Caltech

CSN Community Seismic Network

Low-cost Seismic Monitoring: The Community Seismic Network

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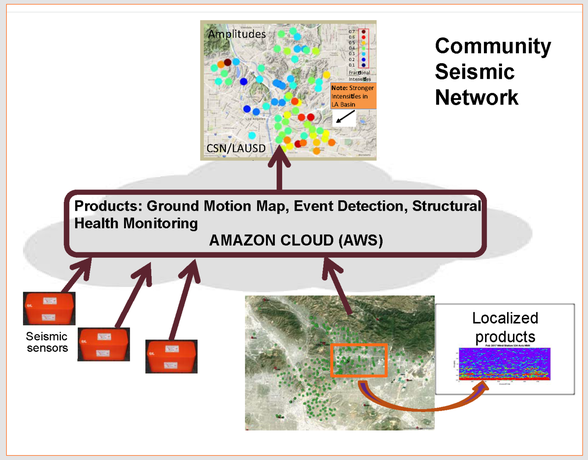
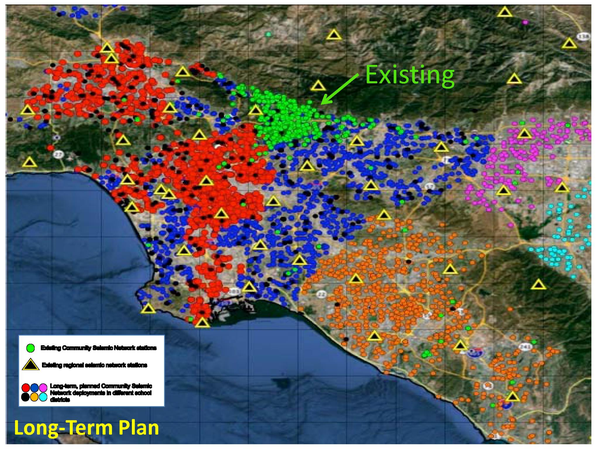
The Community Seismic Network (CSN)

The *Community Seismic Network (CSN)* is a permanent, Cloud-based, strong-motion network, currently comprising hundreds of elements, located in the greater Los Angeles area. It uses:

- inexpensive, three-component, MEMS accelerometers, and can detect low-magnitude events in southern California.
- *low-cost*, distributed computing design for densely-spaced, fast network operations.
- next-generation Cloud computing to
  - Streamline customized algorithms and data products for subsets of sensors to be defined as desired - e.g. site response or probability of damage in a specific geographic region.
  - Exploit computing resources of each station and speed up data flow.
  - Integrate with sparse regional networks.



CSN's architecture



Current CSN sites: on-going and planned expansions

CSN's key features:

- Recording continuous acceleration time series 24/7/365 at 250 sps.
- Real-time access to the data.
- Automated real-time event detection.
- Distributed "on-board" computing.

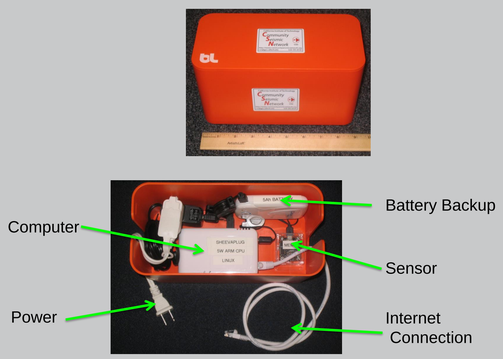
Real-time products: seismicity parameters (magnitude, location, time), ground shaking intensity (ShakeMap), probability of damage to infrastructure (fragility analysis).

Intermediate-term products: site response from shear-wave velocity imaging, microzonation maps from small earthquakes for seismic risk assessment.

Low-Cost Sensor Hardware

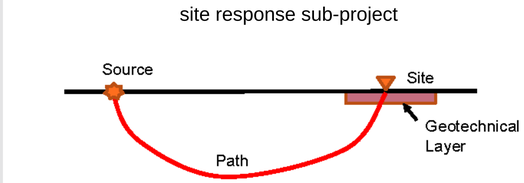
The deployed (current generation) package includes:

- MEMS accelerometer (Phidget 1041, range of ±2g and a sensitivity ~70 μg)
- On board computation unit (Raspberry Pi 3 - ARMv8 processor, 1G RAM, 4 cores running Linux)
- Nonvolatile memory unit, or an SD card (can store up to 3 weeks of data)
- Battery backup



Motivating science questions for GMG

- How are time-varying and spatially-varying seismicity levels related to disposal water pumping pressures, e.g. injection rates?
- What are relationships among injection water pressure, localized seismicity around injection site, and regional tectonic seismicity?
- What are infrastructure damage impacts due to ground shaking?
- How can Cloud computing features be exploited to advance seismic monitoring and seismic hazard analysis?



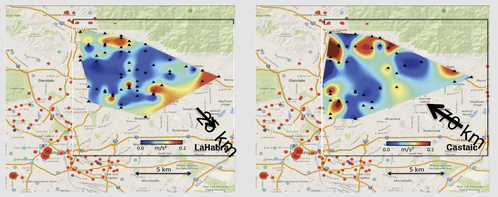
Actual Vs30 measurements are sparse

Propose to use measurements with CSN sensors at all free-field locations
- Ambient noise correlations – surface waves- 1 km depth resolution
- H/V measurements – constrain top 500 m in surface waves
- Minimum noise levels –empirical measurements of amplification
- Amplifications determined by small earthquakes

Product: map of shear-wave velocity in top 1 km on a scale length of <1 km

CSN's ShakeMap & ShakeCast

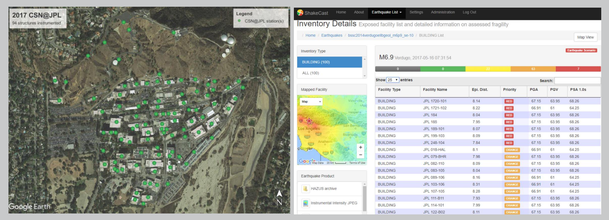
- An experimental *ShakeMap* uses measurements from CSN stations and provides users with ground shaking intensity measurements.
- CSN's spatially-dense instrumentation allows for higher-resolution ShakeMaps than currently being produced with regional seismic network data.
- Customized configurations of *ShakeCast* for CSN sensor locations can be developed that compute fragility curves to estimate probability of damage.



La Habra & Castaic Earthquakes ShakeMaps

The example mini-city of the JPL campus

- 220 CSN stations are deployed at JPL (100 at ground level).
- The ground-level stations are contributing to CSN's ShakeMap.
- Each instrumented building has a canonical fragility curve associated with it.
- A ShakeCast instance configured for the JPL campus shows the assessed fragilities below for a scenario earthquake.



The JPL stations & ShakeCast interface

Dense Building Instrumentation & Finite-Element Modeling

In addition to ground-level instrumentation, a number of buildings have been instrumented with dense CSN sensor arrays (one or more triaxial sensors per floor).
For these select buildings, high-fidelity finite-element models have been developed, giving us the ability to:

- ❑ *forward* model structural response, stress evaluation, etc, and
- ❑ *inverse* model for structural parameter estimation, damage detection.