NEES@UTexas

George E. Brown, Jr. Network for Earthquake Engineering Simulation

NEES

Overview of NEES@UTexas Site

The 4th International Symposium on the Effects of Surface Geology on Strong Ground Motion

Prepared by Farn-Yuh Menq
Presented by Robert Nigbor

Overview of NEES@UTexas Site

- **Site equipment**
- **Applications**

Large Shakers Available for Scientists and Engineers at NEES@UTexas

a. High-force, three-axis shaker called T-Rex

b. Low-frequency, two-axis shaker called Liquidator

c. Single-axis, vertical shaker called Raptor

d. Single-axis, horizontal shaker called Rattler

e. Urban, three-axis shaker called Thumper

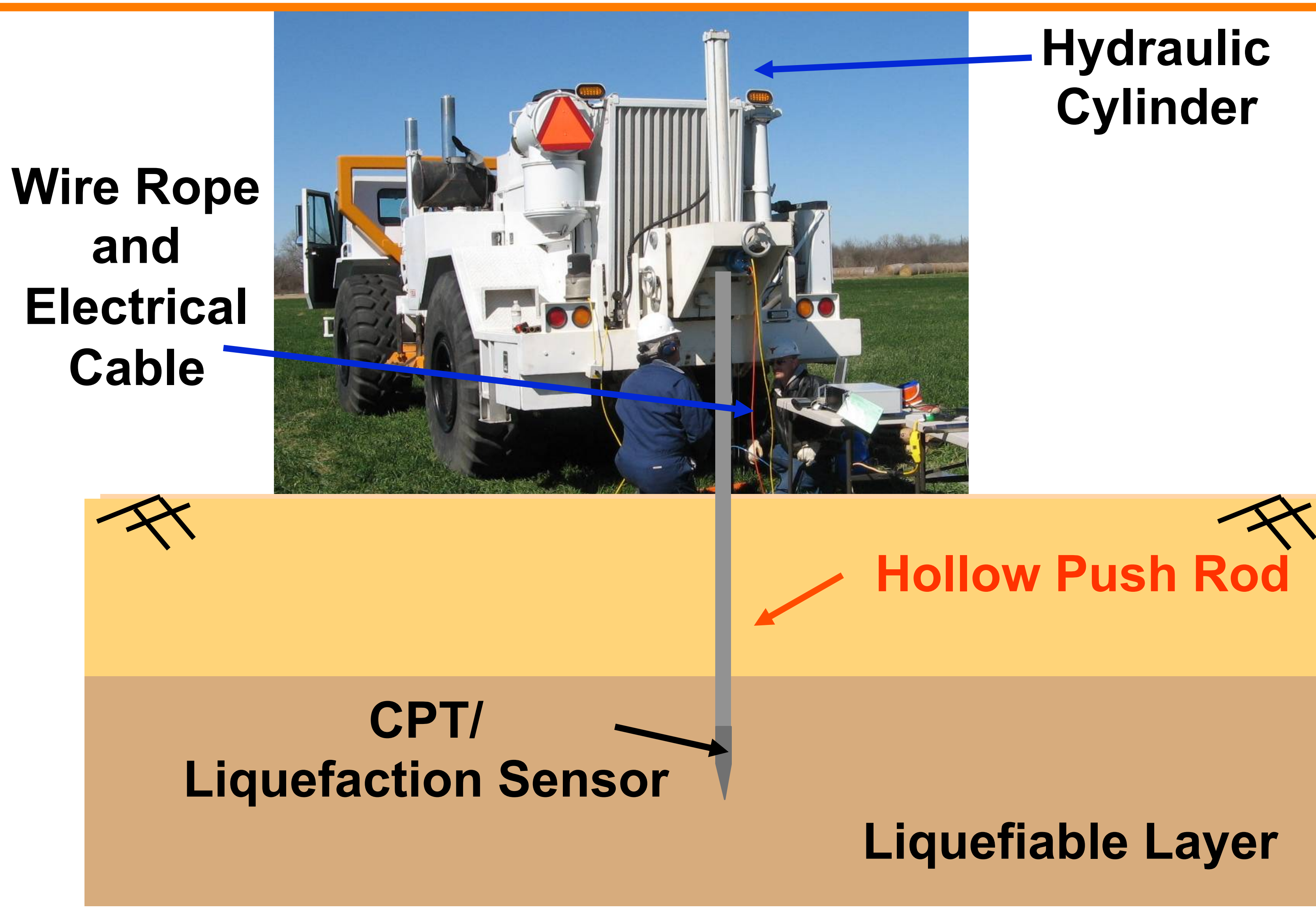
f. Tractor-trailer rig with T-Rex

Tri-Axial Shaker ("T-Rex")

- Buggy-mounted vibrator
- Total weight – 64,000 lb (29,030 kg)
- 32 ft (9.8 m) long
- 8 ft (2.4 m) wide

- 3 Vibration orientations
  - Vertical
  - Horizontal in-line
  - Horizontal cross-line
- Uses vegetable-based hydraulic oil (Panolin oil model number: HLP SYNTH 46)

Installation of Embedded Sensors



Low-Frequency Shaker ("Liquidator")

- Built on same platform as the T-Rex
- Optimized for low-frequency (down to 0.5 Hz) force output

Urban Shaker ("Thumper")

- Built for high-frequency force output (beyond range of T-Rex and Liquidator)
- Built for use in urban environments
- Total weight = 24,800 lb (11,300 kg)
- Peak force = 6,000 lb (26.7 kN)
- Transformable to operate vertically or horizontally

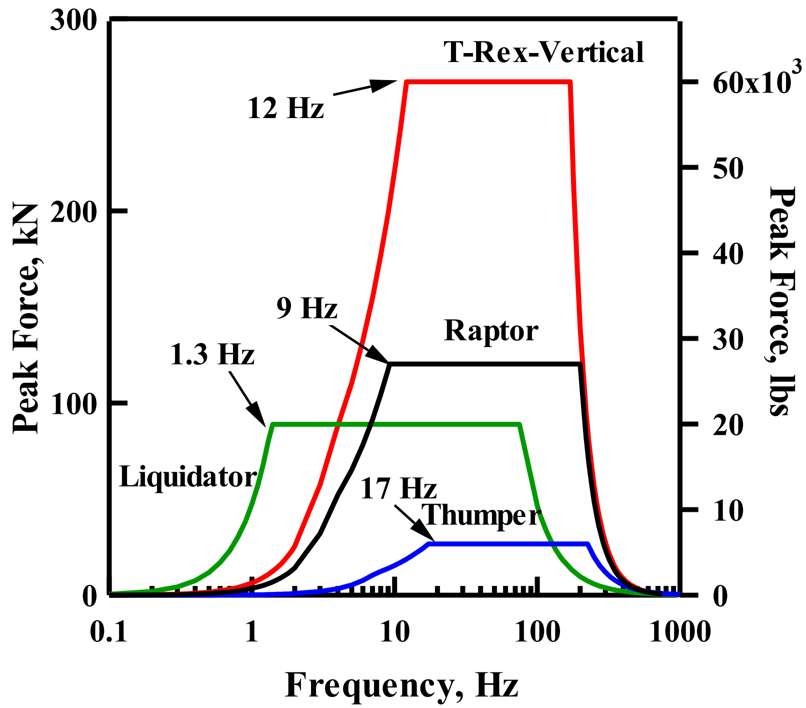
Mid-Size P-Wave Shaker ("Raptor")

- **1982 International Paystar Y-1100 P-Wave Vibrator**
- **Peak force = 27,000 lb (120 kN)**
- **Ideal for locations where the force output of Thumper is not sufficient but the operation of T-Rex would certainly draw unwanted attention**

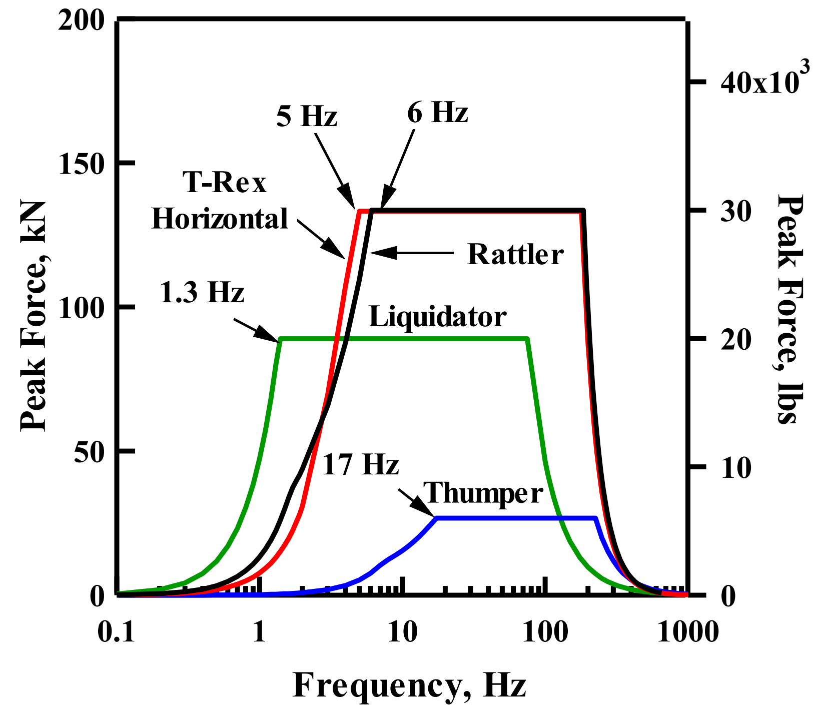
Shear-Wave Shaker (“Rattler”)

- 1980 Mertz Model 13/609 Shear-wave Vibrator
- Peak force = 30,000 lb (133.5 kN)
- Can be synchronized with T-Rex to excite in a condition closer to a plane-strain condition for in-situ liquefaction and nonlinear soil testing

Theoretical Force Output of nees@UTexas Shakers



Vertical Force Output

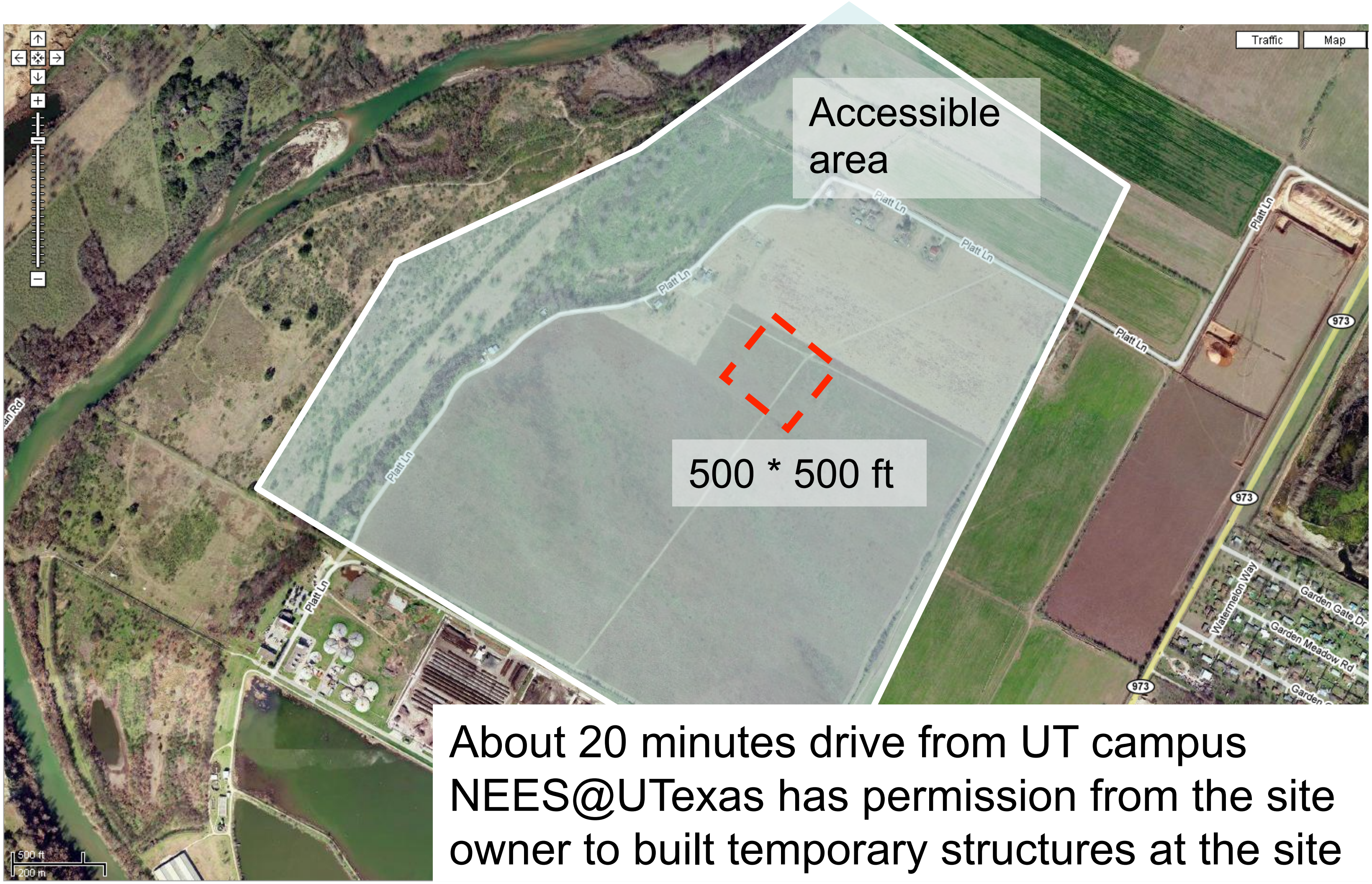


Horizontal Force Output

Other Supporting Vehicles

Instrumentation Trailer

Local Test Site for Proof-of-Concept Trials

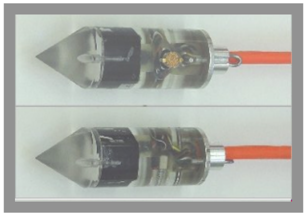


About 20 minutes drive from UT campus
NEES@UTexas has permission from the site owner to built temporary structures at the site

Data Acquisition Systems (DAS)

- DataPhysics
  - VXI system: 64 channels of acquisition at a sampling rate of 100 kS/s and 8 channels of acquisition at a sampling rate of 196 kS/s.
  - DataPhysics system: 32 channels of acquisition at a sampling rate of 200 kS/s
  - 4 channel DataPhysics analyzer
- Taurus Digital Seismograph * 10
  - 3 Channel each
  - Data stored in MiniSeed format
  - Battery powered
  - Compact packages for ease of deployment

Sensors



- 64 of 1-Hz vertical geophones
- 24 of 1-Hz Horizontal geophones,
- 12 of 10-Hz 3-D geophones,
- 13 of Trillium Compact, 3-component, 120 second seismometers
- Prototype in-situ liquefaction sensors,
- Cone penetrometer test (CPT) and seismic CPT equipment

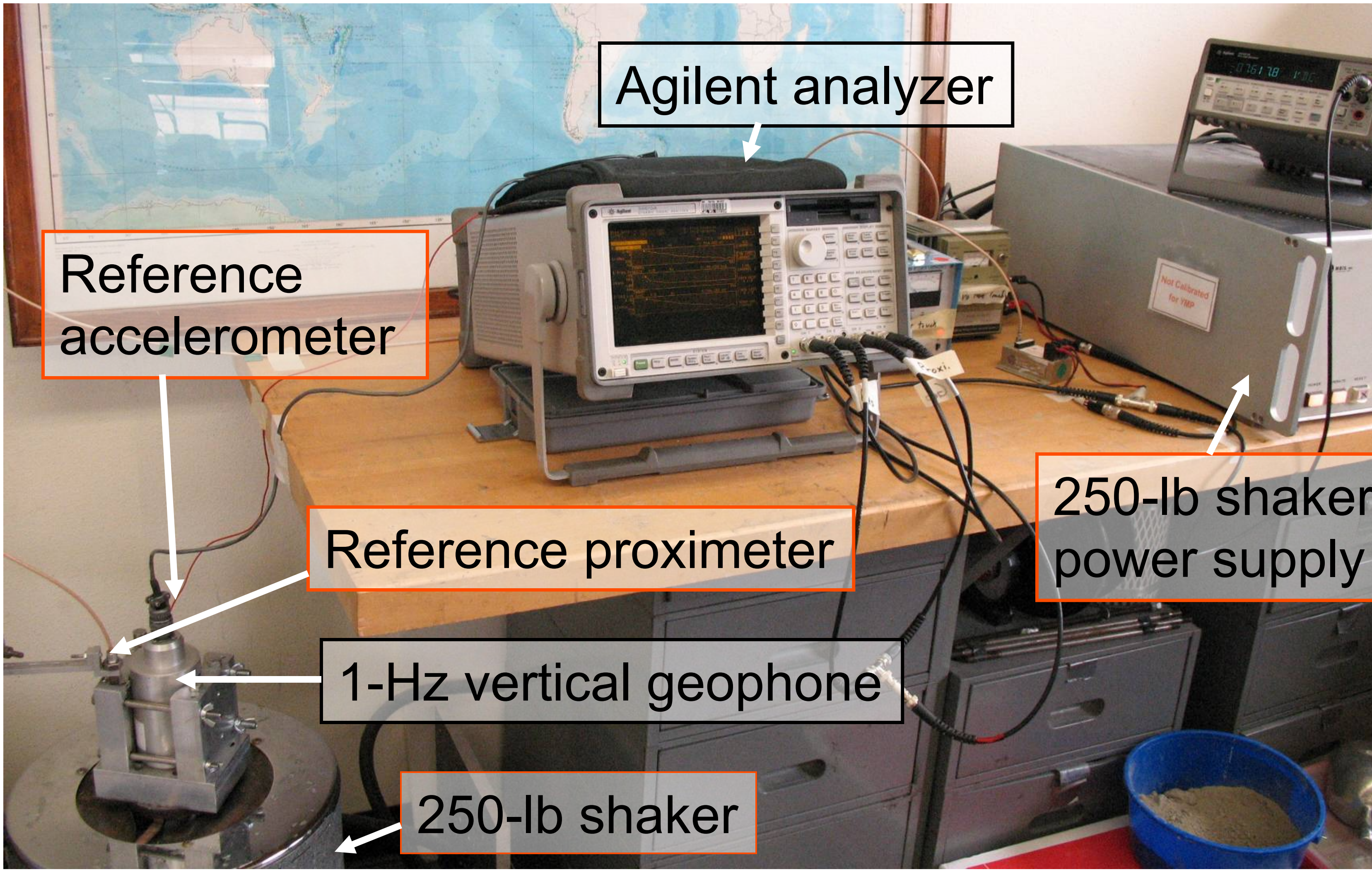
Calibrations - Overview

- Soil and Rock Dynamics Laboratory at the Univ. of Texas at Austin is a Nuclear Quality Assurance Level 1 (NQA1) certified laboratory for both field and laboratory dynamic measurements since 1998.
- Calibrations of NEES@UTexas equipment are piggyback on the QA program developed in the Soil and Rock Dynamics Laboratory.

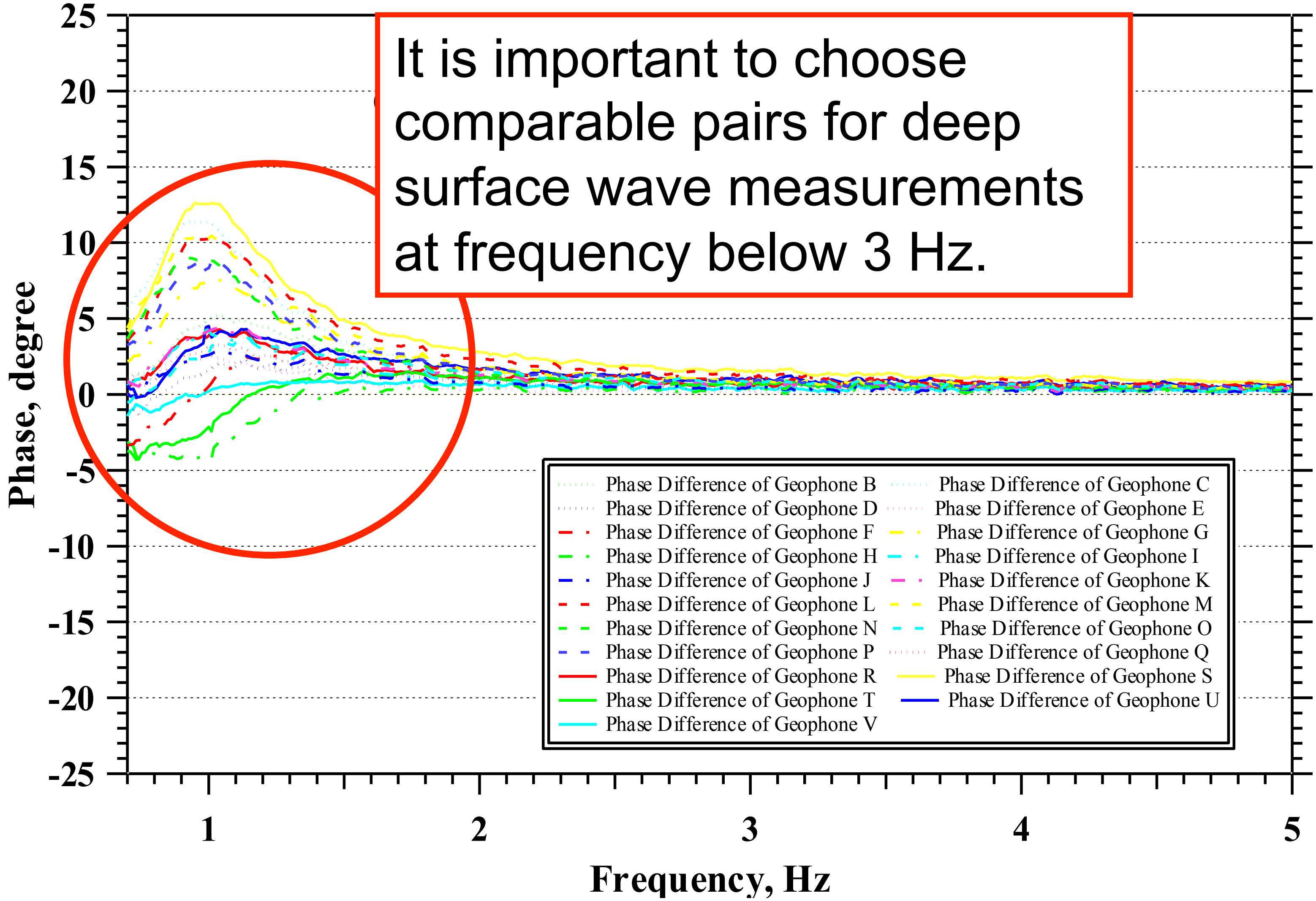
Calibrations – Project Oriented

- Sensors and DAS are calibrated each year based on the request of NEESR and added shared-use projects.
- DAS systems are
    1. calibrated in house following the QA program developed in the Soil and Rock Dynamics Laboratory with calibrated instrumentation
    2. calibrated by the manufacturer.
- Sensors are calibrated in house following the QA program developed in the Soil and Rock Dynamics Laboratory with calibrated instrumentation and reference sensors
- Cables and connectors are inspected before and after field tests

Calibration Examples – 1-Hz Geophone



Calibration Examples – 1Hz Geophone

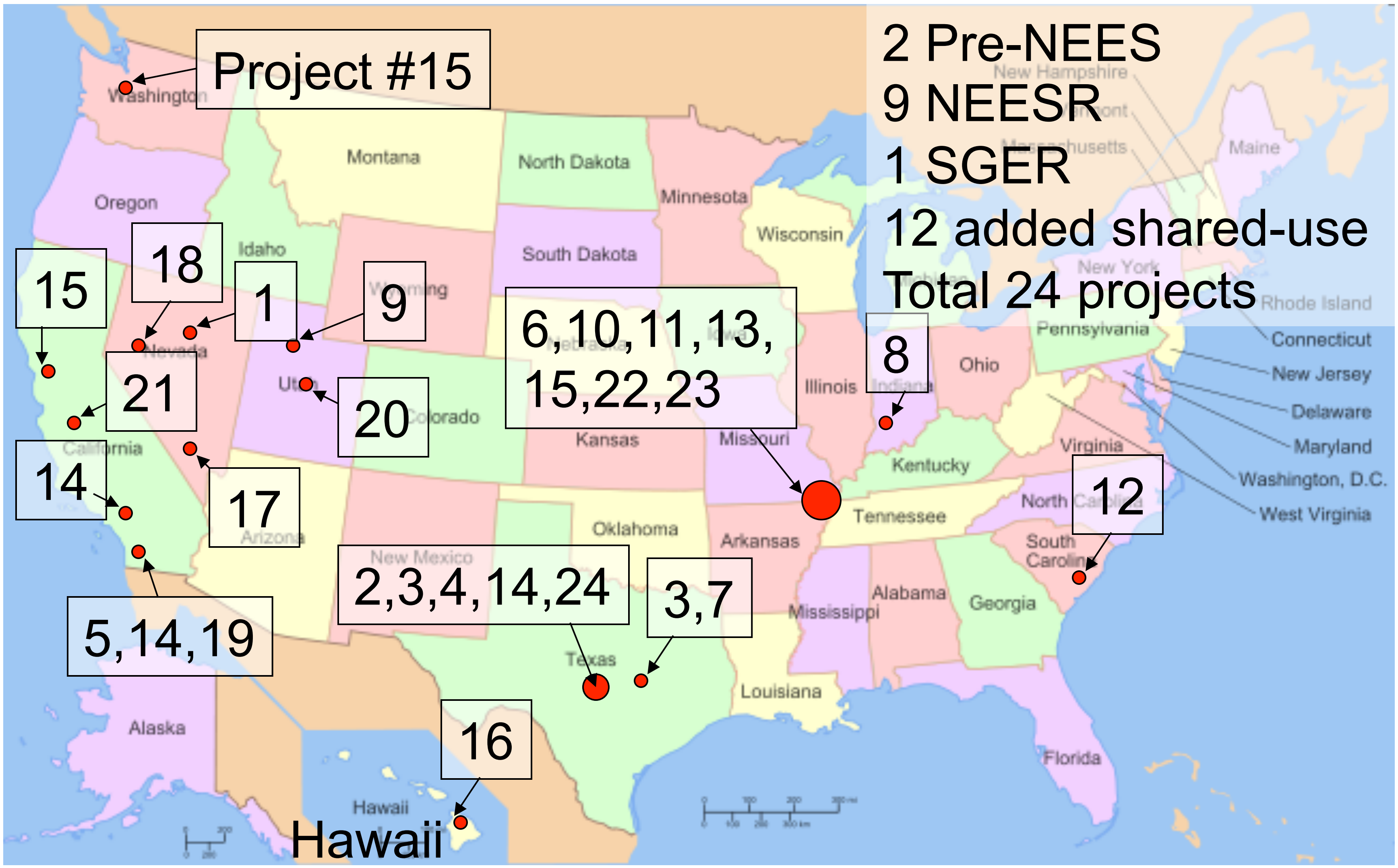


Research Areas of Shared-Use Projects

24 NEESR and added shared-use projects in the areas of:

- soil-foundation-structure interaction studies,
- deep shear-wave velocity profiling,
- in-situ nonlinear shear modulus measurements of soil,
- in-situ liquefaction tests,
- geophysical studies.

Locations of Shared-Use Projects



Shared-Use Projects

1. Pre NEES - Title: NW Nevada Seismic Experiment (2004), PI: Simon Klemperer @ Stanford Univ.
2.1. Pre NEES - Title: Collaborative Research: Using NEES as a Testbed for Studying Soil-Foundation-Structure-Interaction (2004), PI: Sharon Wood @ UT Austin
2.2. Pre NEES - Title: Field Measurements of the Linear And Nonlinear Shear Moduli of Soils (2006), PI: Sharon Wood @ UT Austin
3. NEESR - Title: In-Situ Determination of Soil Modulus and Damping as a Function of Level of Strain (2005), PI: Giovanna Biscontin @ TXAM
4. Added Share-use - Title: In-Situ Soil Nonlinear Properties Study (2005), PI: Joan Gomberg @ USGS
5. Added Share-use - Title: Collaborative Study of Field Evaluation of Liquefaction Resistance at Previous Liquefaction Sites in Southern California (2005), PI: Kenneth H. Stokoe @ UT Austin
6. NEESR II - Title: Study of Surface Wave Methods for Deep Shear Wave Velocity Profiling Applied to the Deep Sediments of the Mississippi Embayment (2006), PI: Brent Rosenblad @ University of Missouri-Columbia
7. NEESR Piggy back - Title: A Phase 1 Prediction of Dynamic Response of Spread Footings on Sand (2006), PI: Dennis R. Hiltunen @ University of Florida
8. NEESR II - Title: Mechanisms and Implications of Time Dependent Changes in the State and Properties of Recently Liquefied Sands (2006), PI: Russell A. Green et al. @ University of Michigan
9. Added Share-use - Title: SASW Testing in the Salt Lake Valley, UT (2006), PI: Kenneth H. Stokoe @ UT Austin
10. Added Share-use - Title: Seismic Reflection Transect Across the New Madrid Seismic Zone: Imaging Spatial and Long-Term Temporal (2006), PI: Robert Williams @ USGS
11. Added Share-use - Title: Study of Surface Wave Methods for Deep Shear Wave Velocity Profiling Applied to the Deep Sediments of the Mississippi Embayment - Phase II (2007), PI: Brent Rosenblad @ University of Missouri-Columbia
12. NEESR GC - Title: Seismic Risk Mitigation for Ports: nees@UTexas equipment will be used for an in-situ liquefaction investigation (2007), PI: Glenn Rix et al. @ Georgia Institute of Technology

Shared-Use Projects – Continue

13. Added Share-use - Title: Collaborative USGS-NEES Studies in the Mississippi Embayment (2007), PI: Robert Williams @ USGS
14. NEESR - Title: High-Fidelity Site Characterization by Experimentation, Field Observation, and Inversion-Based Modeling (2007), PI: Jacobo Bielak @ Carnegie Mellon University

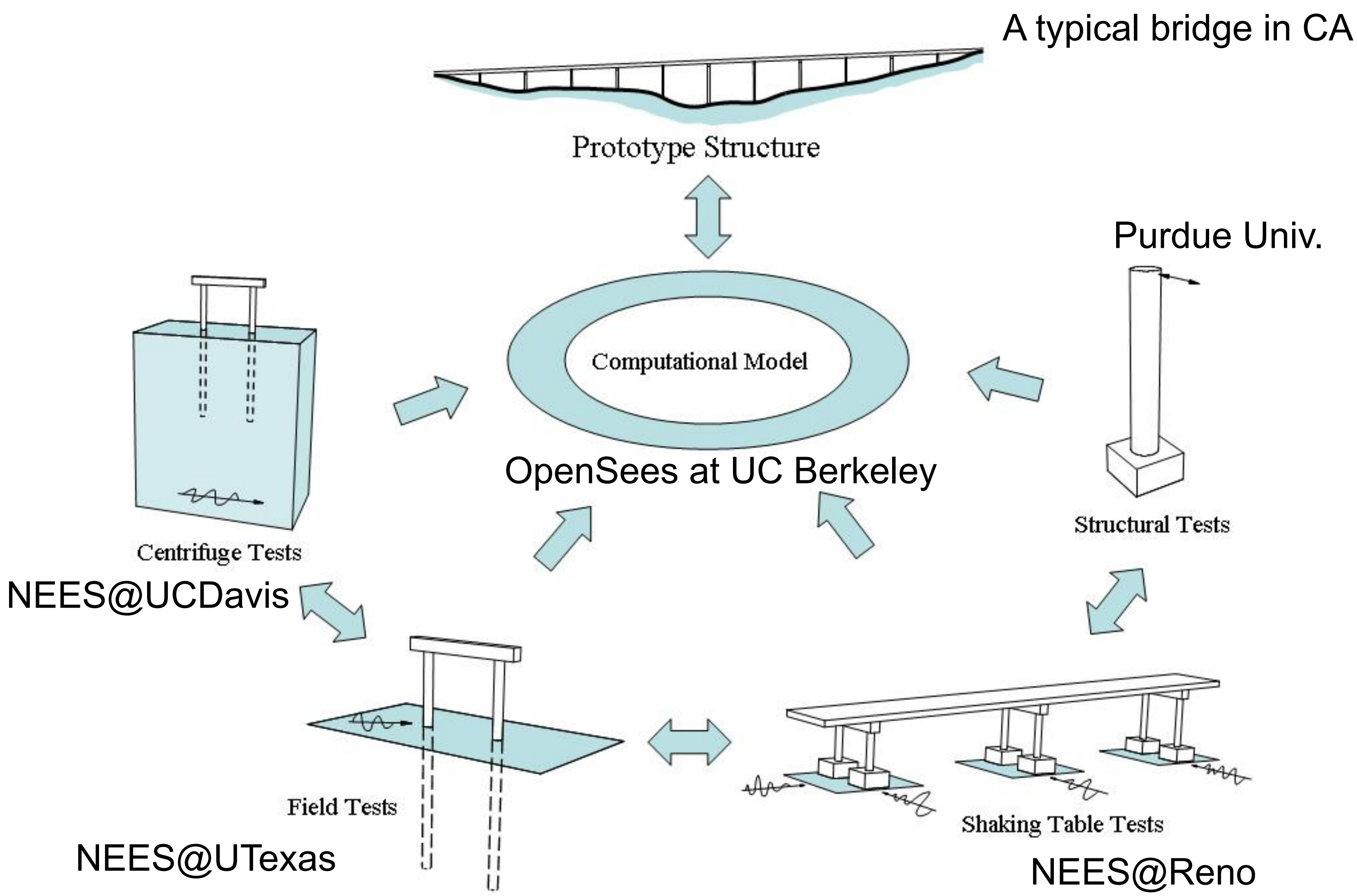
15.1. Added Share-use - Title: Collaborative USGS-NEES Studies in the Santa Rosa Plain, California (2008), PI: Robert Williams @ USGS

15.2. Added Share-use - Title: Collaborative USGS-NEES Studies in the Mississippi embayment and the Seattle Basin (2008), PI: Robert Williams @ USGS

16. Added Share-use - Title: SASW Measurements at USGS Hawaiian Strong Motion Network (2008), PI: Ivan Wang @ URS
17. SGER - Title: Deep Shear Wave Velocity Measurements in the Las Vegas Basin (2008), PI: Barbara Luke @ University of Nevada, Las Vegas
18. Added Share-use - Title: Collaborative USGS-NEES Earthquake Hazard Studies in the Reno-Carson City Urban Corridor, Nevada, 2009 (2009), PI: William Stephenson @ USGS
19. NEESR-II - Title: Advanced Site Monitoring and Effective Characterization of Site Nonlinear Dynamic Properties and Model Calibration (2009), PI: Mourad Zeghal @ Rensselaer Polytechnic Institute
20. NEESR-CR - Title: Topographic Effects in Strong Ground Motion - From Physical and Numerical Modeling to Design (2010), PI: Adrian Rodriguez-Marek @ Washington State University
21. Added Share-use - Title: Shear Wave Velocity Measurements at Stanford University (2009), PI: Ivan Wang @ URS
22. Added Share-use - Title: Collaborative USGS-NEES Earthquake Hazard Studies in the New Madrid Seismic zone and Puget Sound, Washington (2010), PI: Robert Williams @ USGS
23. Added Share-use - Title: Characterizing the geometry and time of deformation of the Meeman-Shelby Fault, near Memphis, TN (2010), PI: M.Beatrice Magnani @ University of Memphis
24. NEESR-CR - Title: Seismic Response of Landfills: In-situ Evaluation of Dynamic Properties of Municipal Solid Waste, Comparison to Laboratory Testing, and Impact on Numerical Analyses (2010), PI: Dimitrios Zekkos @ University of Michigan

Collaborative Research: Using NEES as a Testbed for Studying Soil-Foundation-Structure-Interaction

PI: Sharon L. Wood (UT Austin)



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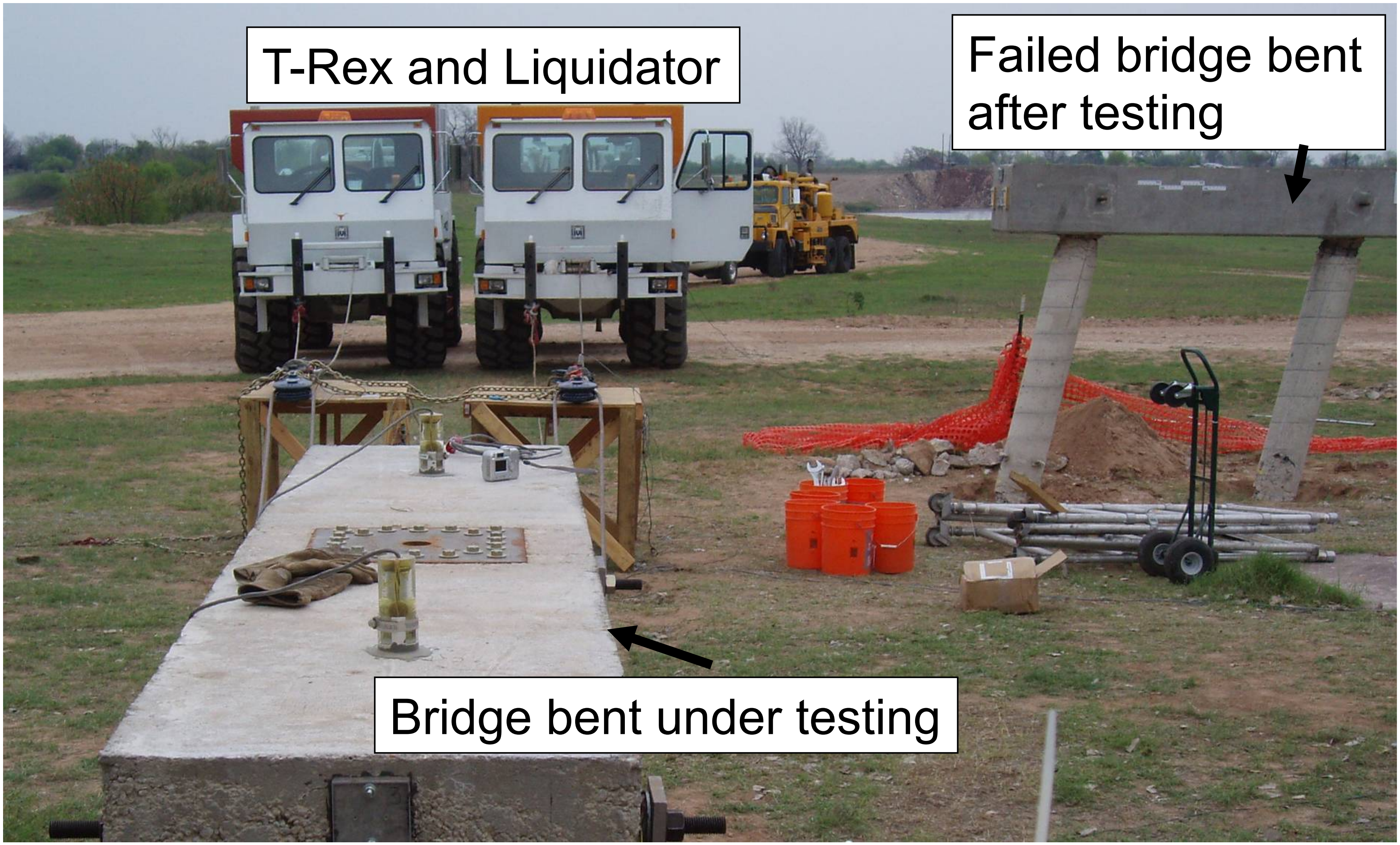


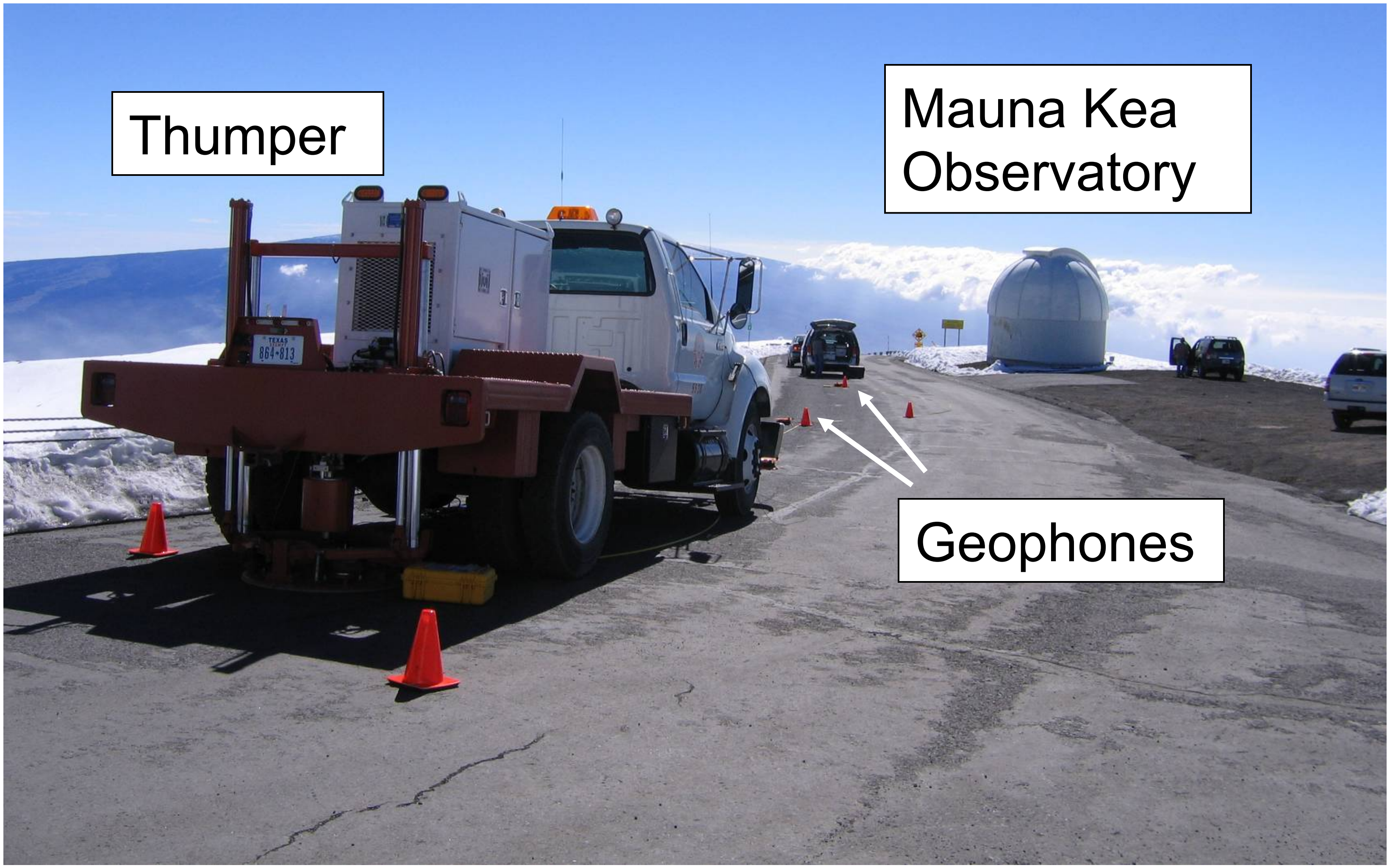
Site Amplification Studies

Required:

1. Stiffness (shear modulus)
   - Shear modulus at small strain: shear-wave velocity (V_S) profile
   - Shear modulus at large strain: in-situ nonlinear shear modulus measurements of soil
2. Material damping

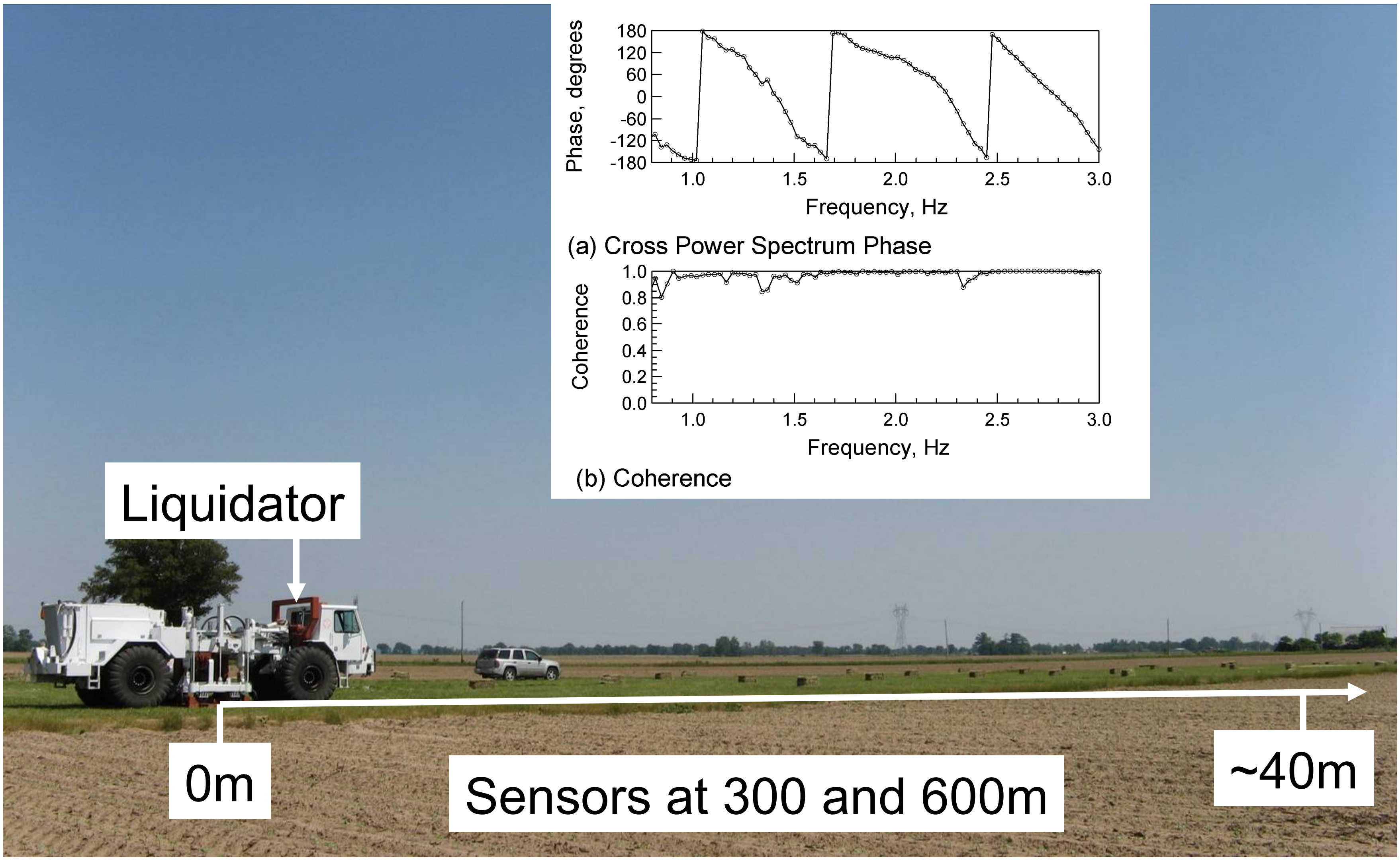
SASW Measurements at USGS Hawaiian Strong Motion Network

PI: Ivan Wang (URS)



Study of Surface Wave Methods for Deep Shear Wave Velocity Profiling of the Mississippi Embayment

PI: Brent Rosenblad (Univ. of Missouri)



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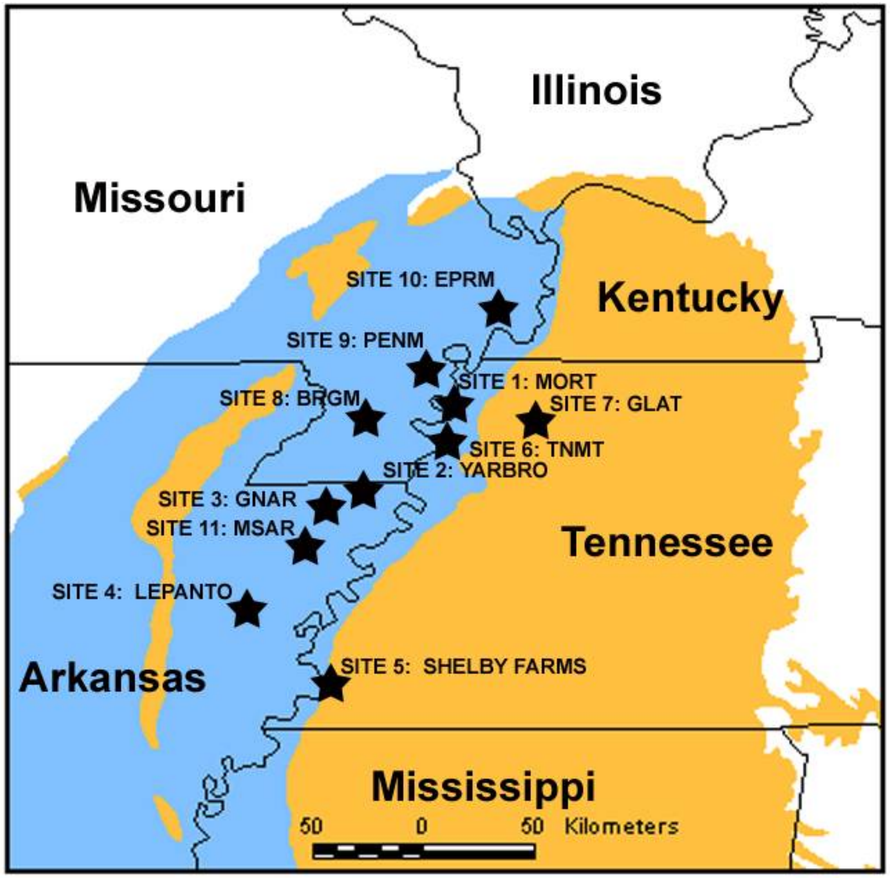


- Deep shear wave velocity measurements (> 200m) at 11 sites
- Comparing 4 surface wave measurement techniques:

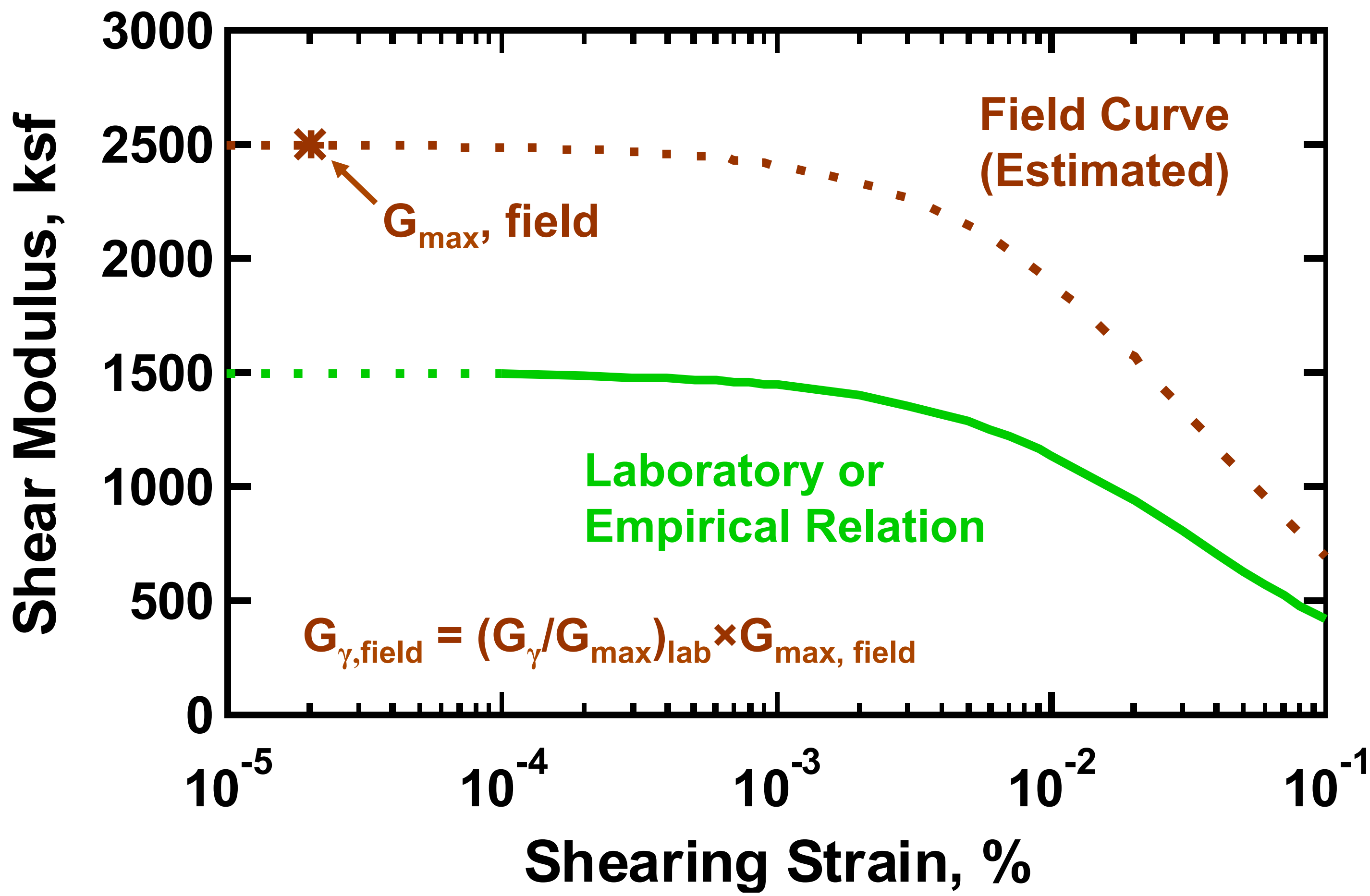
(1) active source, SASW

(2) active source, MASW

(3) passive source with circular array,

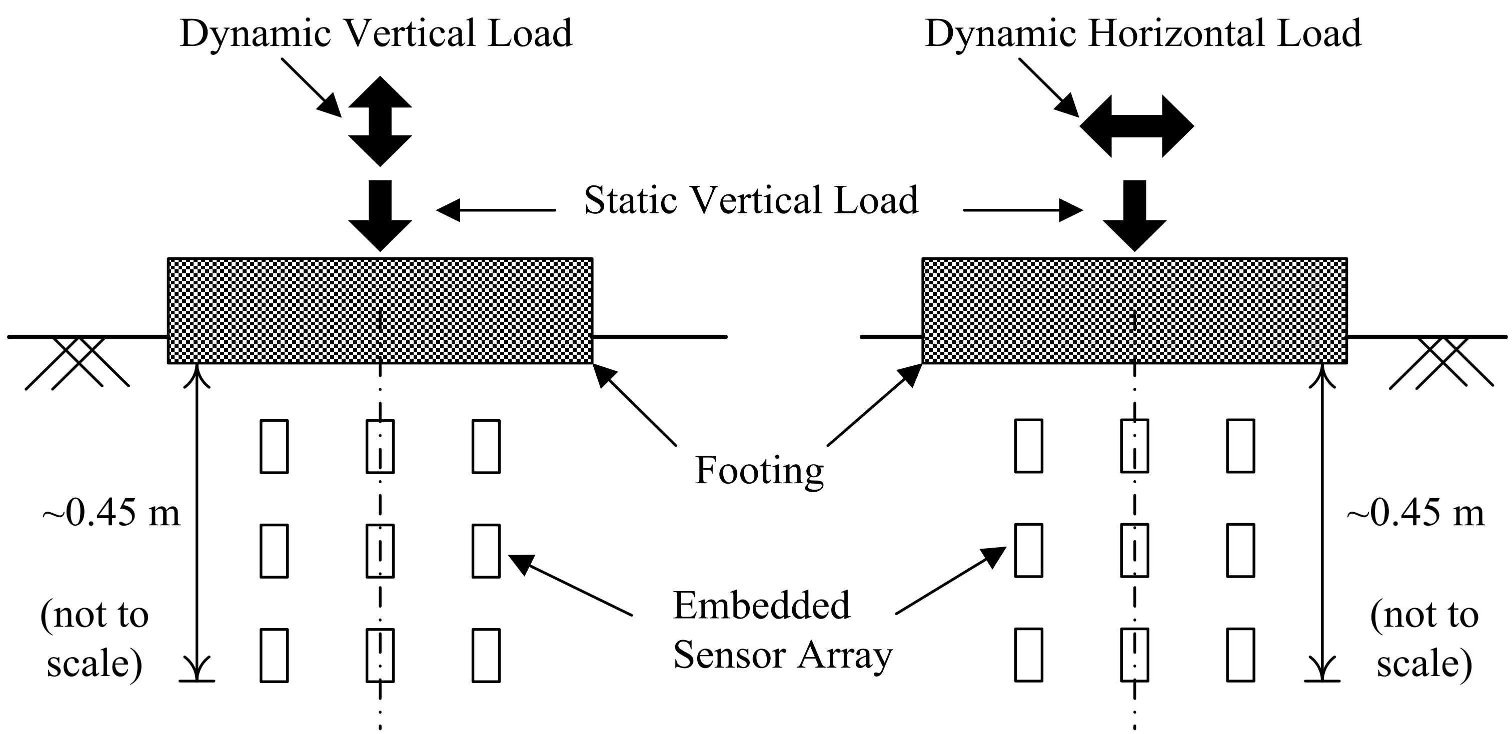
(4) passive source with linear array

Current Approach to Evaluate Field Nonlinear Shear Modulus with Shear Strain Level



In-situ nonlinear shear modulus measurements of soil (College Station, TX)

PI: Giovanna Biscontin (TXAM Univ.)



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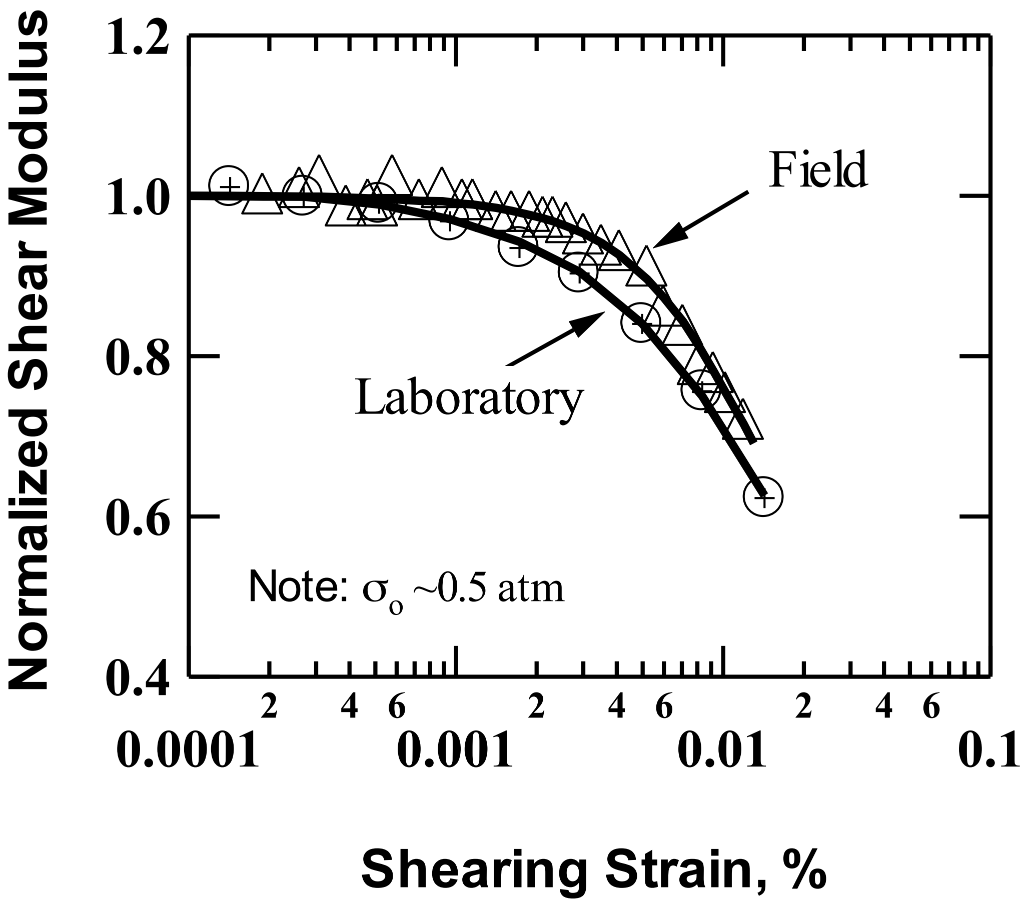
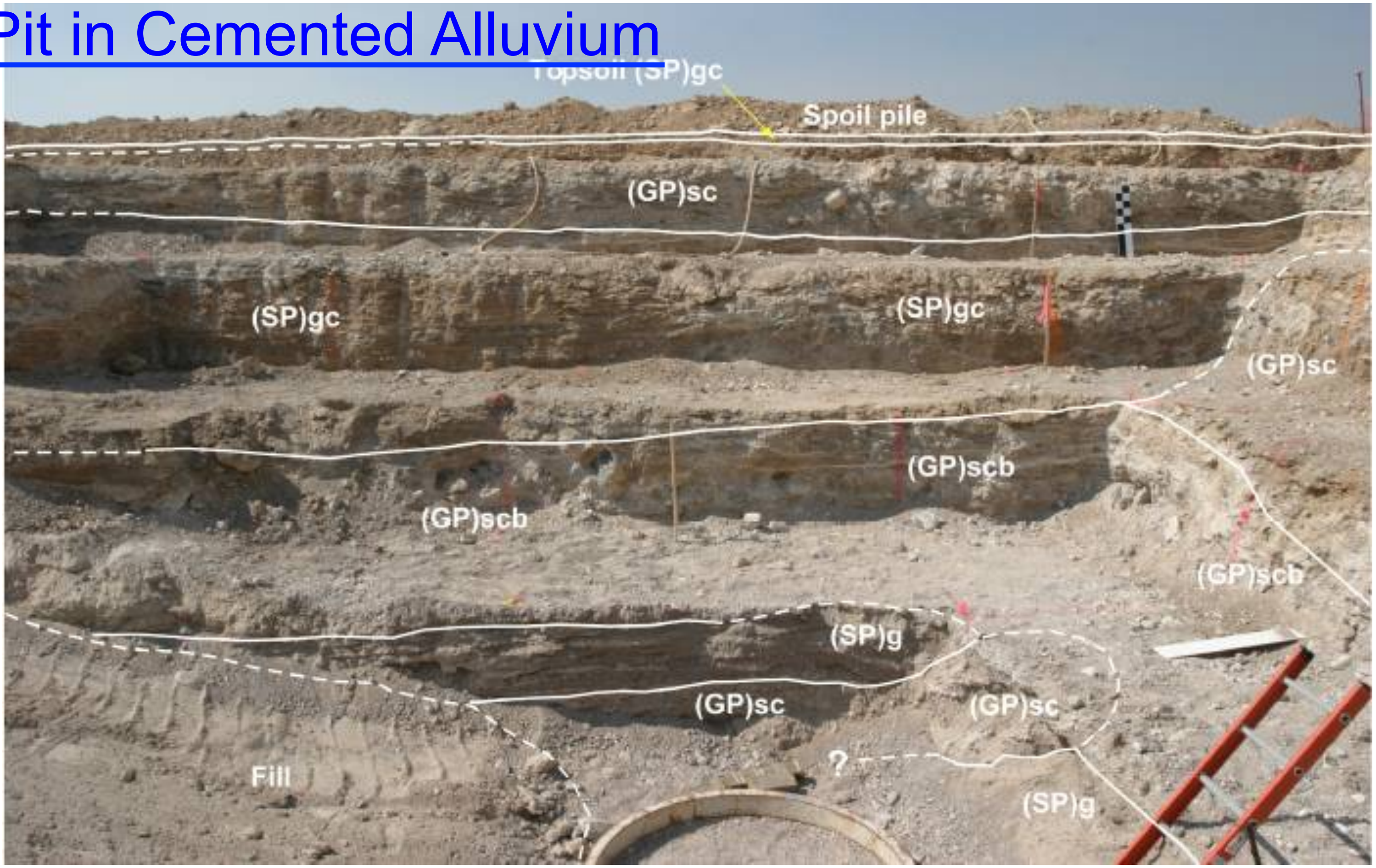


In-situ nonlinear shear modulus measurements at Yucca Mountain (Material can't be tested in the lab)

Test Pit in Cemented Alluvium



Coarse Grain: D_{50} = 0.4-24.8 mm, C_u = 16-86, w = ~0%
Cementation: visible and quite variable spatially

Source: Schuhen, 2008

Soil Liquefactions

- What are the mechanisms of soil liquefactions?
- How can we determine if a site of interest will liquefy during an earthquake?
- How can we mitigate soil liquefaction induced hazards?

Field Evaluation of Liquefaction Resistance at Previous Liquefaction Sites in Southern California (Imperial Valley)

PI: Kenneth H. Stokoe, II (UT Austin)

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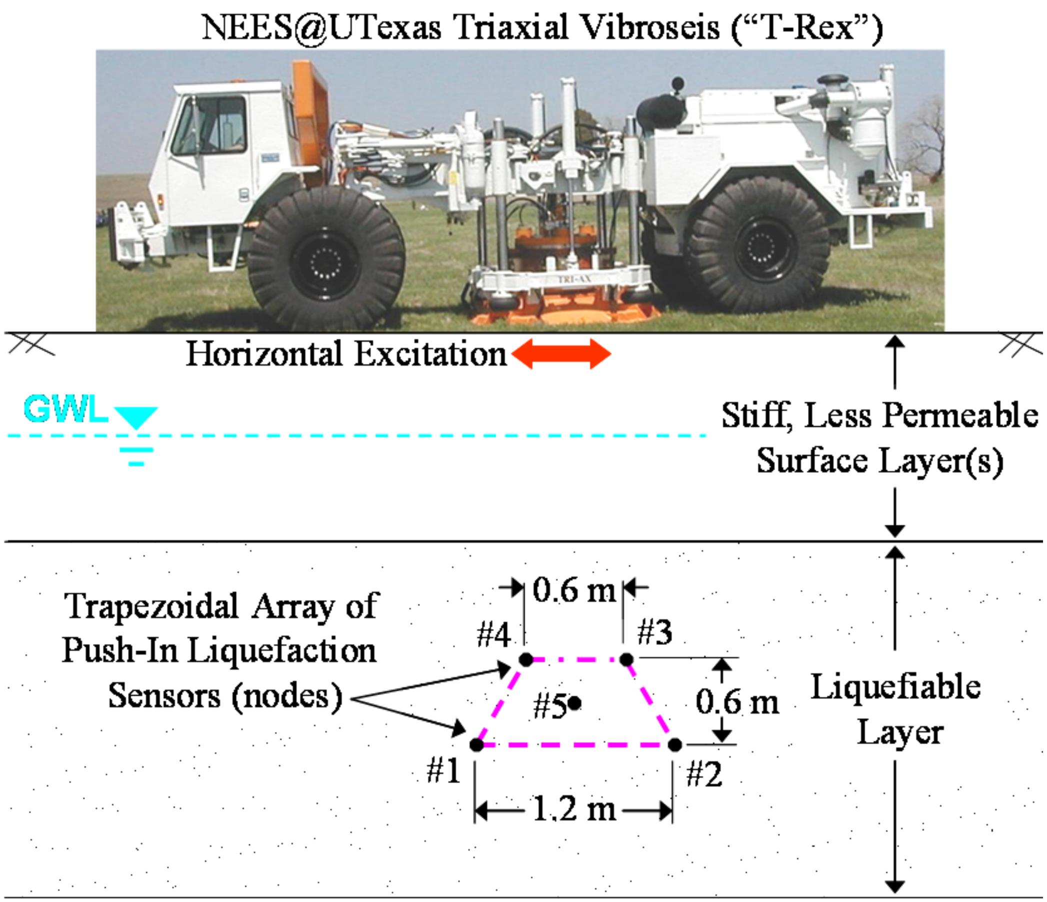

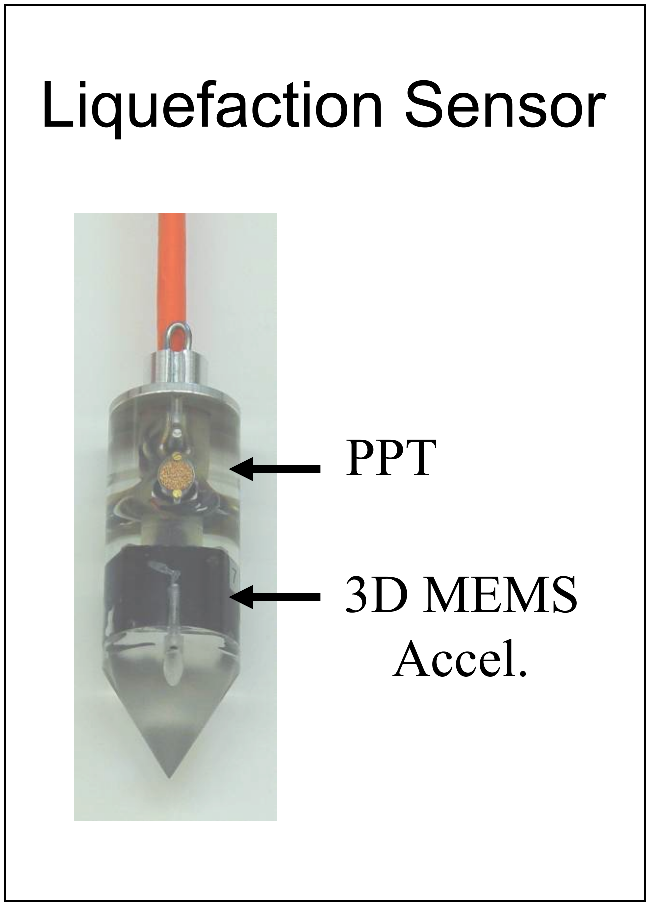

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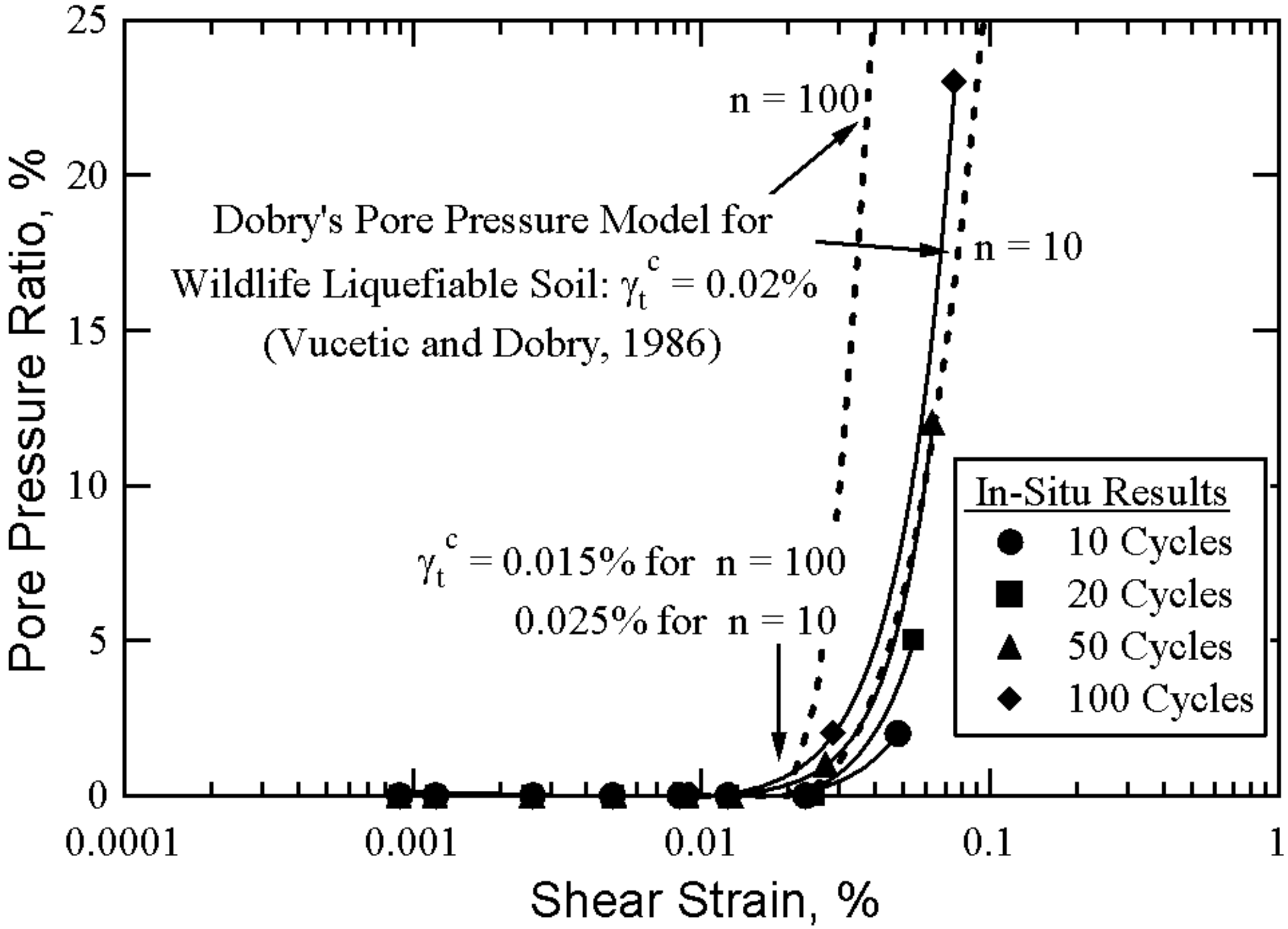

Mechanisms and Implications of Time Dependent Changes in the State and Properties of Recently Liquefied Sands

PIs: Russell A. Green (Univ. of Michigan)

Seismic Risk Mitigation for Ports
Soil Improvement of Soil Liquefaction Resistance
PI: Glenn Rix (Georgia Institute of Technology)

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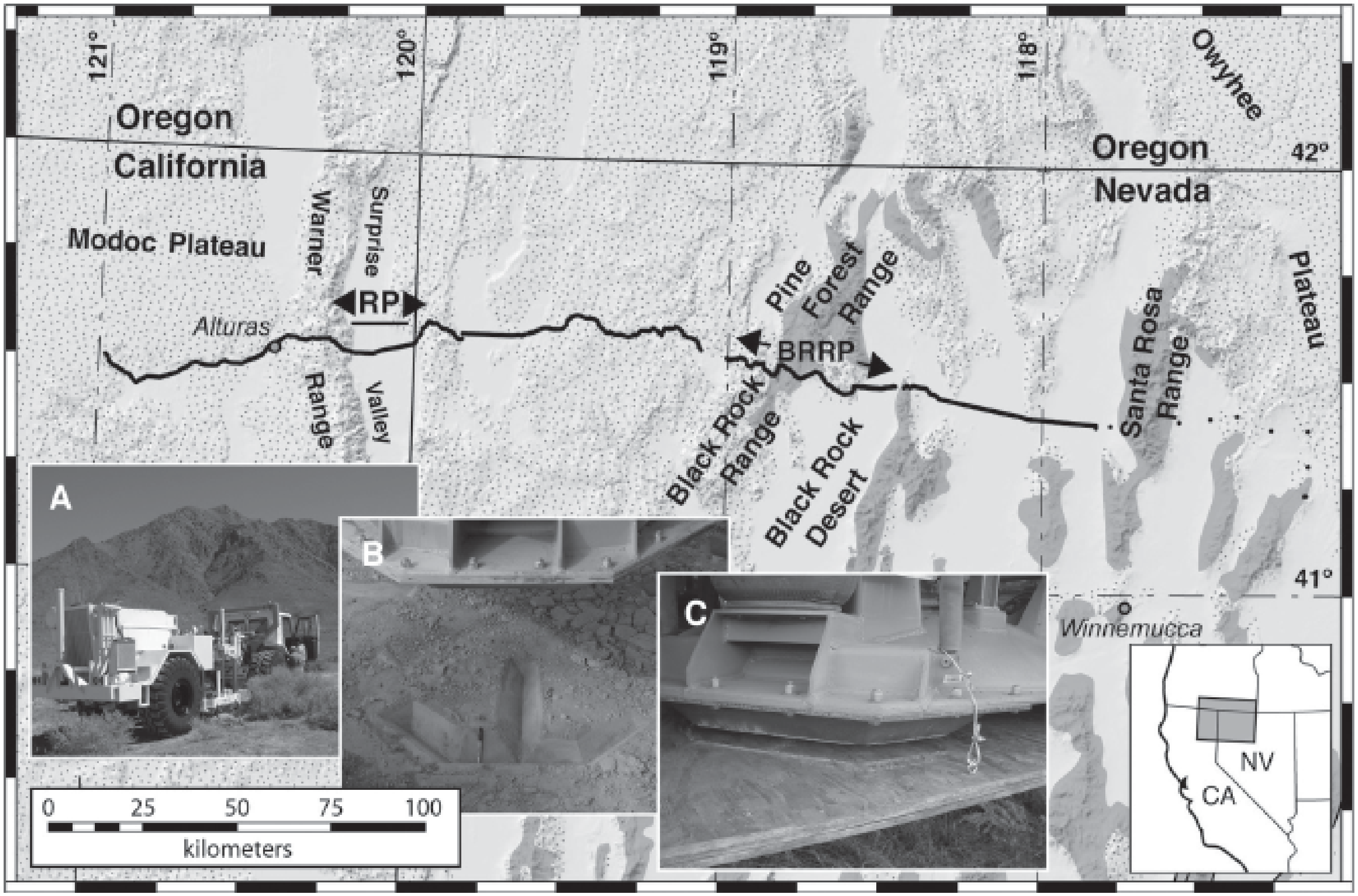
Application of the NEES T-Rex Vibrator for 3-component Crustal Reflection/Refraction Profiling

PIs: Simon Klemperer (Stanford Univ.)



Derek W. Lerch, Simon L. Klemperer, Kenneth H. Stokoe, and Farn-Yuh Menq, , (2008) "Integration of the NEES T-Rex Vibrator and PASSCAL Texan Recorders for Seismic Profiling of Shallow and Deep Crustal Targets," Seismological Research Letters , Vol. 79, No.1, pp 791-809

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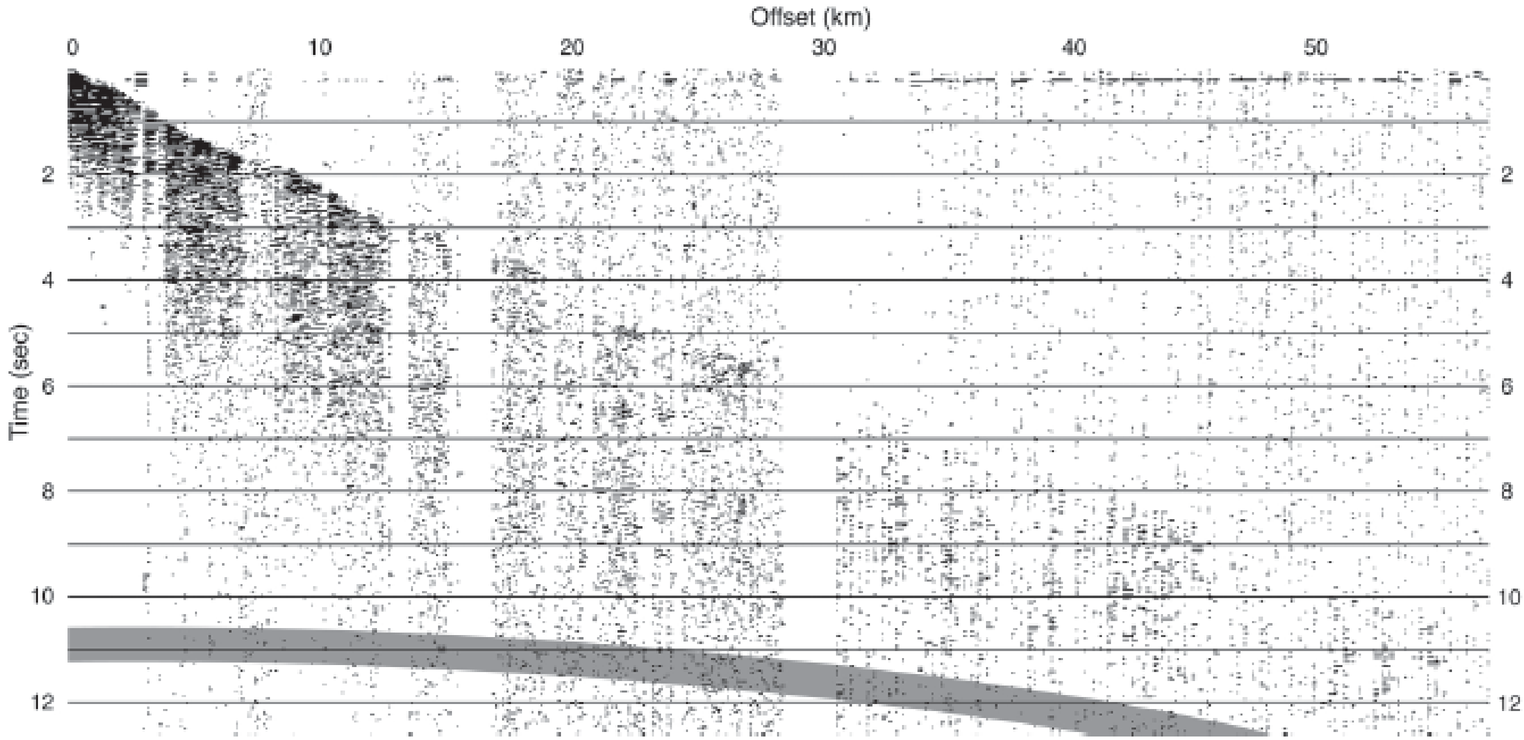

▲ **Figure 2.** Best source gather from crustal profile. Coherent arrivals visible to offsets of ~ 20 km, with discontinuous energy visible to ~50 km. Wide gray line represents Moho travel time calculated from the Lerch *et al.* (2007) wide-angle velocity model. Gather produced by stacking ten coincident sweeps, applying a bandpass filter (4-6-36-42 Hz), and performing a predictive deconvolution.

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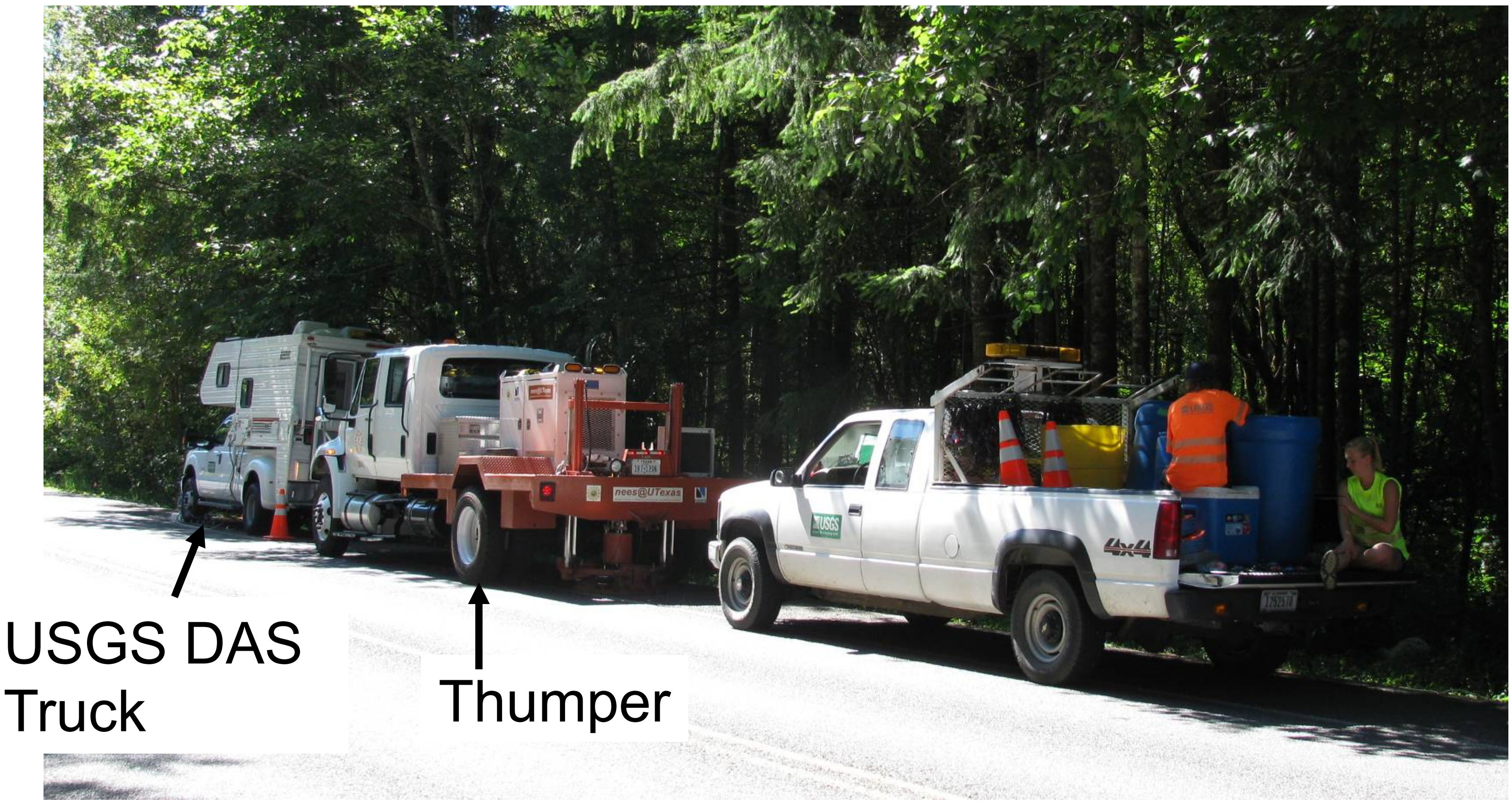
Reflection Survey of Fault Structures Sponsored by USGS
PIs: Robert Williams & William Stephenson (USGS)

One to two field tests each year at: (1) the New Madrid Seismic Zone, (2) the Santa Rosa Plain, CA, (3) the Seattle Basin, and (4) the Reno-Carson City Urban Corridor, NV



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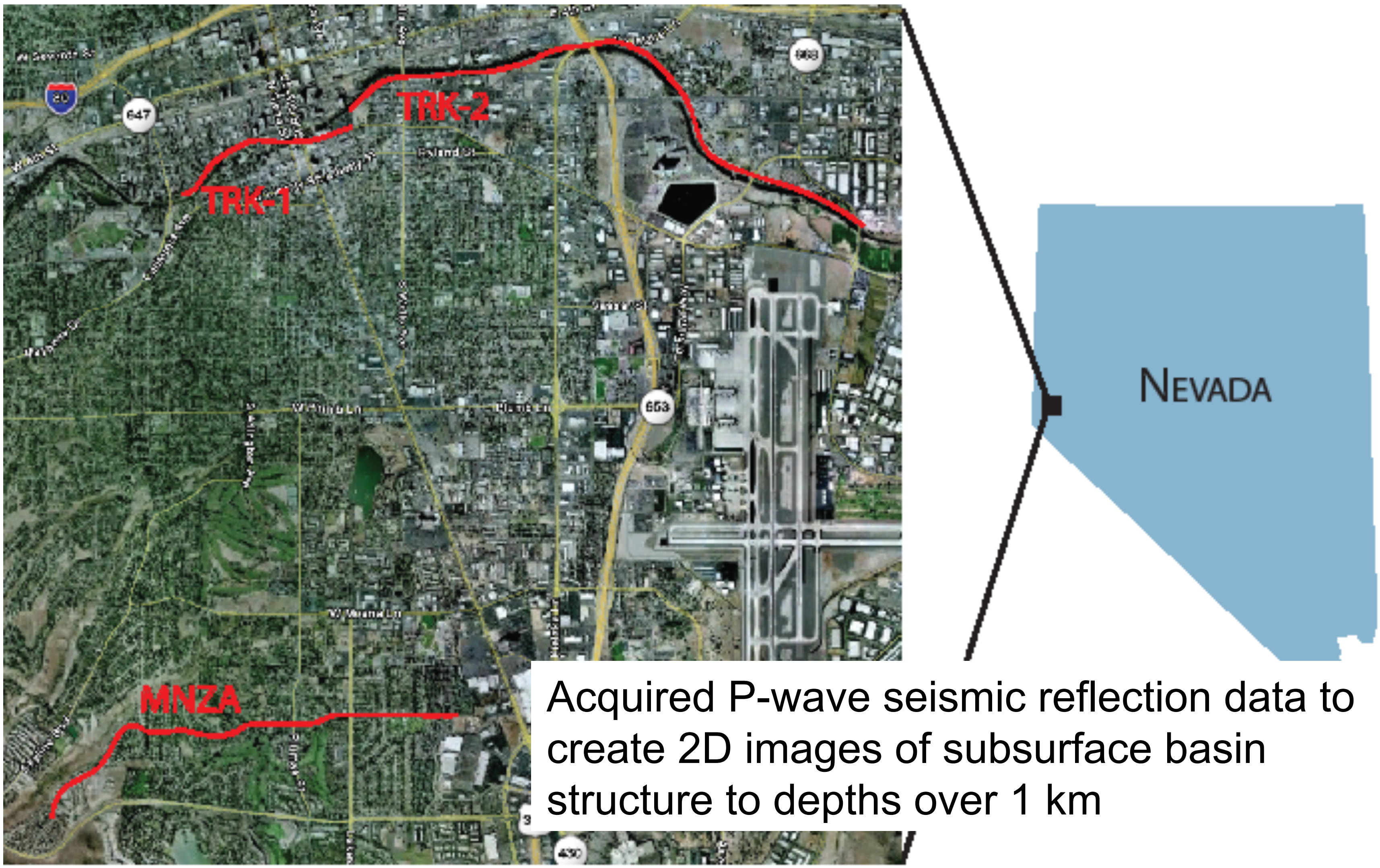

Acquired P-wave seismic reflection data to create 2D images of subsurface basin structure to depths over 1 km

Reflection Survey of Fault Structures Sponsored by USGS
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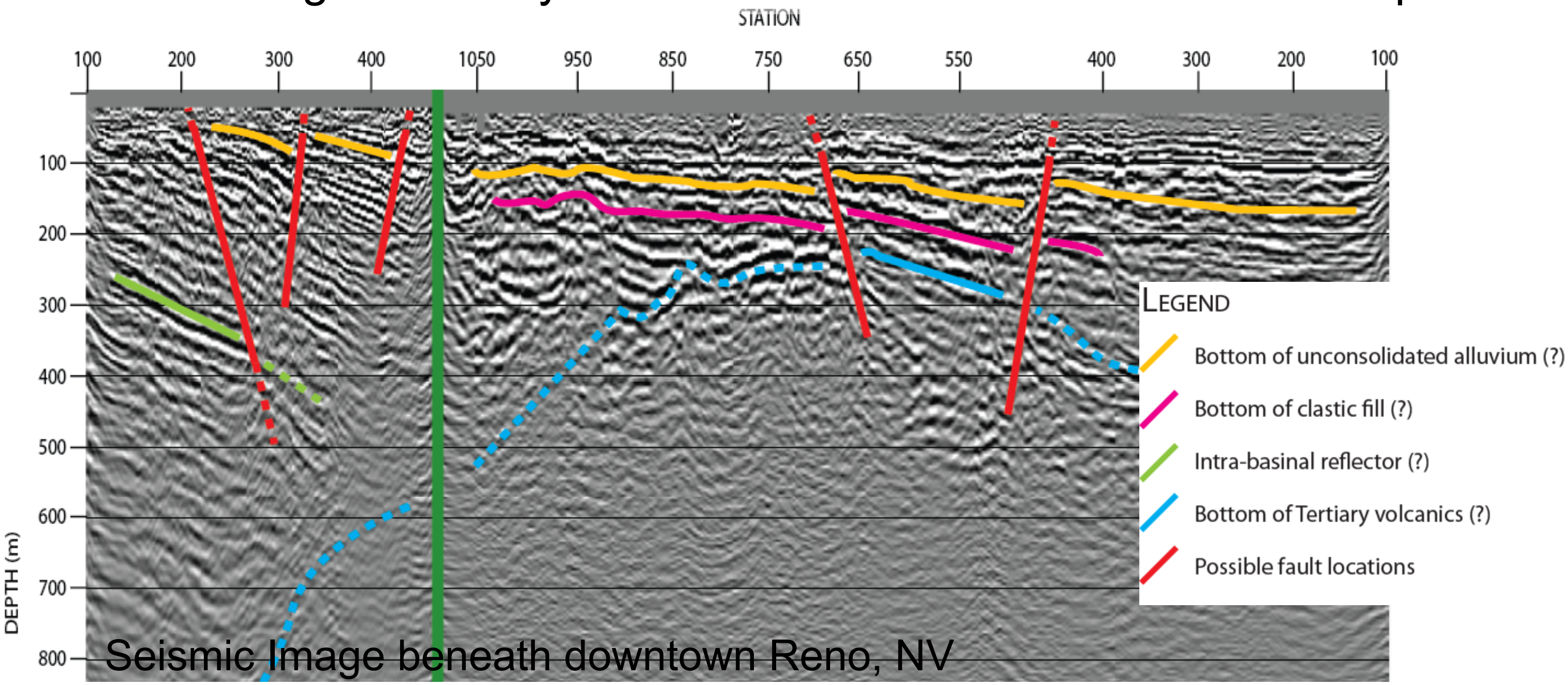
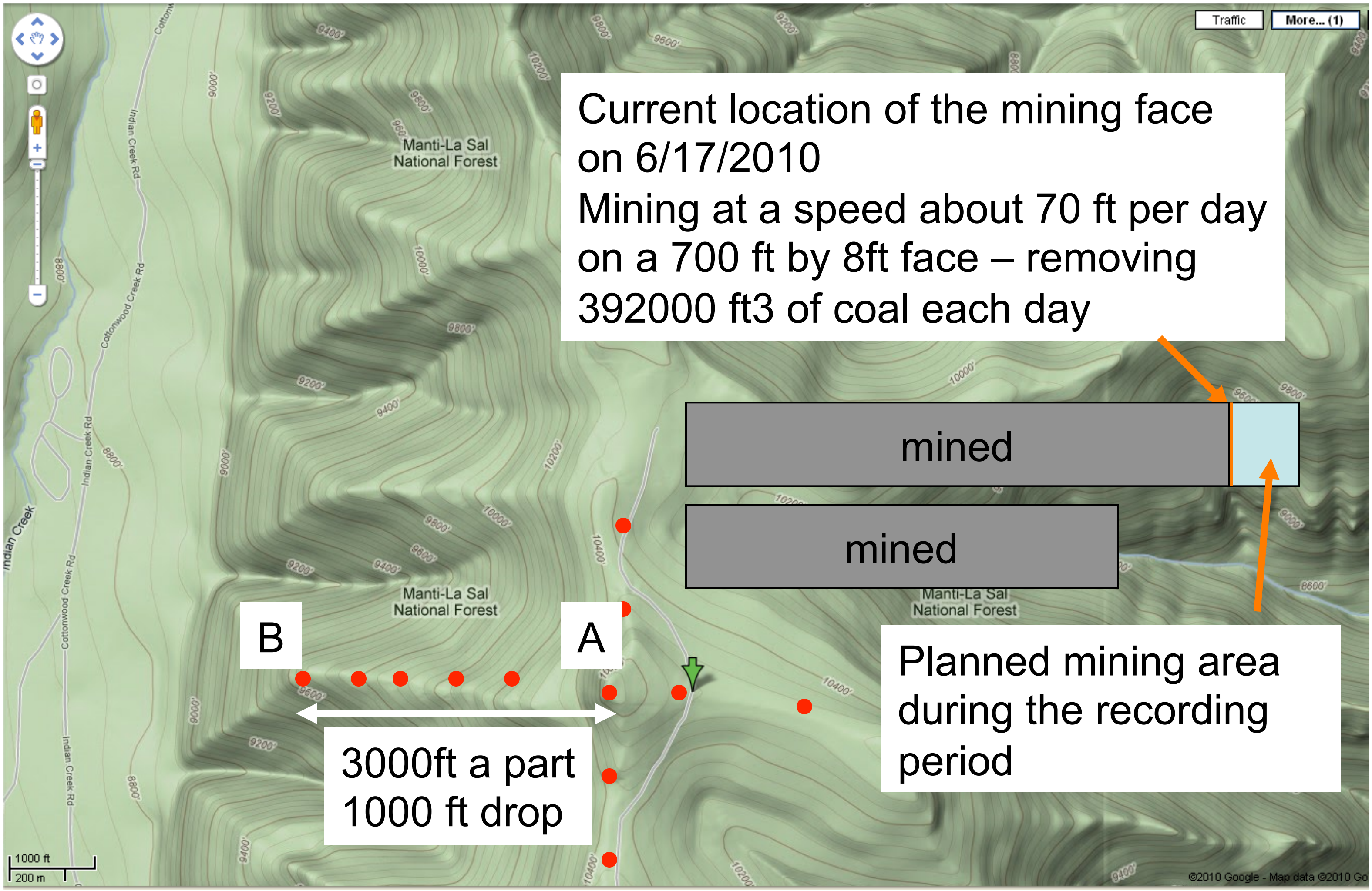
- Provide high-resolution images of the sediment structure and faults (total 55+ km since 2004)
- The end-member product of the information will be contribution to both the U.S. Geological Survey National and Urban seismic hazard maps.



Seismic Image beneath downtown Reno, NV
Prior to this study, these faults and basin geometry were unknown

Topographic Effects in Strong Ground Motion
Field Measurements
PI: Adrian Rodriguez-Marek (Washington State Univ.)



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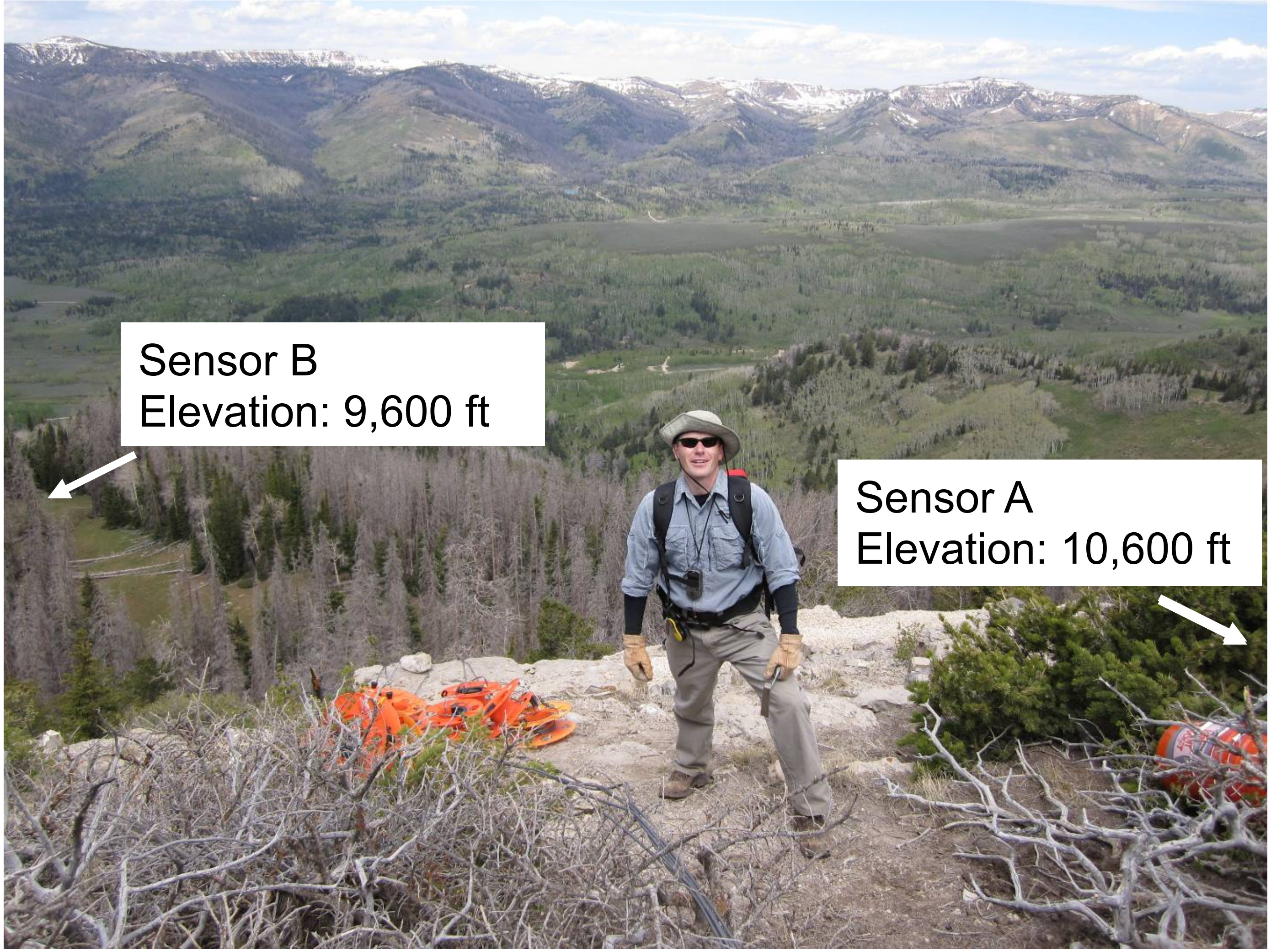

Thank you,

U. S. National Science Foundation, Directorate for Engineering, Division of Civil and Mechanical Systems for funding under the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Program Contract No. CMS-0086605 (Construction Phase)

NEEScomm supported by the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Program of the National Science Foundation under Award Number CMS-0402490 (Operation Phase)