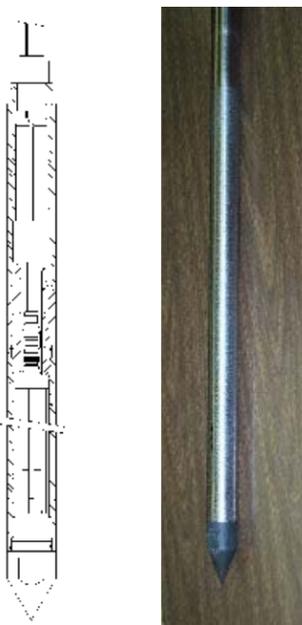


## Retrieval Subsurface Accelerometers (RSA)

The nees@UCLA site has developed a Retrieval Subsurface Accelerometer to obtain vibration measurements during forced vibration experiments. The RSA can be rapidly installed using the cone penetration testing (CPT) truck and subsequently retrieved using structural cables and a winch. This eliminates the need for conventional borehole drilling and grouting, which often exceeds the cost of the downhole sensor. The RSA's are compatible with the Q330 data loggers thereby enabling time synchronization across the full sensor array.

### RSA Technical Specifications

Model	Silicon Designs 1221J MEMS
Type	Capacitive
Freq.	0 to 200 Hz
Full scale	±2 g
Noise	2 µg/root Hz



Retrieval Subsurface Accelerometer

## HIGH PERFORMANCE MOBILE NETWORK

The High Performance Mobile Network provides real-time connectivity between the nees@UCLA Equipment Site and other NEES researchers through NEESgrid. It is composed of two distinct local area networks (LANs), the Campus-LAN and the Field-LAN. The Campus-LAN contains servers and network infrastructure to enable Gb/s connectivity to NEESgrid. The Field-LAN contains data acquisition and telepresence servers to enable remote data and video collection from a nearby wireless network located in the test structure.

The Campus-LAN hosts the NEESpop server, the gateway to NEESgrid, as well as local data storage servers. It also contains Gb switches and routers high speed connectivity to NEESgrid.

The Field-LAN is housed in a mobile command center with Gb/s connectivity between all the servers. Data is sent to NEESpop in the Campus-LAN via satellite from the field. From NEESpop, the data gets routed through the UCLA campus backbone to Internet2 and then to NEESgrid all at Gb/s speeds. The Field-LAN is also capable of connecting directly into the Campus-LAN when the mobile command center is on-site.

The telepresence server allows remote observation of experiments and is a component of NEESpop. Telepresence offers viewing of live streaming data in real-time. It allows researchers to setup and view experiments remotely and monitor events as they occur. Part of the telepresence services include an electronic notebook, or e-notebook, that is used much like a traditional experimental field notebook.



Mobile Command Center

### Project Personnel

John W. Wallace (PI)  
Jonathan P. Stewart (co-PI)  
Robert Nigbor (Proj. Manager)  
Erica Eskes (Admin. Specialist)  
Steve Kang (Systems Admin)  
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## Program Overview

Previous studies of the field performance of full-scale structural systems have traditionally been limited in their coupling of detailed performance data with nonlinear response. This paucity of data impacts design procedures in the form of significant uncertainty on the response of highly nonlinear structural systems.

The vision of the nees@UCLA Equipment Site is to fill this critical gap in engineering characterization of structural and geotechnical performance by developing and implementing a state-of-the-art mobile field laboratory for forced-vibration testing and monitoring of full-scale structural systems. In accomplishing this goal, the nees@UCLA equipment portfolio will include the following broad categories:

- Vibration equipment to provide excitation of full-scale structural systems. This includes three eccentric mass shakers and a linear inertial shaker capable of broadband excitation.
- Field data acquisition system and sensors employing the latest in wireless telemetry to enable rapid deployment. This includes building sensors (accelerometers and displacement gauges), a cone penetration testing truck for subsurface characterization and retrievable subsurface accelerometers.
- High performance mobile network to enable real-time connectivity to NEESgrid. This includes a mobile command center, satellite equipment, switches and routers.



Four Seasons Project Team



Monitoring the new Carquinez Bridge

## Applications

The nees@UCLA mobile field laboratory provides unique field testing capabilities that can be used to characterize nonlinear structural response, the effect of non-structural elements, soil-foundation-structure interaction (SFSI) effects, and wave propagation. Potential equipment use scenarios include synchronizing the MK-15 large capacity eccentric mass shakers to excite torsional modes or produce a combined peak force of 200 kips in order to investigate nonlinear structural response, using the linear shaker to simulate the structural response during an earthquake, also known as the Linear Shaker Seismic Simulation (LSSS) test method, and using the wireless field data acquisition system to monitor aftershock events.

The mobile field laboratory has been used to perform forced vibration testing at the Four Seasons Building in Sherman Oaks, CA, the new Carquinez Bridge span in the San Francisco Bay Area and the UCSD Camp Elliot site. The Four Seasons Building is a 4-story RC office building that was damaged in the 1994 Northridge event, and has since been scheduled for demolition. The new span of the Carquinez Bridge replaces one of the two older existing ones. The UCSD Camp Elliot shakedown involves obtaining dynamic ground motion data for the virtual model of the nees@UCSD Large High-Performance Shake Table facility.



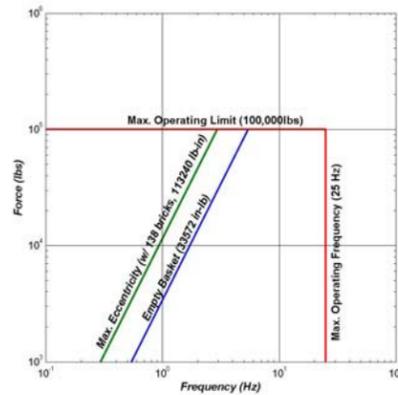
## VIBRATION EQUIPMENT

### Eccentric Mass Shakers

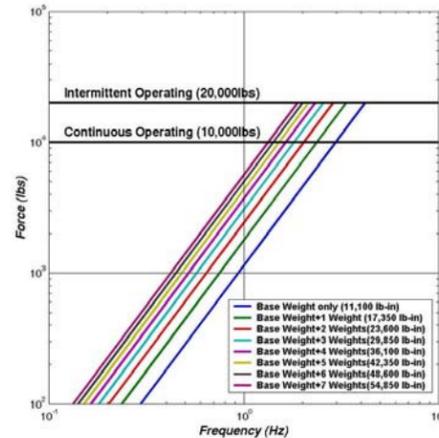
Three eccentric mass shakers were developed by Anco Engineers to provide harmonic excitation to structural systems. This includes one MK-14 omni-directional and two MK-15 uni-directional shakers.

Shaker	Type	Wireless control	Synch.	Peak force (kips)	Max. freq. (Hz)
MK-14	Omni-directional	Yes	No	20	4.2
MK-15A	Uni-directional	Yes	Yes	100	25
MK-15B	Uni-directional	No	Yes	100	25

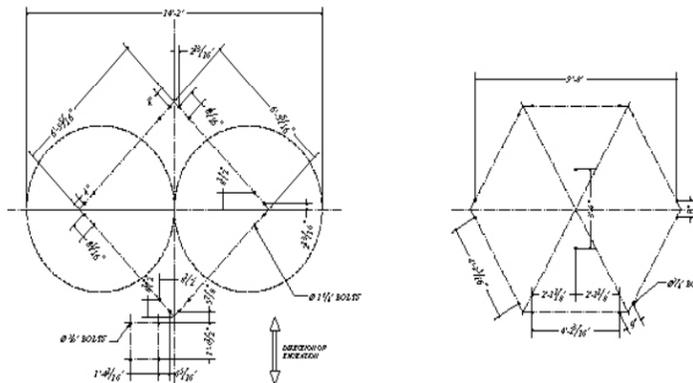
All three shakers are controlled using Danfoss inverter drives to enable highly accurate frequency control. A digitally-supervised control system has been implemented for the MK-14 and MK-15A shakers to enable wireless remote control. Moreover, the MK-15 shakers can be synchronized in and out-of-phase to excite translational and torsional modes at a combined peak force of 200 kips.



Force-Frequency Curve for MK15



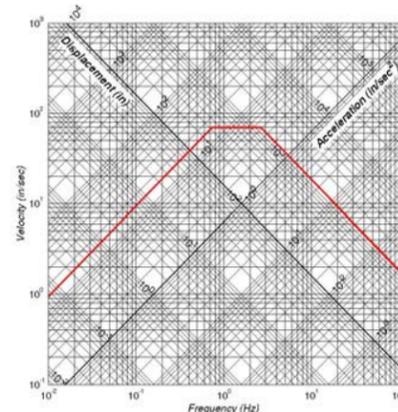
Force-Frequency Curve for MK14



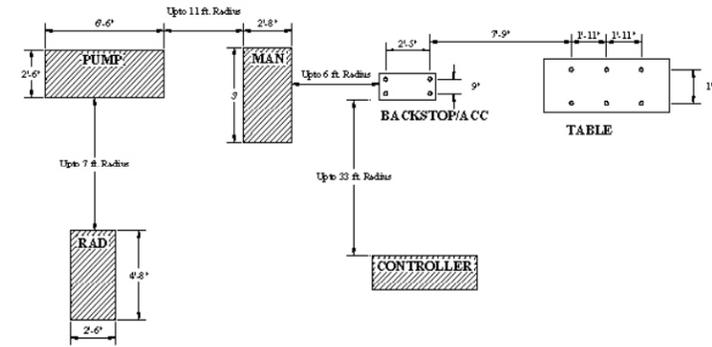
Footprint for MK15 (left) and MK14 (right)

### Linear Inertial Shaker

A linear inertial shaker capable of broadband excitation was developed jointly by Anco Engineers, dSPACE, Inc. and Sysendes. The linear shaker is replete with digital controllers (PID, linear quadratic and adaptive) for more accurate control. The controllers were implemented on a dSPACE D1103 DSP board, and are capable of either force or displacement control. The nominal performance specifications for the linear shaker are a peak force amplitude of 15 kips, 30 inch stroke and 90 gpm servovalve capacity.



Linear shaker performance spec.



Footprint for Linear Shaker

## FIELD DATA ACQUISITION & SENSORS

### Field Data Loggers

The nees@UCLA data acquisition system includes 120 channels of Kinemetrics, Inc. Quanterra Q330 data loggers. The Q330 data loggers contain true 24-bit A/D with a 200 Hz max. sampling rate, a dynamic range of 145 dB and a GPS sensor for time synchronization. The Q330's are low power (1 W), true internet devices that use TCP/IP protocol to transmit data back to the central workstation running the Antelope software package. Data transfer to Antelope can be performed reliably in real-time using wireless telemetry (IEEE 802.11b) after the data packets from the Q330's are digitized and time stamped. In addition, long term field vibration monitoring can be performed using a battery-powered Sun Fire station to locally store data.



Q330 data logger and Episensor

### Building Sensors

100 (15 triaxial and 55 uniaxial) channels of Kinemetrics, Inc. force balance Episensor accelerometers have been purchased. In addition, 30 Transtek, Inc. Series 240 DC LVDTs and can be used to monitor displacement responses. Lastly, fiber optic reading units will be purchased to enable high precision but limited amplitude measurements of local displacements. The fiber optic sensors themselves are not included in the nees@UCLA equipment portfolio, and should be purchased on a project-specific basis.

### Kinemetrics FBA Episensors

Bandwidth	0 to 200 Hz
Dynamic range	> 155 dB
Full scale	$\pm 2$ g
Linearity	< 1000 $\mu\text{g/g}^2$
Hysteresis	< 0.1% full scale
Cross-axis sensitivity	< 1% (including misalignment)
Physical size	5.2 inch diameter (cylinder), 2.4 inch high

### Transtek DC LVDTs

Working Range	$\pm 1$ to 2 inches
Non-linearity	< 0.5%
Excitation	6 to 30 VDC
Output Imped.	5600 Ohms
Freq. Response	100 Hz

### Cone Penetration Testing Truck

The nees@UCLA equipment portfolio includes a Hogentogler cone penetration testing truck, equipped with a seismic-piezocone to characterize soil consistency, pore water pressure and shear wave velocities. The rig has a 20-ton hydraulic push capacity and side augers to provide the necessary reaction force to penetrate to 90 m. A fully automatic 5-channel ESFCS data acquisition system records measurements of cone tip resistance, sleeve friction, probe inclination, pore water pressure and shear wave velocities.



Cone Penetration Testing Truck

