

Consortium of Organizations for Strong-Motion Observations Systems

COSMOS

Urban Strong-Motion Reference Station Guidelines

Goals, Criteria and Specifications for Urban Strong-Motion Reference Stations

by

Strong-Motion Program Board of COSMOS

1. Goals

The goals of urban strong-motion reference stations are to provide:

- 1.1 Reliable information for accurate, effective characterization of the shaking by ShakeMap and other rapid post-earthquake tools;
- 1.2 Recorded motion for post-earthquake performance analysis of structures;
- 1.3 Empirical basis for long-term improvements in the seismic provisions of building codes and construction guidelines; and
- 1.4 Seismological data, complementing data from non-urban stations, to improve the understanding of earthquake generation and seismic wave propagation in areas with inadequate measurements.

2. Criteria

As a general optimization strategy, one or a combination of the following measures should be used to optimize the locations of instruments:

- 2.1 **Probability of Shaking:** highest likelihood of shaking (percentage in N years), split into two groupings:

2.1.1 Probability of Short-Period Shaking: addressing the many short-period structures that occur widely across the country.

2.1.2 Probability of Long-Period Shaking: addressing the long-period hazard to tall, high-rise buildings that occur in major cities at specific locations in the country.

- 2.2 Probability of Property Damage:** Areas without the highest probability to shaking, but elevated probability of damage because of serious consequences, if an event were to occur.
- 2.3 Probability of Life and Indirect Loss:** Areas with elevated probability of loss, even though they are not areas of highest shaking or damage probability, because of their increased likelihood for casualties, death, or human suffering due to the fragility of the infrastructure or wide-spread impact of failure (utilities, transportation, etc.).
- 2.4 Probability of Learning:** Areas of major uncertainty in knowledge about earthquake generation or seismic wave propagation and the attenuation of peak ground motion and spectral levels in order to improve the understanding of the hazard in those areas.
- 2.5 Value in Emergency Response:** Location and areas of strategic, optimal value for providing effective, rapid shaking information for emergency response.

In general the probabilistic maps should serve as a basis for planning, augmented by HAZUS maps of damage and loss which incorporate shaking probabilities, the infrastructure and structure inventory and its fragility, and the impacts of loss of function.

3. Instrument Specifications

- 3.1 Overall recording range:** Accelerograph system (sensor plus recorder) shall be able to record an acceleration range of +/-2g Full Scale, and meet industry-accepted accelerograph specifications.
- 3.2 Recorder dynamic range:** New instrumentation shall have 18-bit or greater resolution (114 dB), and fixed gain (no gain ranging), so that the recorder's resolution (LSB) is 0.015 mg ($2g/2^{17}$).
- 3.3 Noise floor:** The noise level of the accelerometer plus recorder system shall be less than 0.02 mg rms in the frequency range of 0-40 Hz.
- 3.4 Communication:** The instrument shall either have reliable, continuous telemetry or automated dial-out communication upon triggering, using phone lines. A certain portion of the stations will require real time communication in order to provide the most rapid preliminary ShakeMap. Regardless of communication mode, the instrument shall provide on-site recording for 2 hours or more of strong motion recording. The instrument shall also communicate, via real time or dial-out communication, when it encounters state-of-health problems (e.g., low battery, loss of AC, intrusion, etc).
- 3.5 Timing accuracy:** Within 1/10th of a sampling interval of absolute time (UTC).

- 3.6 Sample rate:** 200 samples per second (5 ms sampling interval). Adequate anti-alias filtering shall be included (filter corner at 80% of the Nyquist frequency, and down by 100 dB at the Nyquist).
- 3.7 Triggering:** Nominal trigger level of 1-5 mg (0.1 - 0.5%g) acceleration, within a pass band of 0.1 to 12 Hz; actual trigger level to be established by noise levels at the site. (A successful trigger level will cause occasional, but not frequent, triggering, thus providing ongoing knowledge of instrument performance between significant recordings). Once triggered, the recorder shall stay triggered for at least 30 seconds after the last occurrence of acceleration over 5 mg. Recorders at sites likely to experience significant basin effects or other long-duration motion effects should stay triggered for at least 60 seconds after the last 5 mg acceleration.
- 3.8 Pre-event memory:** Recorder shall include pre-event memory of 30 seconds or greater and must record, on-site, 2 hours or more of ground motion data.
- 3.9 Data Format:** Recorder may produce event files in a format native to the instrument or manufacturer. However, the manufacturer shall provide conversion utilities to convert the native files to COSMOS and SEED formats. The native files shall include a cyclic redundancy check or other method to verify recorded file integrity.
- 3.10 Calibration:** Instrument shall accommodate and read bi-directional tilt tests to allow calibration of the sensitivity constants of the sensors.
- 3.11 Pre-Procurement and Post-Deliver Acceptance Testing:** Prior to purchase, candidate instruments must be tested to verify that they meet specifications. After purchase, all instruments must be tested, and non-performing instruments repaired by the manufacturer.
- 3.12 Data Dissemination:** Data should be disseminated via a central site with convenient access to the user community.
- 3.13 Maintenance Program:** Adequate maintenance program is essential to the success of an advance seismic system.

4. Siting Specifications

In general, urban strong-motion reference instruments should be located in small housings, on grade, and not at subsurface locations or in large buildings, so that the motion recorded corresponds to that on the ground in the surrounding area.

- 4.1 Location Strategy:** Urban strong-motion reference stations should be located to record representative ground motion in the vicinity of significant business districts or groups of structures where possible. Locations should be chosen

with site geology representative of the area and preferably within 1 km of a significant business district or structure grouping. Additional stations may be required in areas with unique geologies or expected to experience altered shaking due to other factors (e.g., topography, distance to fault, soil-structure interaction).

- 4.2 Station Housing:** Small building, without significant basement; 1-2 story light structure, wood frame preferable but reinforced masonry acceptable; building generally less than ~ 4000 sq.ft in plan.
- 4.3 Station Housing Foundation:** Concrete pad (6 in. or less), on grade, without piles or piers. If a special, light instrument hut is used, the pad should be approximately 4 ft square, with 6 in. x 18 in. piers to ensure effective coupling, especially in soft soils.
- 4.4 Nearby Structures:** Stations should be sited away from structures likely to cause significant soil-structure interaction effects that may be recorded in the data. A distance of at least one major structure dimension away from all large/massive structures in the vicinity should be maintained where possible.
- 4.5 Site Conditions:** Stations should be sited to avoid highly localized characteristics of the geology or nearby topography unless special documentation is performed.
- 4.6 Site Geology Documentation:** Site geology at stations should be characterized through on-site geologic inspection or special investigations.

5. Installation Specifications

- 5.1 Orientation of Recorder:** Instrument to be oriented with connector, or other fundamental element, oriented in a cardinal direction, preferably true North. Orientation to be well documented (photographically) and controlled by an effective process making very unlikely, or impossible, mistaken component orientations after an important earthquake. Triaxial acceleration sensors to be fastened securely with fixed, accurate orientation relative to the sensor housing enclosure. Sensors to be no more than 3 degrees out of orthogonality
- 5.2 Orientation of Sensors:** Sensors, if not mounted within the recorder, should be mounted orthogonally, within 2 degrees, and oriented with the housing connector of other reference element oriented in a cardinal direction, preferably true North, with orientation well documented and controlled, as for the recorder.
- 5.3 Station Location Accuracy:** Accuracy of one ten-thousandth of a degree in latitude and longitude, with documentation (WGS884 standard) is recommended.

- 5.4 Anchoring** of sensors, recorder and auxiliary components to pad: All elements to be bolted securely, with concrete anchors that remain tight over time.
- 5.5 Autonomy:** Station shall include adequate backup batteries to operate for 4 days without power in case of loss of AC power. The power connection shall be hardwired or otherwise securely connected to the power source.

Adopted after revision at the meeting of the COSMOS Strong Motion Programs Board on January 19, 2000, with participants N. Abrahamson, J. Anderson, R. Archuleta, B. Bolt, R. Borchardt, C. Stepp, and A. Shakal (Chair), with additional input by M. Huang, W. Joyner, C. Kircher, and W.H.K. Lee.

Earlier versions adopted by the TriNet Technical Advisory Committee (C. Poland, Chair), the TriNet Steering Committee (J. Davis, Chair), and the California Strong Motion Instrumentation Advisory Committee (B. Bolt, Chair).