Shared-Use of NHERI@UTexas Mobile Shakers for Geophysical and Seismological Research

Thursday, December 3, 2020

• 4:00 pm – Welcome
• 4:05 pm – Introduction of NHERI@UTexas (presented by Prof. Kenneth Stokoe, University of Texas at Austin, and Prof. Brady Cox, Utah State University)
• 4:30 pm – Use of Thumper as a source for Full waveform inversion (presented by Prof. Khiem Tran, University of Florida)
• 4:45 pm – Integration of T-Rex Vibrator and PASSCAL Texan Recorders for Seismic Profiling of Shallow and Deep Crustal Targets (presented by Prof. Derek Lerch, Feather River College)
• 5:00 pm – Q&A, (participant self-introduction)
NHERI@UTexas
Large Mobile Shakers
NSF Shared-use Experimental Facility

Presented by
Dr. Kenneth H. Stokoe, P.E., NAE
Professor, UT Austin, Dept. of Civil, Architectural, and Environmental Engineering
Dr. Brady R. Cox, P.E.
Professor, Utah State University, Dept. of Civil and Environmental Engineering

December 3rd, 2020
Natural Hazards Engineering Research Infrastructure

7 Experimental Facilities with Large-Scale Equipment
1 Cyberinfrastructure Facility for Archiving and Sharing Data
1 Computational Modeling/Simulation Center
1 Post-disaster Rapid Response Facility
1 Network Coordination Office

UNIVERSITY OF COLORADO BOULDER
Extreme Event Reconnaissance Coordination
NSF Award #1841338

UNIVERSITY OF WASHINGTON
Natural Hazards Reconnaissance Equipment
NSF Award #1611820

OREGON STATE UNIVERSITY
Wave Basin and Flume
NSF Award #1519679

UNIVERSITY OF TEXAS, AUSTIN
Mobile Field Shakers
NSF Award #1520808

UC DAVIS
Geotechnical Centrifuges
NSF Award #1520581

UC SAN DIEGO
Large Outdoor Shake Table
NSF Award #1520904

UC BERKELEY
Computational Simulation
NSF Award #1612843

UNIVERSITY OF TEXAS, AUSTIN
Community Cyberinfrastructure
NSF Award #1520817

FLORIDA INTERNATIONAL UNIVERSITY
Wind Simulation
NSF Award #1520853

LEHIGH UNIVERSITY
Hybrid Simulation
NSF Award #1520765

PURDUE UNIVERSITY
Network Coordination Office
NSF Award #1612144
Principal Investigators are encouraged to leverage NSF’s investments in the Natural Hazards Engineering Research Infrastructure (NHERI) experimental, computational modeling and simulation, and data resources ([https://www.designsafe-ci.org/](https://www.designsafe-ci.org/)) in their research to accelerate advances needed for reducing the impacts of natural hazards.

- NHERI equipment can be used with funding from any NSF program
- NHERI equipment can be used at higher rates for non-NSF funding (including industry)
Project Team

**Director/PI**
Kenneth Stokoe
Professor, UT Austin

**Co-PI**
Brady Cox
Professor, Utah State Univ.

**Co-PI**
Patricia Clayton
Asst. Professor, UT Austin

**Co-PI**
Robert Gilbert
Chair & Prof., UT Austin

**IT/Cybersecurity**
Robert Kent
UT Austin

**Operations Manager**
Farnyuh Menq
UT Austin

**Mobile Shaker Specialist**
Cecil Hoffpauir
UT Austin

**Hydraulics Technician**
Andrew Valentine
UT Austin
**NHERI@UTexas Equipment Overview**

- **Five (5) large, servo-hydraulic, mobile shaker trucks**
- **Various support vehicles and trailers**
- **A wide array of instrumentation for recording vibration, force, and pore water pressure**

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**T-Rex (Tri-axial Shaker)**
- Off-road buggy
- 32 ft long, 8 ft wide, weight = 64,000 lbs
- Three vibrational orientations
- Push-button transformation of shaking orientation
- Shear mode Peak Force = 30,000 lbs
- Vertical mode Peak Force = 60,000 lbs

**Liquidator (Low Frequency Shaker)**
- Off-road buggy
- 32 ft long, 8 ft wide, weight = 72,000 lbs
- Two vibrational orientations
- One day shop transformation of shaking orientation
- Shear mode Peak Force = 20,000 lbs
- Vertical mode Peak Force = 20,000 lbs

**Thumper (Urban Shaker)**
- Built on a International 4300 truck
- 27 ft long, 8.5 ft wide, weight = 24,800 lbs
- Three vibrational orientations
- Four hours field transformation of shaking orientation
- Shear mode Peak Force = 6,000 lbs
- Vertical mode Peak Force = 6,000 lbs

**Raptor (Mid-Size Shaker)**
- Highway legal truck
- 32 ft long, 8 ft wide, weight = 41,200 lbs
- Vertical mode Peak Force = 27,000 lbs

**Rattler (Horizontal Shaker)**
- Off-road truck
- 29 ft long, 8.5 ft wide, weight = 54,500 lbs
- Shear mode Peak Force = 30,000 lbs

**Big-Rig**
- 26 wheeler tractor-trailer rig for shipping T-Rex, Liquidator, and Rattler
- Overweight permit required

**Fuel-Supply Truck**
- Carries diesel fuel for T-Rex, Liquidator, and Rattler in the field
- Provides a working platform for maintenance and CPT tests

**Instrumentation Van & Trailer**
- A customized Chevrolet cargo van provides an air-conditioned workspace
- A 8 ft by 16 ft cargo trailer provides additional working and storage space

**Hydraulic Cylinder with Adjustable Platform**
- Mounted at the rear of T-Rex
- Platform for installing and retrieving liquefaction, CPT, and seismic CPT sensors
**T-Rex**

- Tri-axial shaker
- Push-button transformation of shaking orientation
- 32 ft long, 8 ft wide, Wt. = 64,000 lbs
- Only operating tri-axial vibroseis we are aware of in the world
T-Rex – Horizontal Shaking
Liquidator

- Custom-built, one-of-a-kind, low frequency shaker
- Two-shaking orientations
- One-day shop transformation of shaking orientation
- 32 ft long, 8 ft wide, Wt. = 72,000 lbs
Liquidator – Standard Configuration
Liquidator – Special Configuration
Raptor

- Standard vibroseis, vertical shaker (P-wave)
- 32 ft long, 8 ft wide, Wt. = 41,200 lbs

Vertical force output
Rattler

- Standard vibroseis, horizontal shaker (S-wave)
- 29 ft long, 8.5 ft wide, Wt. = 30,000 lbs
**Thumper**

- Mini-vibroseis/urban shaker
- Three vibrational orientations
- Two-hour field transformation of shaking orientation
- 27 ft long, 8.5 ft wide, Wt. = 28,400 lbs.
Big Rig

- 26-wheel tractor trailer for shipping T-Rex, Liquidator, and Rattler
Support Vehicles

Field/Fuel Truck

Instrumentation Van

Trailer #1 (with A/C)

Trailer #2

Provide fuel, storage, and workspace in the field.
Instrumentation – Data Acquisition (DAQ)

72-channel VXI DAQ
- 24 bit digitizer
- Up to 50 kHz sampling rate
- Real-time frequency domain capabilities

168 channels of DAQ

96-channel Data Physics DAQ
- 24 bit digitizer
- Up to 200 kHz sampling rate
- Real-time frequency domain capabilities
**Instrumentation – DAS Interrogator**

- **New in 2021**
- **OptaSense ODH4 DAS Interrogator**
- Distributed Acoustic Sensing (DAS); fiber optic sensing
- Capable of measuring with ANY fiber from ANY vendor (single mode, multi-mode or enhanced high backscatter)
- Sample rate up to 100 kHz

High Backscatter Single Fiber 2m Gauge Length
**Instrumentation – Geophones**

- **109, 1-Hz Geophones** (85 vertical & 24 horizontal)
- **15,000 ft of twisted, shielded-pair cable**

- **196, 4.5-Hz Geophones** (98 vertical & 98 horizontal)
- **Refraction cables** (24-channels, 4 @ 2m & 4 @ 5m)
- **Towable landstreamer** (24-sleds)
- **2, 24-channel Geode seismographs**
Instrumentation – 3C Nodal Geophones

- **New in 2021**
- 100, SmartSolo IGU-16HR 3C nodal stations
- 3-component
- 5-Hz geophones
- 24 bit ADC
- GPS synchronized
- Size: 103mm (L) x 95mm (W) x 150mm (H)
- Weight: 1.7kg
Instrumentation – Broadband Seismometers

20, Nanometrics Broadband Seismometer Stations

- 3-component
- GPS synchronized
- 10, 120-sec period and 10, 20-sec period Trillium Compact seismometers
- 10, Taurus and 10, Centaur digitizers (3-component, 24 bits)
- Structural and Geotechnical applications (flat response 0.01 to 100 Hz)
Instrumentation – CPT and Liquefaction Sensors

Cone Penetrometers
- Standard CPT
- Seismic CPT
- 4 different cones

Direct-Push Sensors
- CPT sensor in the ground
- CPT Rod
- Adjustable platform for the CPT hydraulic cylinder

Liquefaction Sensors
- Custom built
- Tri-axial MEMS accelerometers
- 2D or 3D geophones
- Pore water pressure transducers
Additional Instrumentation Resources
IRIS/PASSCAL

- Broadband
- Intermediate-period
- Short-period
- Accelerometers

Magseis Fairfield ZLand 3C Node - 3-Channel All in One, Sensor and Datalogger

The FairfieldNodal ZLand 3C is a compact all-in-one 3-channel sensor & datalogger with onboard GPS timing, and a self-contained power supply. Originally designed for use in large N industry deployments, it has been adopted by the academic community as a useful sensor for both active and short-term passive deployments.

Unlike other sensors & dataloggers at PASSCAL, use of the ZLand 3C requires a deployment plan to be filed in advance with PASSCAL for handheld unit pre-programming. Likewise, the units must be sent back to PASSCAL for data offload.

Specifications:
- This 3-channel all-in-one sensor + datalogger has a frequency of 5Hz and a 24 bit ADC
- Power source: Lithium ion battery with ~35 day lifespan at 500sps continuous recording
- Physical Size: 6.4in x 4.6in with additional 4.6in central spike
- Weight: 6.2lbs

Free to NSF-funded projects
*PI pays for shipping & travel expenses
Hornsby Bend (HB) Test Site

- NHERI@UTexas Facility
- UT main campus
- Austin Airport
- HB
- Test Location 1: 200 m line
- Test Location 2
- Test Location 3
Hornsby Bend (HB) Test Site

Vs using full waveform inversion (Kallivokas et al. 2013)

Soil behavior-type classifications from CPT tests
NHERI@UTexas Science Plan

Improved Subsurface Imaging (2D/3D)  Nonlinear In-Situ Testing

Structural Health Monitoring/Soil-Structure Interaction
"Have shaker trucks, will travel…"

- 55 Projects 2003 - 2014 (NEES, Shared-use, Industry/Gov.)
- 26 Projects 2016 - 2020 (NHERI, Shared-use, Industry/Gov.)
### Example: Cost Estimate

(Testing at Hornsby Bend Site in Austin)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
<th>Hours/day</th>
<th>Days</th>
<th>Rate/hour</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seismic Source (&quot;T-Rex&quot;)</td>
<td>3 hours / day * 5 days * $27 /hour</td>
<td>3</td>
<td>5</td>
<td>$27</td>
<td>$405</td>
</tr>
<tr>
<td>Seismic Source (&quot;Thumper&quot;)</td>
<td>3 hours / day * 5 days * $9 /hour</td>
<td>3</td>
<td>5</td>
<td>$9</td>
<td>$135</td>
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<tr>
<td></td>
<td>(40 miles per day * 2 days) * $0.7 per mile</td>
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<td></td>
<td>$0.7</td>
<td>$56</td>
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<tr>
<td>Fuel Supply Pickup</td>
<td>(40 miles per day * 10 days) * $0.45 per mile</td>
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<td></td>
<td>$0.45</td>
<td>$180</td>
</tr>
<tr>
<td>Tractor-Trailer</td>
<td>(40 miles per day * 2 days) * $1.13 per mile</td>
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<td></td>
<td>$1.13</td>
<td>$90</td>
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<tr>
<td>Misc. field supplies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$500</td>
</tr>
</tbody>
</table>

**Equipment Fuel and Supplies** $1,366  
**Overhead (56.5%)** $772  
**Total** $2,138

**Note:**

1. This cost was estimated in 2017.
2. A cost estimate template is available at [https://utexas.designsafe-ci.org/resources/](https://utexas.designsafe-ci.org/resources/).
Example: Cost Estimate for a Recent Research Proposal (Testing at an Attractive Island)

**LARGE MOBILE SHAKERS**

**NHERI@UTexas**

NHERI@UTexas Cost Estimate for Using T-Rex at [Redacted]

August 18, 2020

**Prepare for:**

**Prepare by:**

Farnyuh Michael Menq (Operations Manager)
NHERI@UTexas Equipment Site
301 E Dean Keeton St., Austin, TX 78712
The University of Texas at Austin
Tel: (512) 232-2049

Total Equipment Fuel Cost: $4,660
Travel Cost: $23,000
Ship T-Rex on a boat: $44,500
Overhead: $42,214
Total Cost: $114,374

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost estimate for an NSF-supported-project using T-Rex for reflection surveys at [Redacted]</td>
<td>$114,374</td>
</tr>
</tbody>
</table>
Additional Information & Proposal Help

• Dr. Kenneth Stokoe (PI) k.stokoe@mail.utexas.edu
• Dr. Brady Cox (co-PI) brady.cox@usu.edu
• Dr. Patricia Clayton (co-PI) clayton@utexas.edu
• Dr. Farnyuh Menq (Operations Manager) fymenq@utexas.edu

• NHERI@UTexas website at www.designsafe-ci.org
  – Webinar slides & updated budgetary info will be posted
Questions?