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# The TREMOR Project: Earthquake-shaking "Radar" for the City of Oakland. A Guide for Users, Sponsors, and the Curious.

by

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## *Description of the TREMOR Project:*

Both earthquake disaster preparation and emergency response benefit from clear knowledge of an earthquake's shaking strength and its effects. TREMOR is a project to produce real-time maps of this shaking strength down to a neighborhood level of detail by deploying a dense network of inexpensive seismographs equipped with rapid telemetry.

Earthquake shaking varies tremendously in strength over very short distances, and seismologists are not yet able to predict all aspects of this complexity accurately. The number and reporting speed of "strong motion" seismographs (ones that stay on scale even when shaken strongly) have been limited severely by the high cost of buying and operating them. Hence, it has been impossible to generate accurate, detailed maps of shaking strength at any time, least of all in the critical first minutes after a dangerous event. We are testing prototypes of a new class of seismograph specifically designed to address these speed and cost issues. By exploiting several new technologies, the TREMOR seismograph combines lower cost and greater ruggedness with modern real-time communications. With the first group of prototype instruments (deploying in the third quarter of 1998), we are beginning what we hope will grow into a large, dense array of instruments across the urbanized San Francisco Bay Area.

We are deploying this prototype array in the City of Oakland (***Figure 1*** shows a preliminary site map on a geological map base). We chose Oakland because of its high risk from the Hayward Fault and its high densities of population and critical infrastructure. Furthermore, FEMA has chosen Oakland as one of its first "Project Impact" cities. Project Impact is an effort to mitigate earthquake, flood, and other disasters through focused, collaborative preparations. Oakland has risen to the challenge with "Project SAFE". TREMOR is part of the USGS contribution to these efforts.

We will combine shaking measurements from the TREMOR instruments with any others available to generate detailed maps of the shaking strength patterns. These maps will be available beginning within about 10 minutes after the earthquake and will improve in accuracy for about the next hour as additional information arrives.

## *Users, and How to Become One:*

We plan to map both regional shaking patterns and the details of shaking down to the neighborhood level. This goal is analogous to Doppler weather radar, which shows the overall shape of a storm as well as the squall lines within the storm. We anticipate that users will include anyone who needs to respond effectively to the emergency. These users certainly would include:

- Government Emergency Services agencies, from local dispatch through FEMA
- Lifeline providers (PG&E, PacBell, CalTrans, railroads, financial institutions, etc.)
- The media and through them the general populace
- Insurance companies
- Ports and airports
- Corporations facing facilities and recovery issues
- Structural engineers
- Earth scientists
- Planners, and many more.

We will make the shake maps available automatically through the Internet and other pathways users may require. At a minimum, we anticipate releasing GIF images on our Web site and actively transmitting a GIS layer to major users (probably MapInfo™/Vertical Mapper™). GIS users might, for example, combine this layer with their existing facilities layers to assist them with response prioritization.

It is essential that all those responding to the emergency have clear, reliable, consistent information on which to base decisions. Furthermore, the same data will help with the preparations for subsequent earthquakes, for example by improving building design and construction and by helping scientists to improve their ability to predict shaking patterns.

***Description of the Instrument:***

The TREMOR prototype seismograph (sketched in ***Figure 2***) is a plastic NEMA™ box about 6×11×9 inches in size (height × width × length). "NEMA" simply means an approved utilities and electronics enclosure. This box contains power-conditioning circuits, a low-cost single-board PC, an analog-to-digital converter, and the sensors—three tough, inexpensive, micromachined Silicon accelerometers similar to those that trigger airbags.

We use weak "5 minute" epoxy glue to attach four "elevator bolts" (bolts with broad, flat heads) to the concrete floor slab of the building. These glue spots are each about one inch in diameter. We then attach the NEMA box to the four bolts to anchor the box to the floor. Should removal become necessary, the epoxy can be broken away, though it may leave a small scar on the slab.

For temperature stability, we cover the NEMA box with a larger box made from two-inch-thick rigid foam insulation of the type used to insulate walls in buildings. This larger box is about 9×19×14 inches in size. We seal it to the floor with removable caulking, which comes away cleanly, leaving only a "wet" mark.

Outside the insulating box are a battery (a 3½×2½×6 inch seven-amp-hour "gel cell"), a battery charger (2×4×7 inches), and the cell-phone modem (1½×3½×6 inches, with an eight-inch cell-phone antenna on the back end). The modem is our connection into the Internet. The battery provides about 3.3 Watts of power to the NEMA box along a short cable, and to the modem along a longer cable. We connect the NEMA box to the modem with an RS-232 cable—the type one uses on a PC's serial ports. The modem is placed up on a roof rafter, a window sill, or wherever else it can contact the cell-phone service while staying out of the way.

The battery can run the system for about 10 hours after the power goes out in a large earthquake. (The red light on the charger will remain illuminated when the power goes out, until the battery runs down.) The battery and its charger will be attached either to the top of the insulating box or to the floor next to it with the removable caulking. In Figure 2, we show the preferred arrangement of battery and charger.

## ***Siting needs:***

- Most of all, we need sponsors willing to host one of these instruments somewhere out of the way in a garage, shed, or utility room. We can remove the instrument at any time with a few days notice, though we hope that the installation will last for many years. Indeed, large earthquakes typically are years to decades apart.

- The instrument must be in a one- or possibly two-story building, preferably of light construction. For example, wood (like most residences) and light steel (like a service station or utility building) are ideal. We can use concrete or masonry structures if nothing lighter is available.

• The instrument should be at least as far away from any nearby large structure as the size of that structure (for example, at least as far from a skyscraper as the height of the skyscraper).

• The building must have a grade-level concrete slab, give or take a few inches in slab height. The NEMA box is attached to this slab by way of the elevator bolts.

> ☞ Being in a low, light building on a grade-level slab results in what seismologists call a "free field" measurement of ground shaking. That is, the measurement is not significantly contaminated by the structure's own vibrations being fed back into the ground. The shaking measurements produced by a free-field instrument are useful damage predictors for the whole neighborhood rather than for a single building. They can be combined with "fragility curves" for any type of structure to estimate how well such structures performed.

• The instrument should be reasonably secure from vandalism, though the security need not be rigorous. It should be out of the way of routine activity, if possible. We assume any risk of damage or loss of the instruments. They are, in any case, very robust to minimize maintenance visits, so they can survive most accidental abuse.

• Our aim is to visit the site no more than about every five years (mainly to replace the battery). Initially, it is likely that we will have to visit more often, since they are new and likely to need software upgrades and possibly other attention.

• The charger draws about 20 Watts from a single wall plug; the charger must be vented because it wastes most of this power as heat.

• The room where the instrument is installed should itself be vented for the first few days because the removable caulking smells while drying. These fumes may be flammable so it must not be installed near a pilot light, such as a water heater.

• Please don't drown it or burn it! Some components are not fireproof, so direct flame must be avoided. The exterior components (the battery, the modem, and especially the charger) must not get seriously wet. If they do, please unplug the charger, taking care not to get a shock, and give us a call when you can. All parts except the battery charger are resistant to water and are low-voltage devices, so minor splashes or spray should not be a problem. However, the charger has open vents and high voltage inside so it must be kept completely dry.

• The instrument should be at least a few yards away from heavy, rotating machines such as washing machines, refrigerators, air conditioners, pumps, and generators. Vehicles driving in and out of a garage are fine, as is foot traffic. Normal household and business activities are no problem (or if they are, they are our problem and we will move or modify the site).

• Please call, write, or e-mail if you have any questions or concerns:

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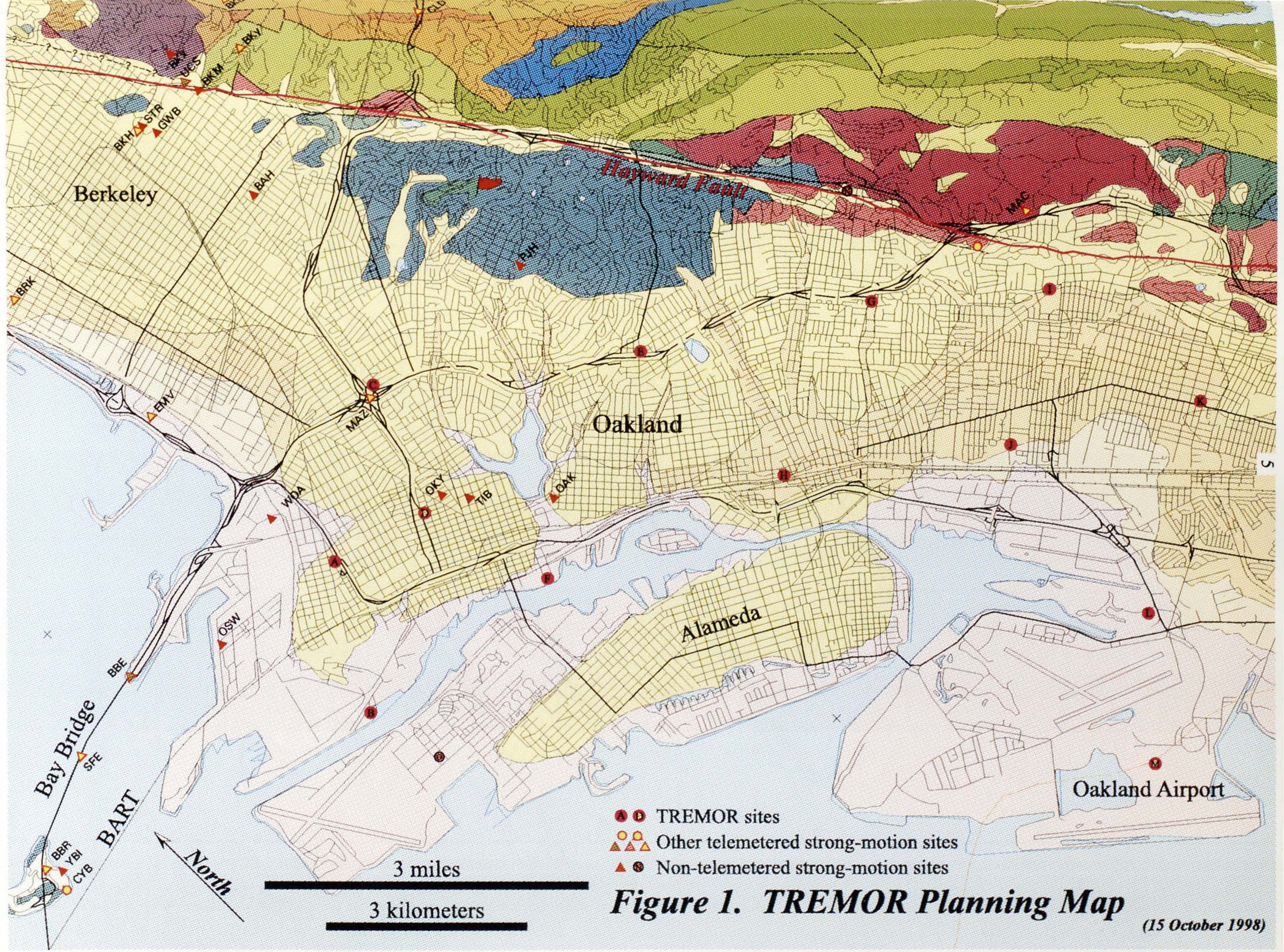


***Figure 1. TREMOR Planning Map***

*(15 October 1998)*

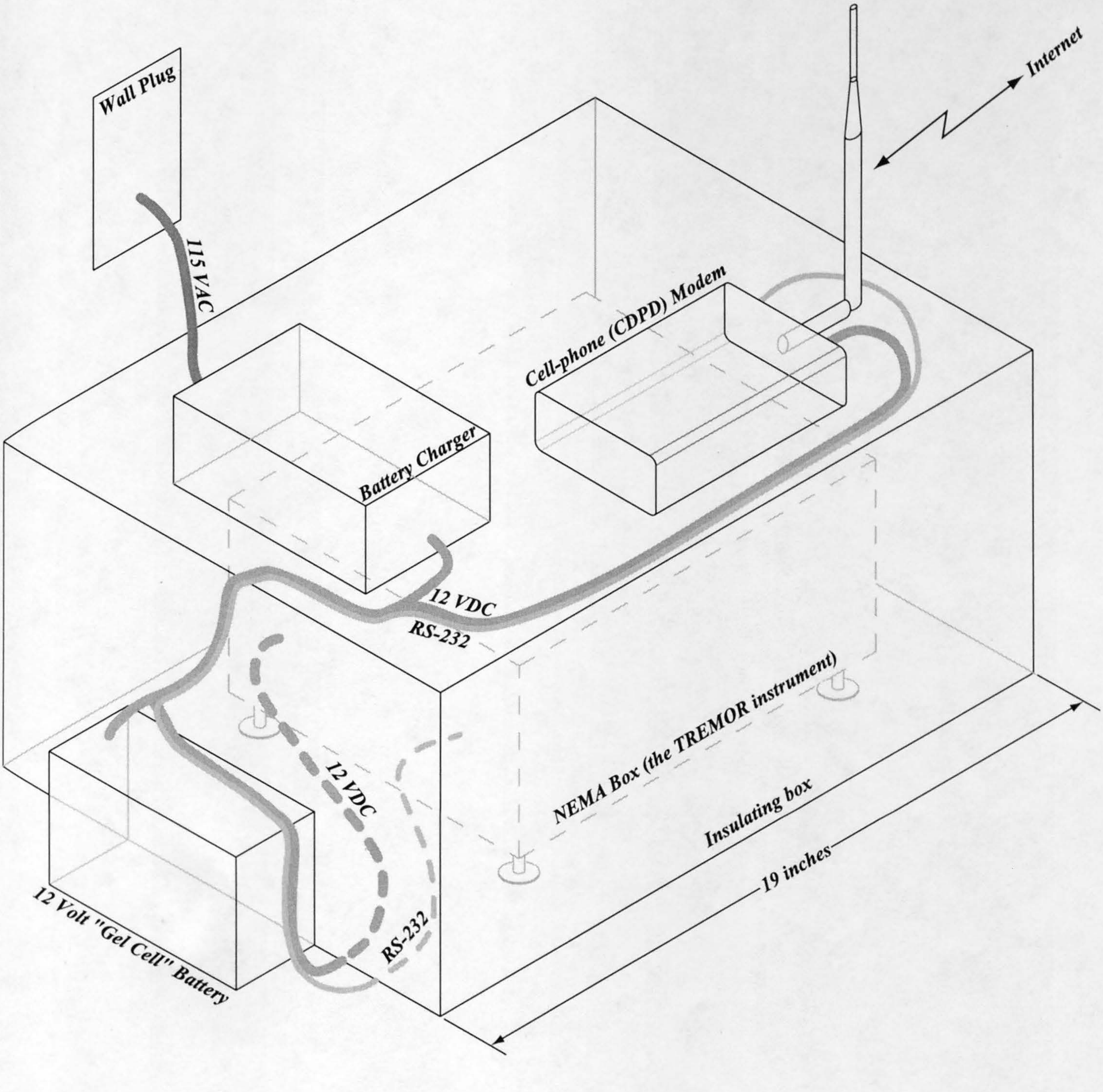


***Figure 2. Sketch of TREMOR prototype seismograph installation.***