ATTACHMENT C

APPENDIX C
Guideline and General Considerations for Strong Motion Instrumentation in Tall Buildings

Strong motion instrumentation should be located strategically in a building in order to learn as much as possible about the response of the building during an earthquake and to confirm/verify design and analysis assumptions.

1. It is important to measure horizontal drift and torsional motion from the base to the roof. This requires (at least) three separated uniaxial horizontal accelerometers, on a number of floors. Two should be located near the perimeter of the building along opposite walls (as distant as practical from the core) to get the best torsional measurement. They should be at the same relative position along the walls (e.g., at mid length) and oriented with sensing direction parallel to the walls. The third should be placed near the center of the floor, oriented perpendicular to the other two, to measure horizontal motion in that direction. (The number of floors to be instrumented is discussed below.)

2. Another goal is to measure rocking at the base of the building, especially for a stiff building founded on soft soils, to determine any rocking contribution to the drift. At least two vertical accelerometers are needed, placed near opposing walls. To measure rocking in both directions, a third is needed near one of the other walls.

3. For interpretation and analysis of the recorded data, sensors on different floors should be stacked vertically if possible, that is, placed at the same relative position on each floor, so the same location in the response is measured.

4. To assist in evaluating the performance of nonstructural components, on every third floor where horizontal sensors are located, at least one vertical sensor should be located midspan between adjacent columns and/or at the center of the longest span on that floor.

5. If there are special features near the roof, such as mechanical equipment in the penthouse or architectural features with mass, it may be important to place additional sensors there.

6. The number of sensors depends on the number of stories:

Stories	Minimum No.	Recommended No.
6-10	12	15
11-20	15	19
21-30	21	26
31-50	24	30
>50	30	38

   As an example, a 34-story building would have a minimum of 24 sensors. Three horizontal sensors would be located at the base level, the roof level, and on five intermediate levels. Three vertical sensors would be located at the base. Additional sensors include, on two of the instrumented floors, a vertical sensor at mid span and possibly one at a nearby column. In general, the intermediate levels would be chosen where there are changes in stiffness or mass, or offsets in the structural system, if any; otherwise they would be evenly distributed over the height.

7. It is often most practical to install the sensors in the interstitial space above the false ceiling, if present. This keeps the sensors out of the way of normal building activities, reducing likelihood of damage. Thus, the sensors planned to measure the motion of the 8th floor would actually be located on the underside, above the ceiling on the 7th floor, for example. Accelerometers are often the most effective sensors in strong motion monitoring but other sensors (e.g., relative/absolute displacement sensors, etc.) may be also be useful in certain situations.

8. The central recorder should be located in a utility or electrical room with AC available, on one of the lower floors of the building for convenience. Communication to the central recorder is essential to access data following a significant event. The communication link should be at least a phone line; a hardwired Ethernet port is the preferred form of communication.

9. Cabling from each sensor to the recorder should be dedicated continuous runs (i.e., no splices) to achieve robustness not possible via a building's internal network, for example. A pathway will need to be established for the vertical run from the sensors on the upper floors to the recorder location. If there is more than one recorder, a dedicated cable is needed to interconnect them for common timing and triggering. Depending on local ordinances and fire codes, cabling may need to be plenum rated.

10. Maintenance and service of the instruments shall be provided by the owner of the building, subject to the approval of the Building Official. Experienced private companies, or agencies like CSMIP or NSMP, should be contracted for monitoring and/or maintenance. Data produced by the instruments shall be made available to the Building Official upon request. A sign stating, "Maintain clear access to this instrument" shall be posted in a conspicuous location near each sensor and the recorder.

Documentation

Documentation is important since after an earthquake it may not be possible to access certain areas in a building until building officials have visited. With good documentation, analysis of the recorded data and assessment of the structural response could occur without accessing the building.

The sensor locations should be well documented to facilitate interpretation of the data. A sensor layout diagram should be prepared similar to Figure 1, showing the sensor locations and on plan and typical sections. Strong shaking is infrequent, and care must be taken that by the time an earthquake occurs sensors have not been moved for construction and not returned to the original location and orientation. Digital photos should be taken to document the location and orientation of each sensor at installation and after construction is completed. It is valuable to archive design plans, especially structural plans, to allow thorough analysis of the data and finite-element modeling of the building when earthquake motion has been recorded.