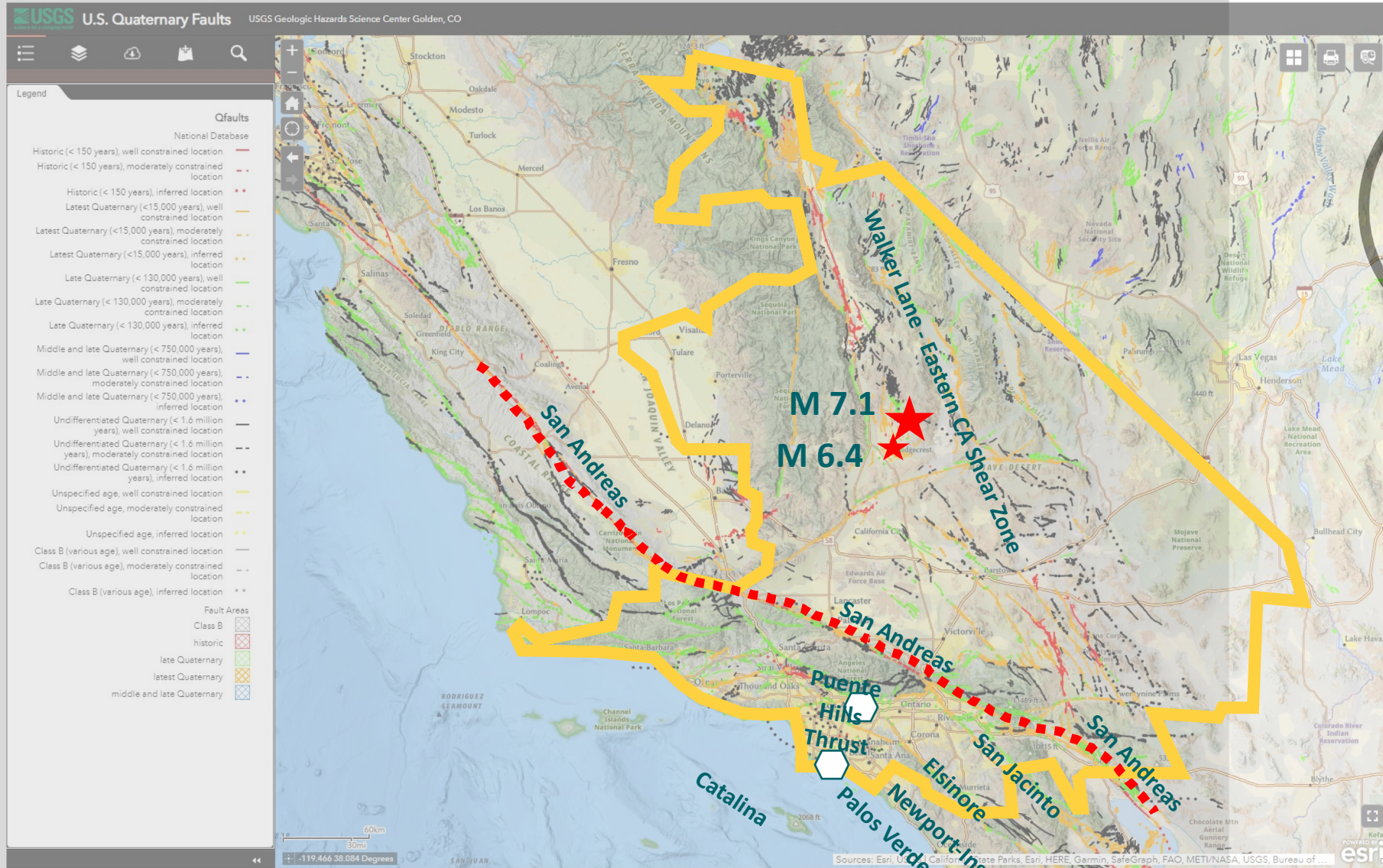
1986 M 6.0
SCE Switchyard Damage
Photo Credit: Ken Lubas



International standard (IEEE 693) has been made more stringent after damaging earthquakes, and SCE's bulk substation switchyards have been mitigated

Engineering and geohazards guidance matters; we know what to do, but mitigations are costly, so the work needs to be prioritized

Faults



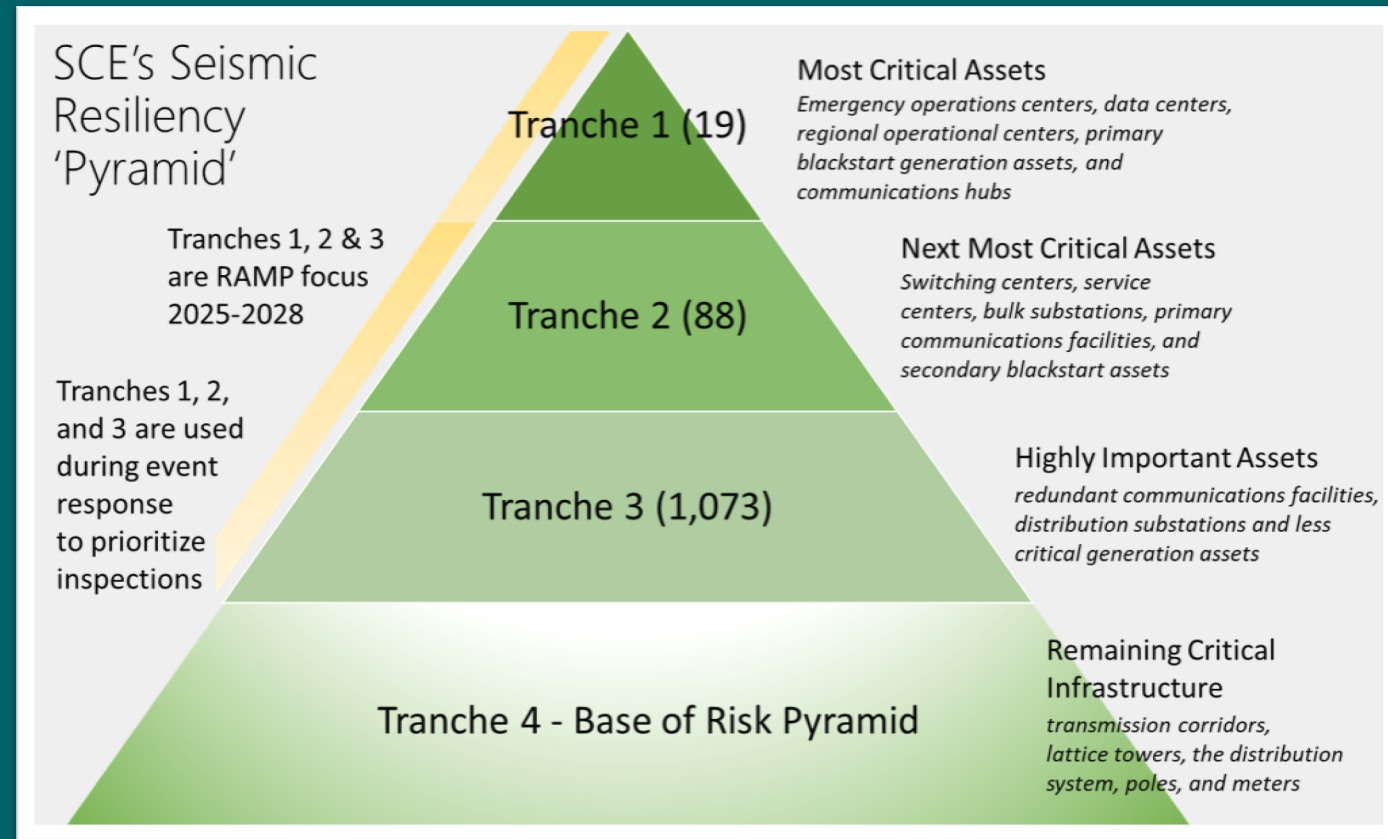
Changing the Outcome

By mitigating ahead of time, SCE will strategically reduce the *safety* and *reliability* impacts of future ‘severe’ & ‘catastrophic’ earthquakes

Key Concepts:

- Seismic Resiliency Pyramid
 - start with top assets
 - e.g., highly occupied buildings
 - “chip away” & reduce *safety* risks
- Reduce Widespread Outage
 - prioritize mitigations to speed system restoration – *reliability!*

SCE Seismic Resiliency Program (2016 – present)



\$156.7M invested by SCE in seismic mitigation projects from 2016-2021



50 Electric Mitigation projects completed



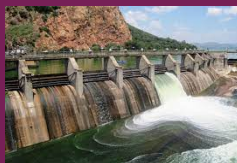
33 Bulk power MEER Buildings Assessed **4** MEER building mitigations completed and **6** under Mitigation in 2022



28 Facility Mitigation projects completed
60 Facility Assessments completed



60 Rack and Cabinet Mitigations completed at a DC and **13** Telecom Racks Mitigated between **2** substations.



23 Generation Facility Assessments Completed

Seismic Assessments & Mitigation: MEER and Control Bldg's



How is the building going to perform during earthquake

What are potential deficiencies?



Need retrofit?



Completed Seismic Retrofit of a Reinforced Masonry Wall at an SCE AA Substation; Vertical Pipes Added and Ties from Walls to Roof Added



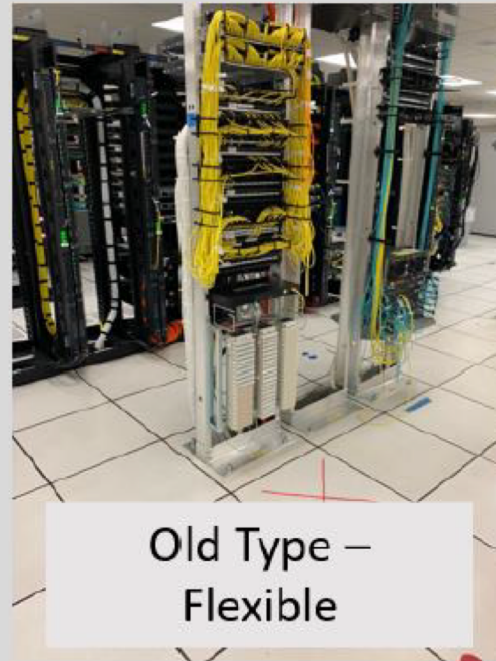
‘Strongbacks’ are pipes attached to an exterior wall of a MEER

Completed Seismic Mitigations in Comm Rooms and SCE Data Center: Equipment Racks Retrofitted or Replaced



Shake-table tests identified the need to strengthen existing aluminum racks to limit swaying.

They are either replaced with seismic qualified 2-post steel racks or retrofitted with additional bracing



Old Type – Flexible



New Type – Much Less Flexible

Two-post aluminum racks for equipment were replaced with 4-post seismic qualified racks to secure critical equipment