DEVELOPMENT OF AN OPEN SOURCE STRUCTURAL HEALTH MONITORING AND DAMAGE DETECTION SYSTEM FOR RESILIENT STRUCTURES

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USGS science for a changing world

We would like to dedicate this work to the memory of Mr. Krishna Banga from the U.S. Department of Veterans Affairs, a colleague with whom we have worked with for many years.

EARTHQUAKES

Photo source: Celebi and Page (2005)

1971 M6.6 San Fernando (California) earthquake resulted in the collapse and severe damage to several hospital buildings

MOTIVATION

- Critical facilities need to be operational after an earthquake. However, the structure itself may have been damaged and, consequently, may pose a hazard to occupants; the risk of collapse is elevated due to aftershocks.

Damaged hospital in Sylmar during the San Fernando earthquake

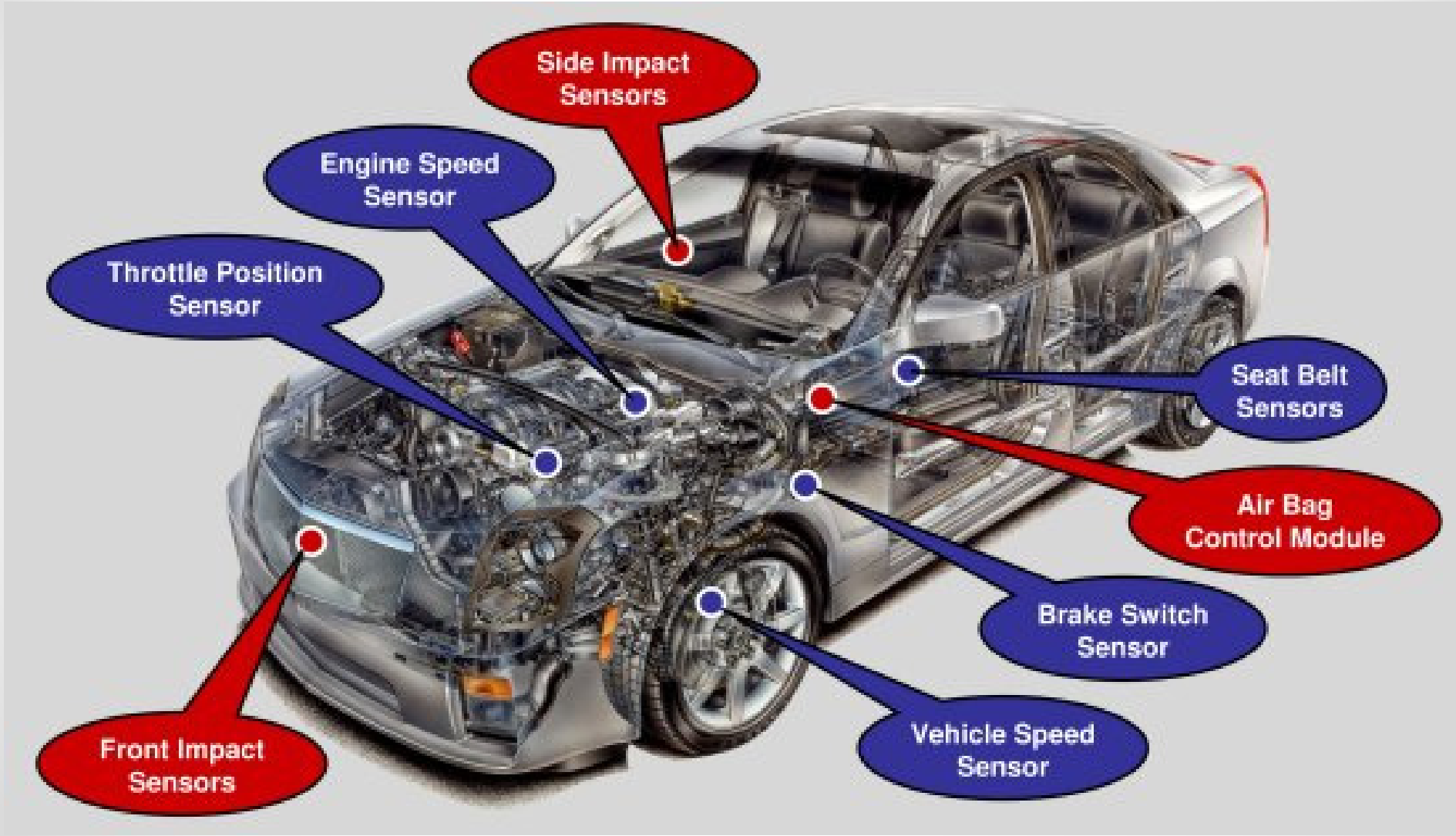
- Authorities need information necessary to make a rapid decision, whether to utilize or evacuate the buildings in the aftermath of an event.

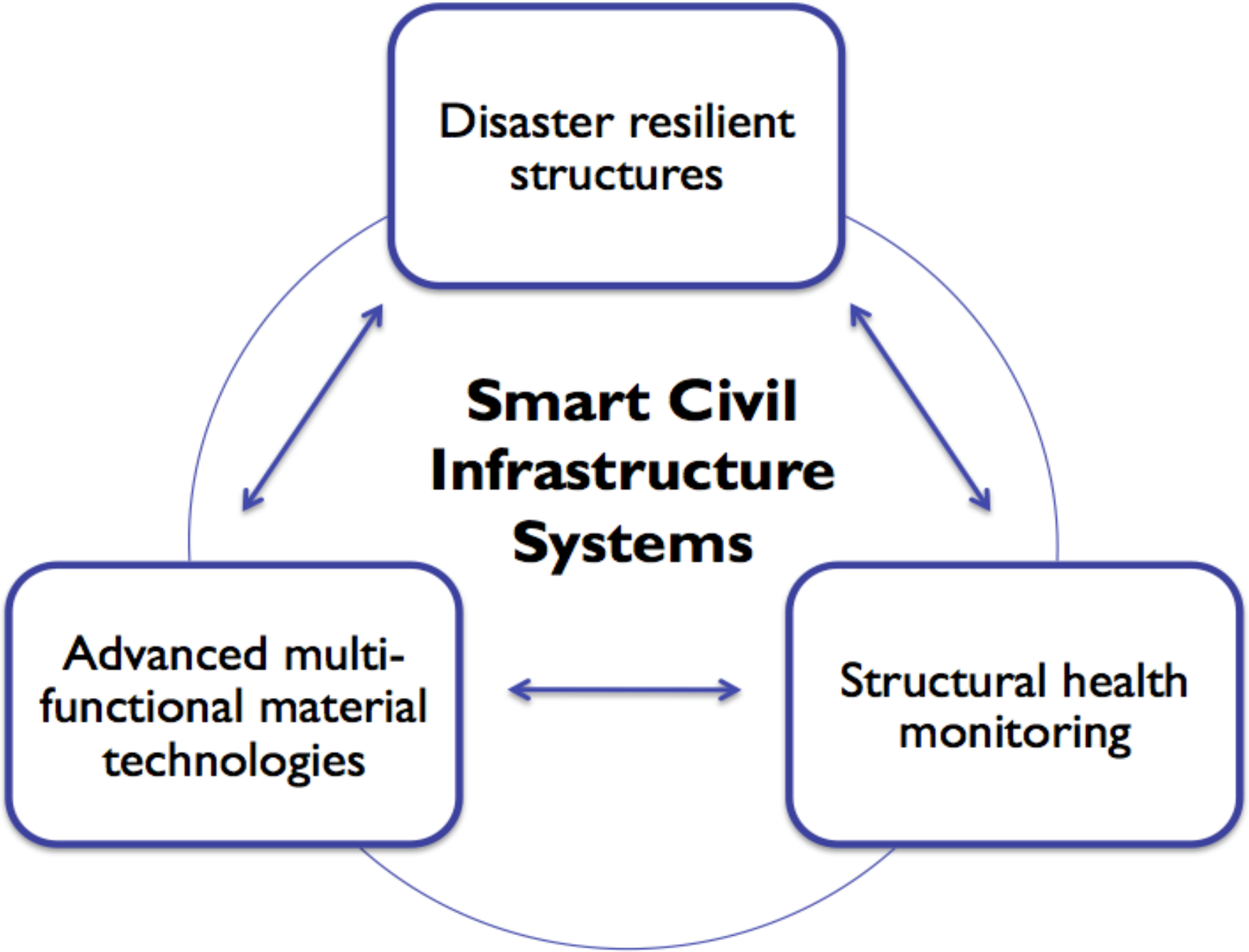
An ambulance that was crushed during the San Fernando earthquake

- Early assessment of the structural integrity is valuable in

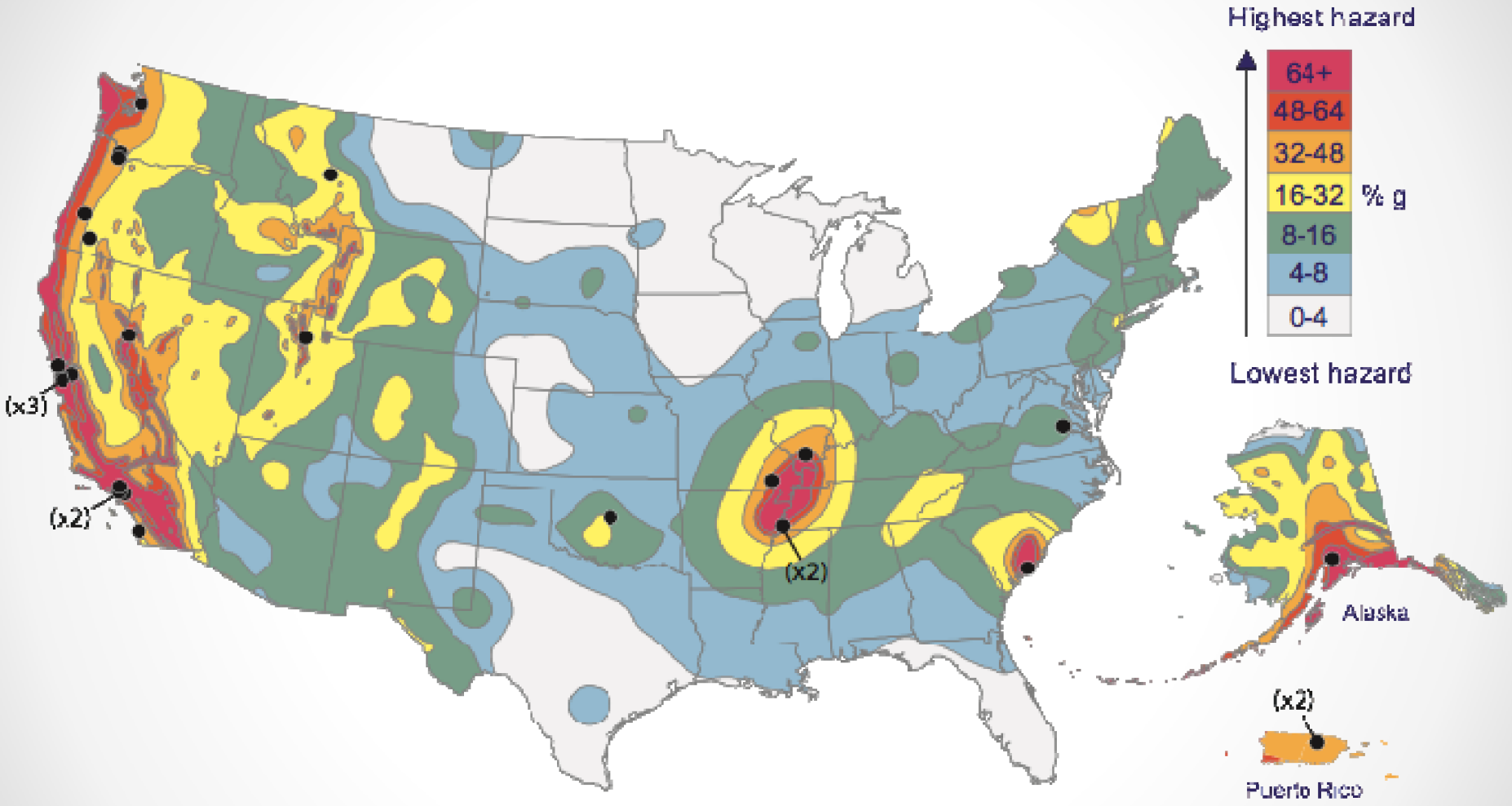
HOSPITALS

SENSORS


Side Impact Sensors
Engine Speed Sensor
Throttle Position Sensor
Seat Belt Sensors
Air Bag Control Module
Brake Switch Sensor
Vehicle Speed Sensor
Front Impact Sensors


Disaster resilient structures
Smart Civil Infrastructure Systems
Advanced multi-functional material technologies
Structural health monitoring

PROJECT HIGHLIGHTS

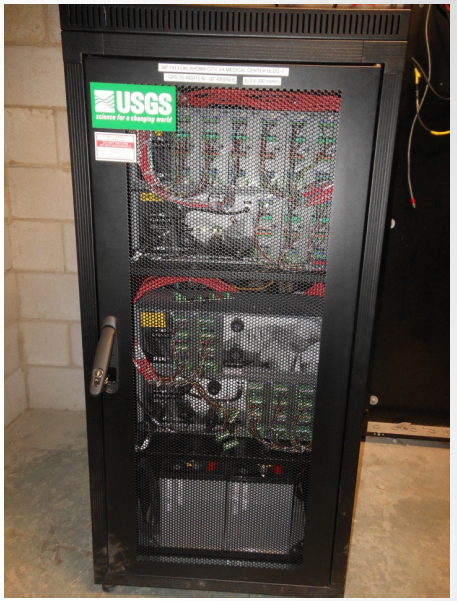


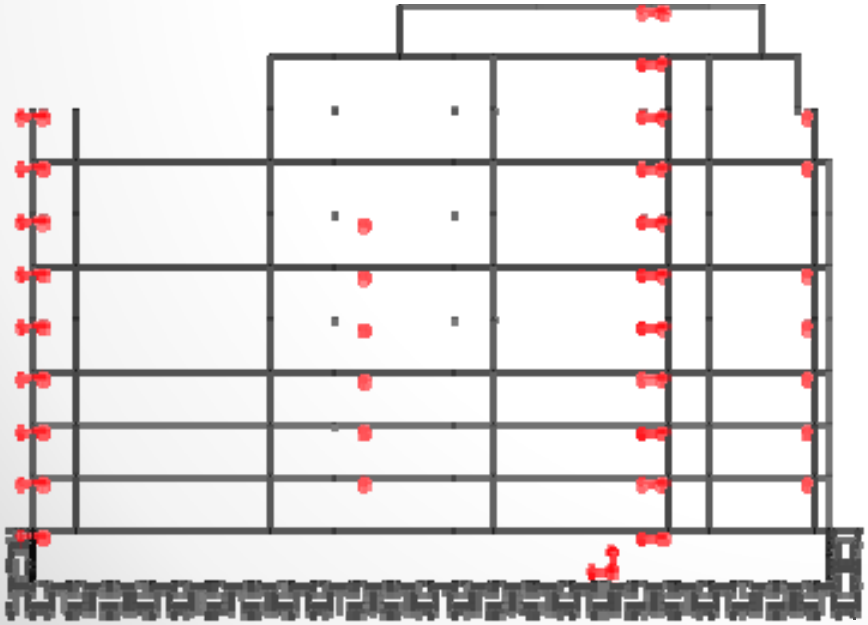
28 hospitals in seismic regions including western U.S., New Madrid Zone, Charleston, Alaska and Puerto Rico have been instrumented.

INSTRUMENTATION

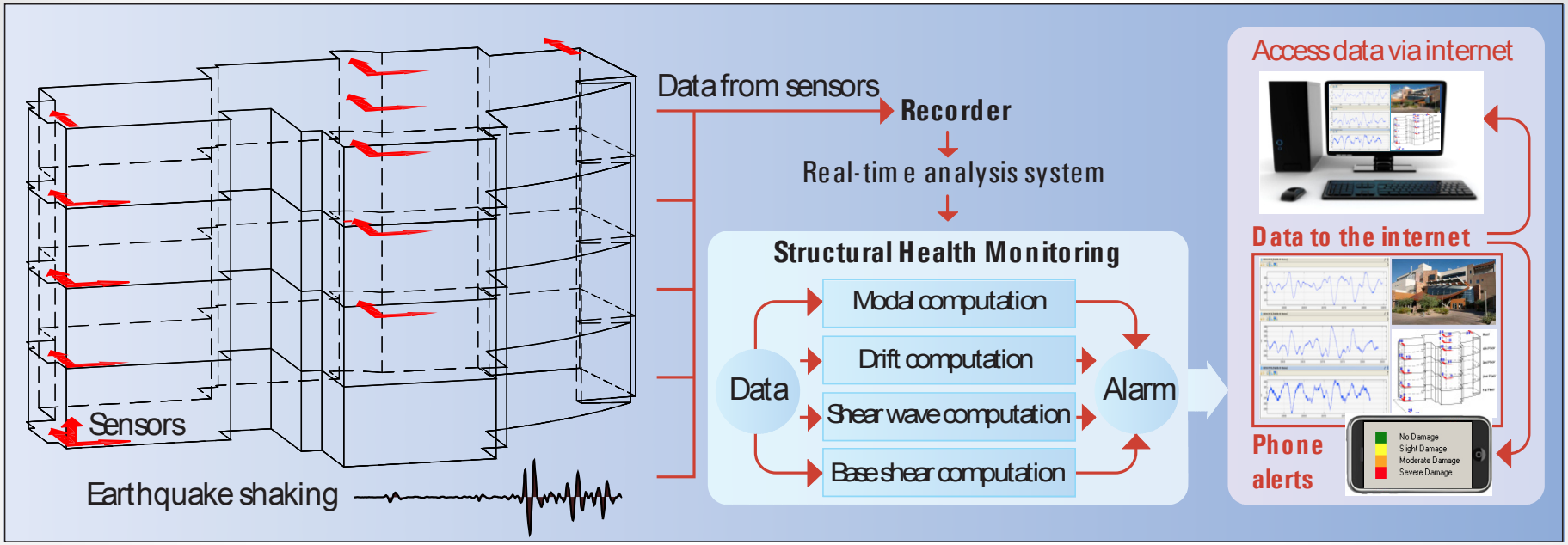
- At least three sensors at every floor
- 24-bit IP-based multi-channel recorder
- Dedicated free-field station
- Timing via GPS
- Telemetry via GSM or DSL
- On site computer running OpenSHM (in progress)

RECENT INSTRUMENTATION



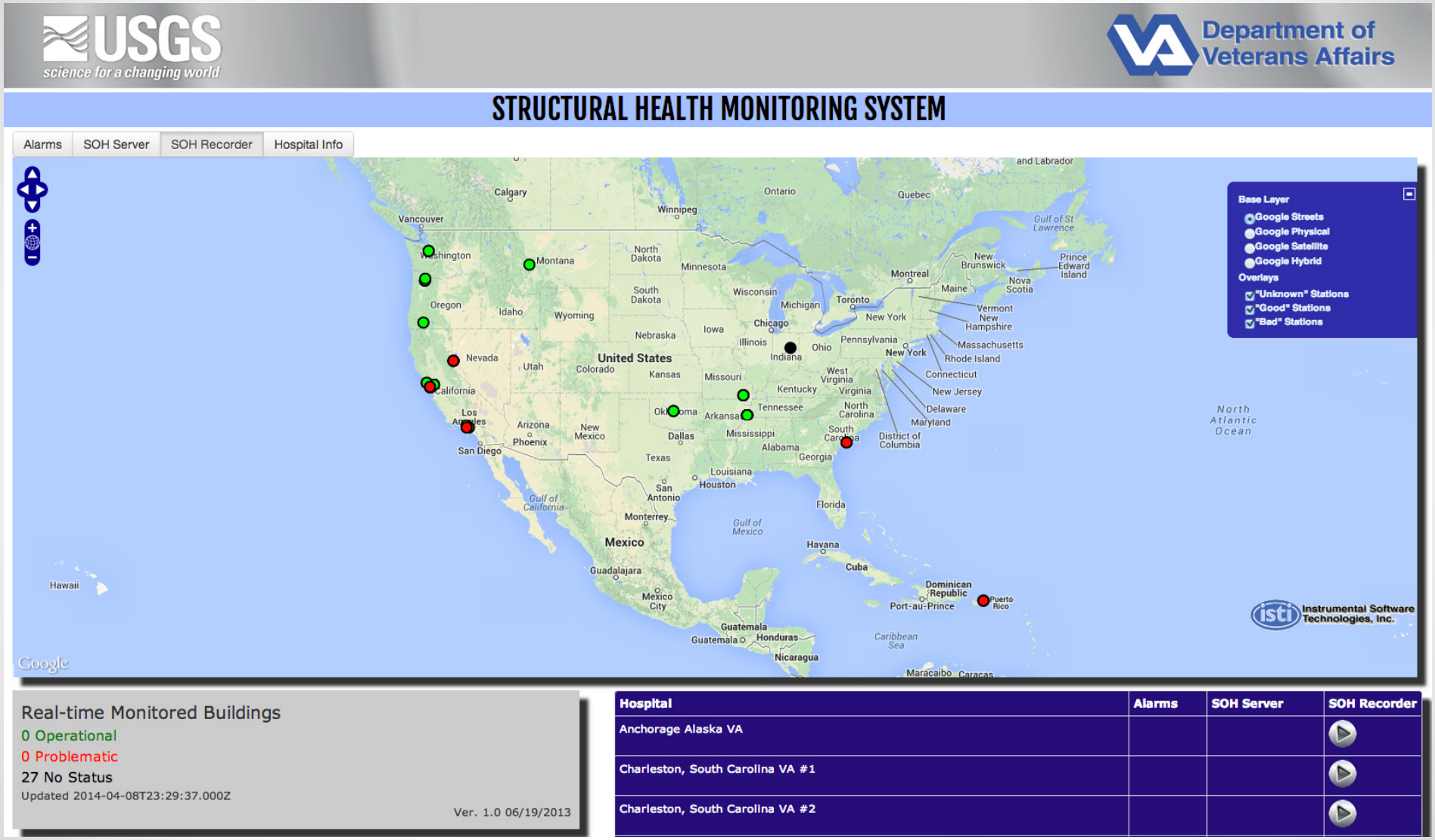


HOW OpenSHM WORKS



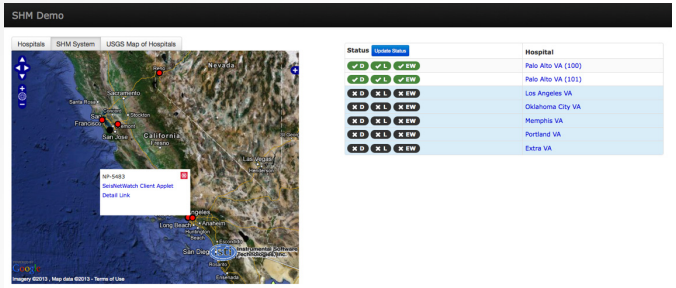
- Open source platform structured on “Earthworm” (Johnson et al. 1995), which is an open source waveform and automated earthquake data processing software,
- Real-time data visualization,
- Operates locally, and remotely monitored via web interface

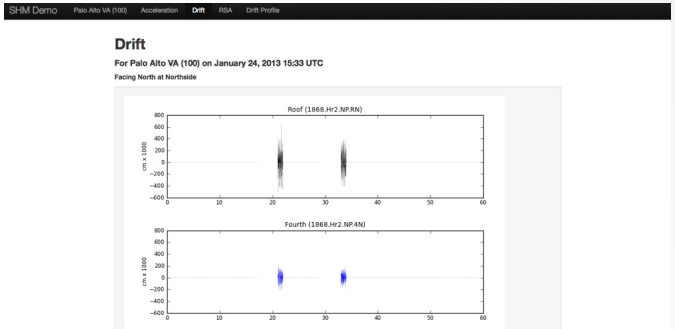
WEB-BASED MONITORING SYSTEM

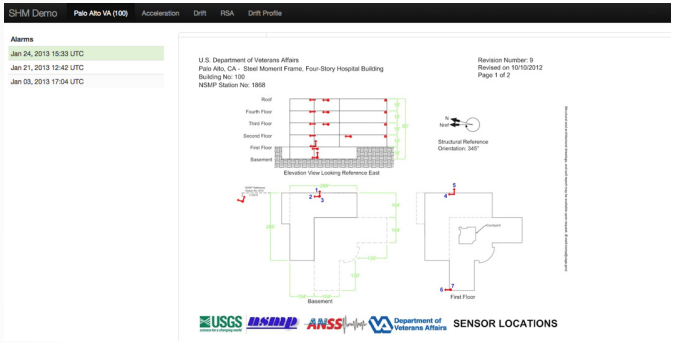


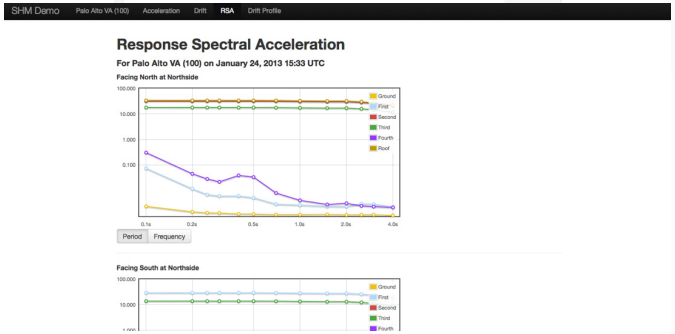
TABS: ALARMS, SOH SERVER, SOH RECORDER, HOSPITAL INFO

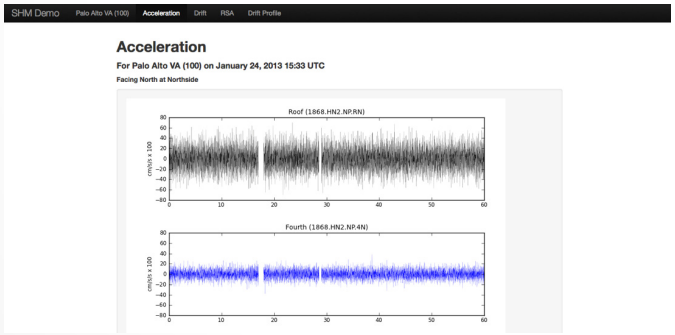
HEALTH MONITORING & DIAGNOSIS

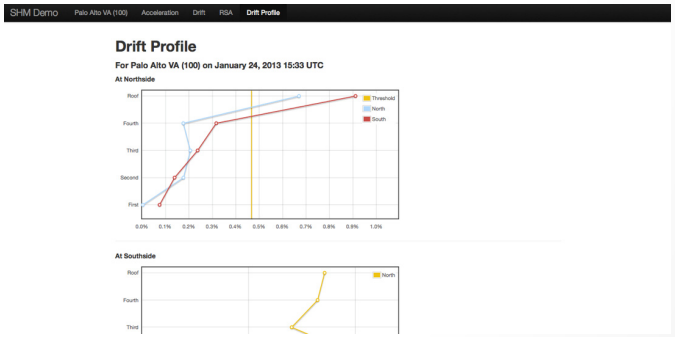






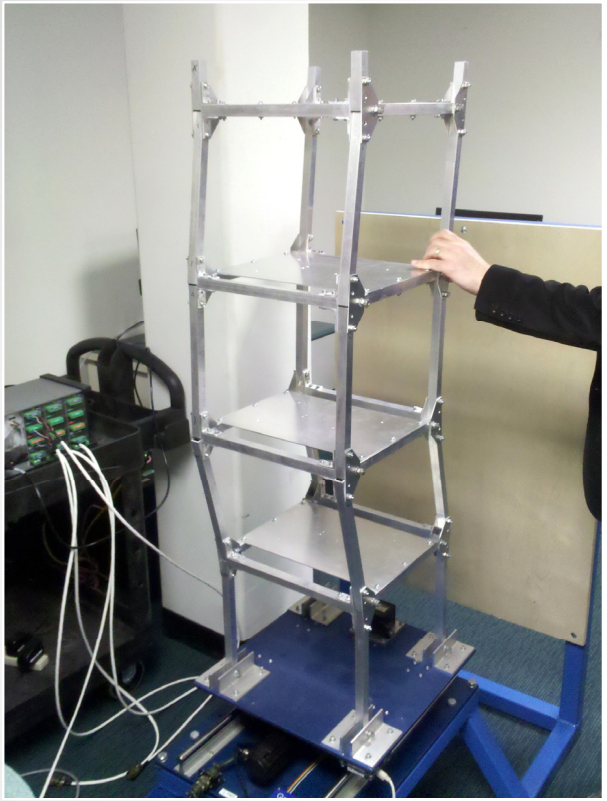






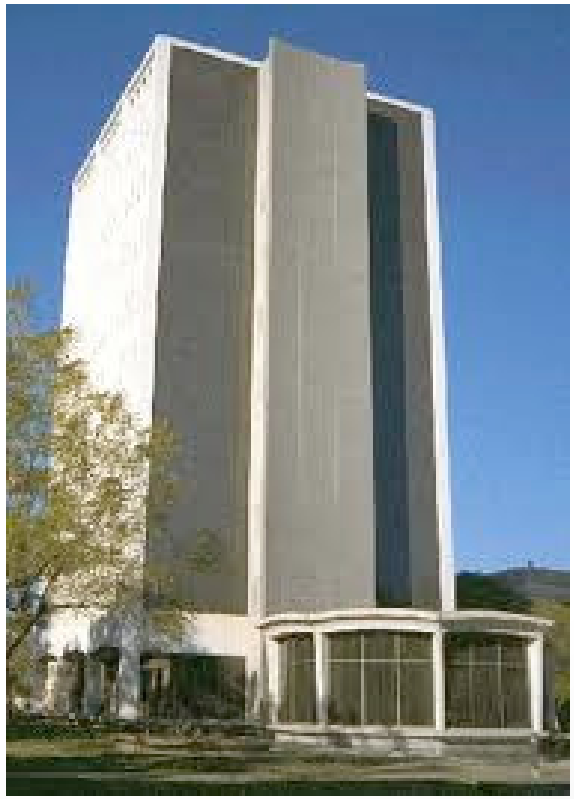
- System health status (both recorder, EW system and Linux server) is monitored near real-time using a web interface
- Alarm conditions can be checked immediately after an event
- Demand parameters (acceleration, response spectra, drift) can be investigated

VALIDATION AND VERIFICATION



Small-scale 4-story structure was constructed and set on a uni-directional shake-table for initial testing of data flow and integration algorithm.

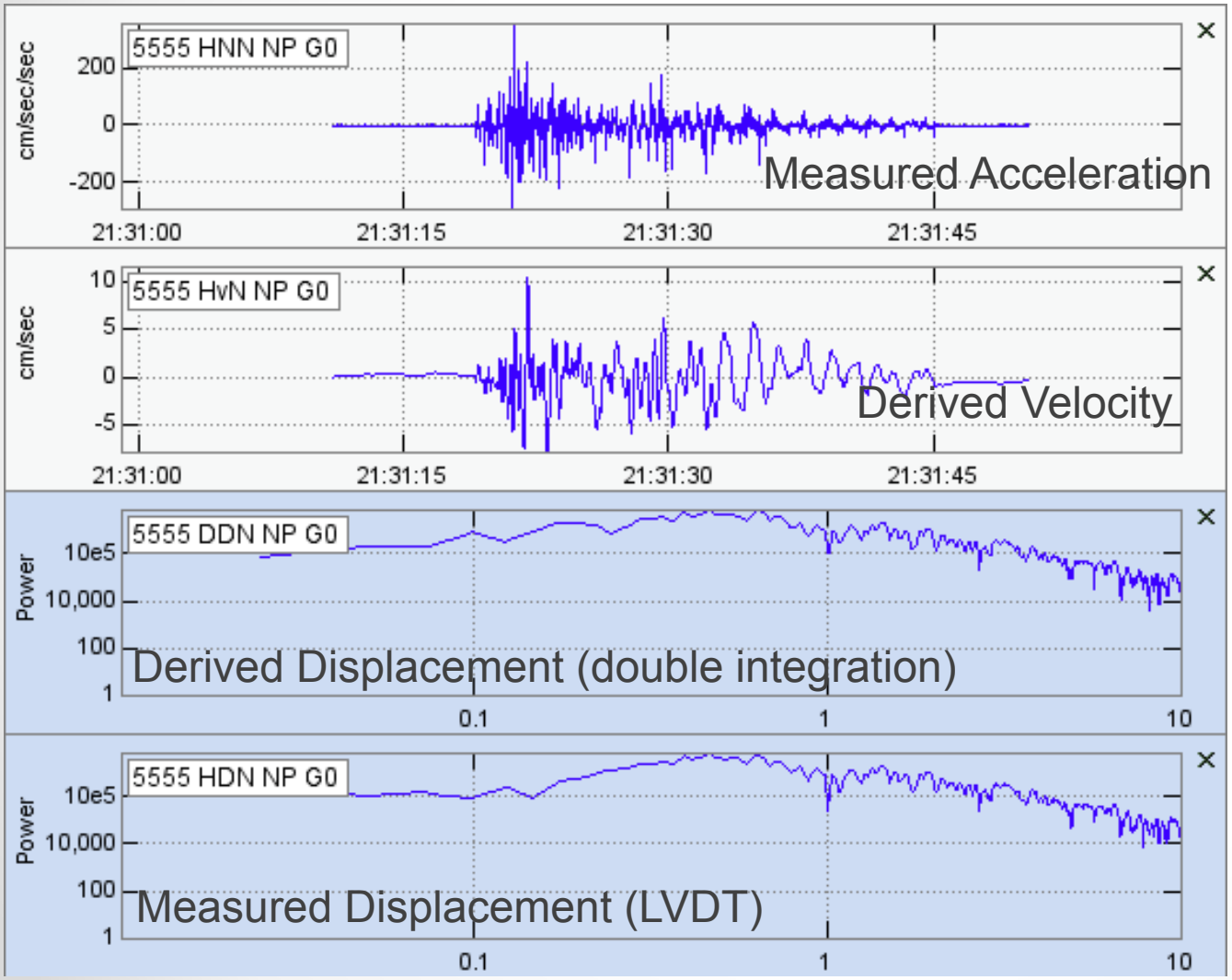
Initial validation and verification of the modal analysis module of the OpenSHM is performed by using low amplitude earthquake data recorded at 9-story RC structure at Caltech.

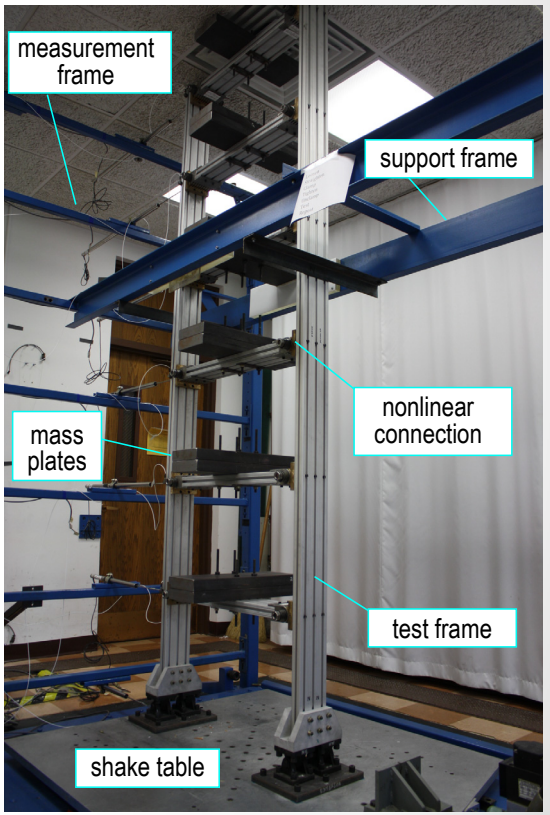


Instrumentation

- 36 accelerometers
- 2 rotational sensors

Notre Dame Shake Table playback in Earthworm





Our research on damage detection and localization is based on data from shake table tests of 7-story full scale RC structure at UCSD – NEES Lab.

Instrumentation

- 139 accelerometers
- 88 displacement sensors
- 314 strain gages

Shaking Procedure

- Four earthquake excitations for progressive damage

- White-Noise and ambient measurements between earthquakes

OUTREACH

Project website offers updates and and interactive map showing location of instrumented hospitals, their photos and sensor layouts

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EARTHQUAKES HAZARDS LEARN PREPARE MONITORING RESEARCH

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- Volunteer Monitoring
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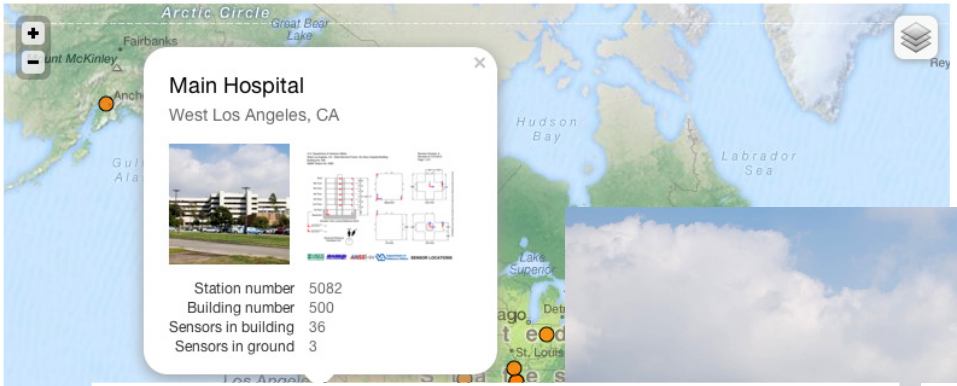
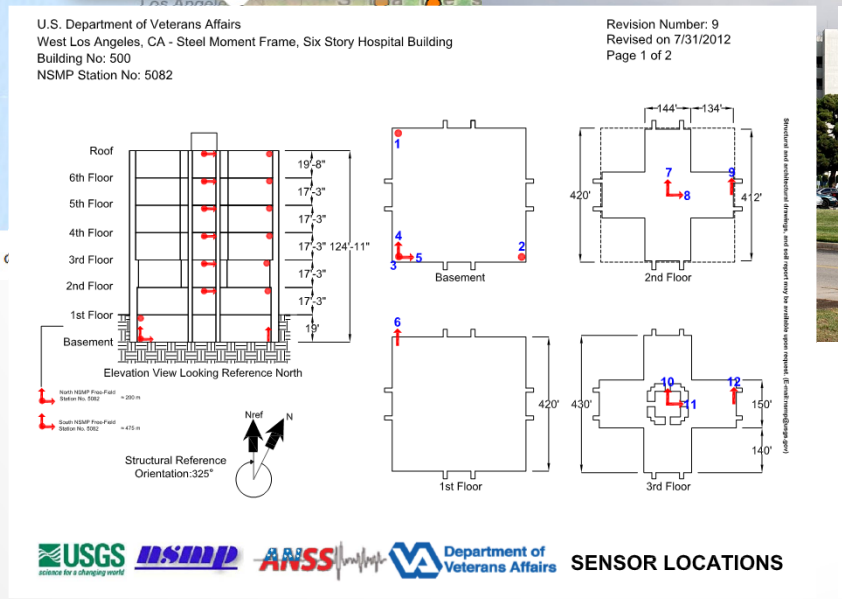
- Network Operations
- Seismogram Displays
- Buildings
- National Strong Motion Project
- Crustal Deformation Monitoring
- Data

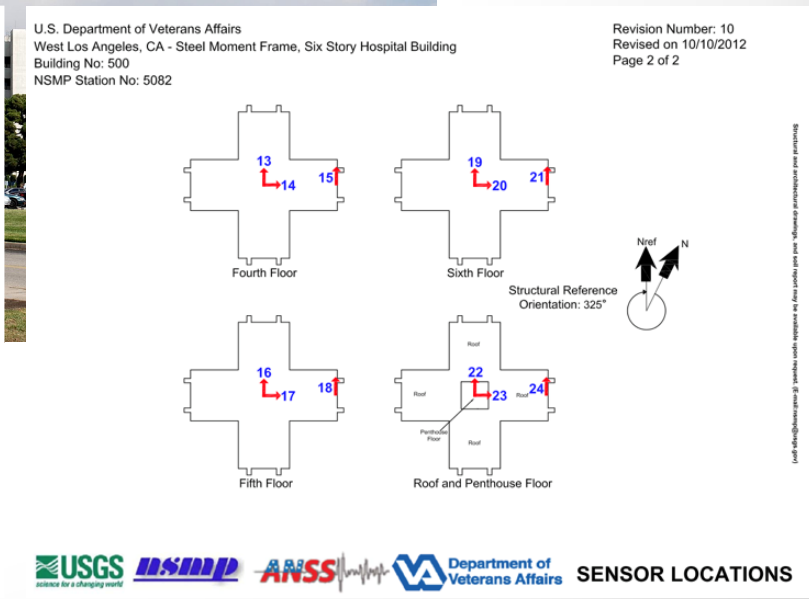
Structural Health Monitoring of Veterans Affairs' Hospital Buildings

In collaboration with the U.S. Department of Veterans Affairs (VA), the National Strong Motion Project of the U.S. Geological Survey has been installing sophisticated seismic systems that will monitor the structural integrity of 29 VA hospital buildings located in conterminous United States, Alaska and Puerto Rico during earthquake shaking. These monitoring systems, which combine sensitive accelerometers and real-time computer calculations, are capable of determining the structural health of each instrumented structure rapidly after an event, helping to ensure the safety of patients and staff.



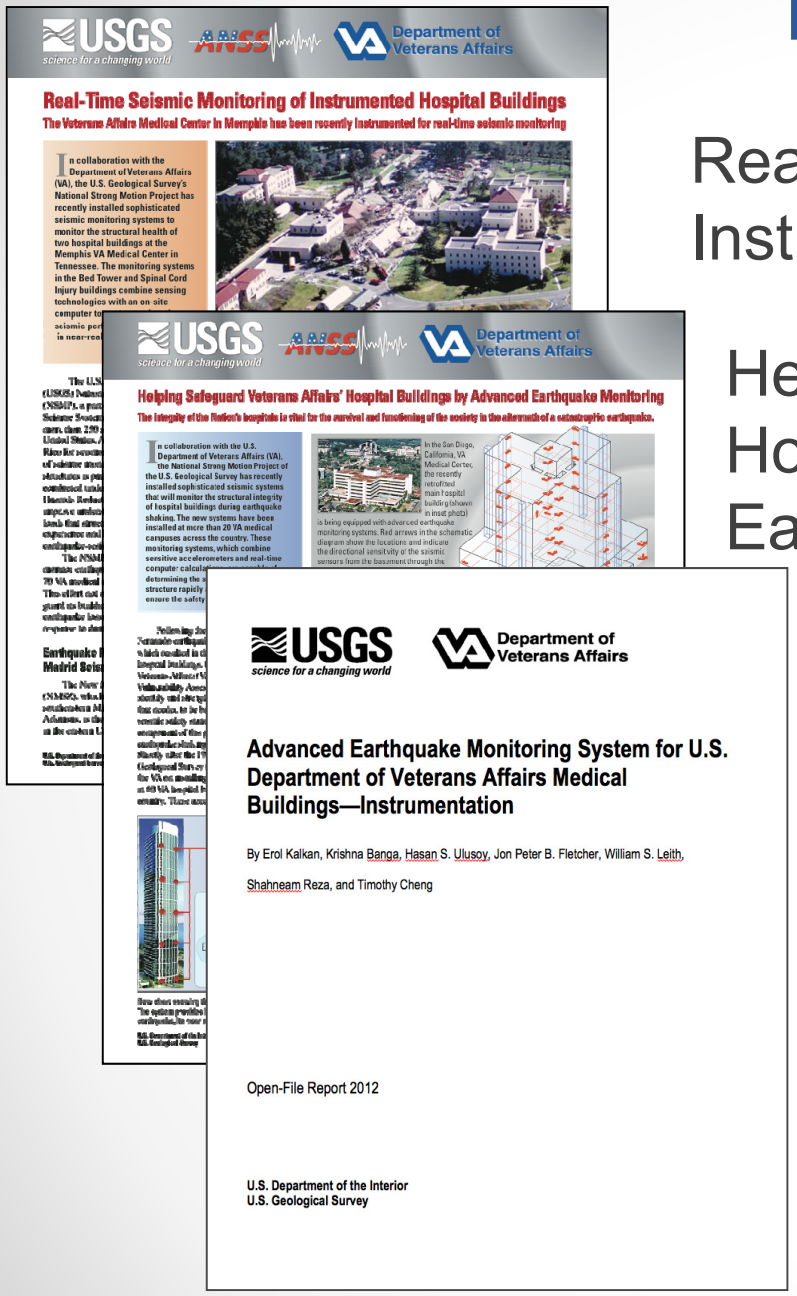
Click on an





http://earthquake.usgs.gov/monitoring/buildings/

DOCUMENTATION



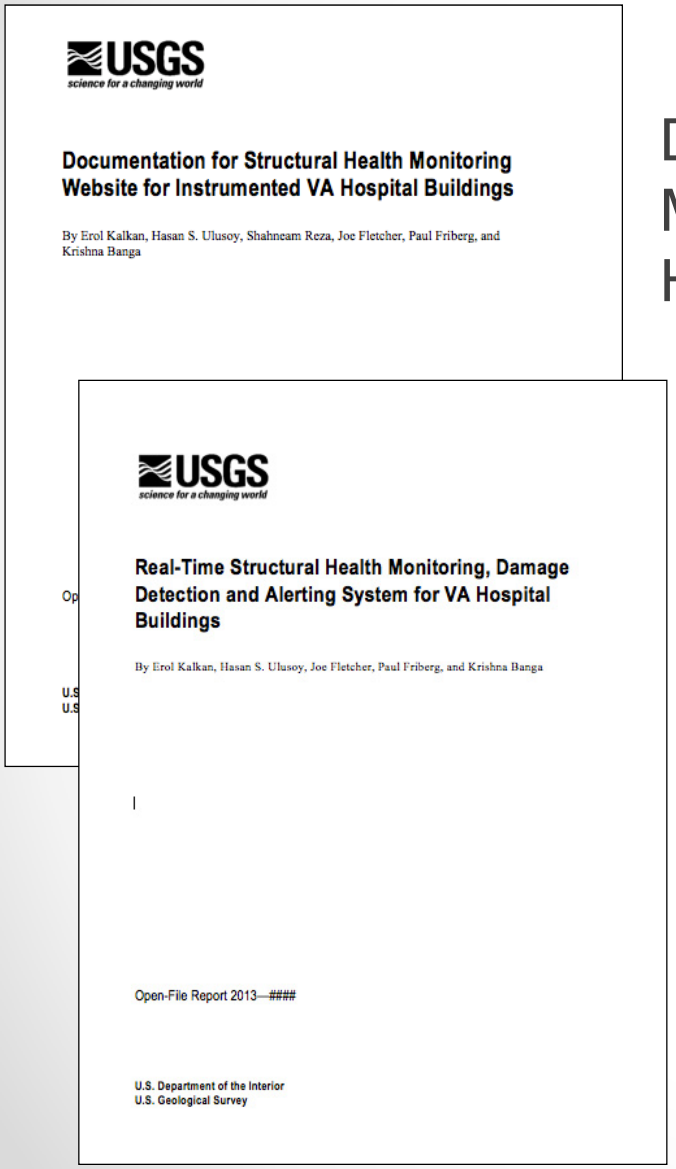
Real-Time Seismic Monitoring of Instrumented Hospital Buildings

Helping Safeguard Veterans Affairs' Hospital Buildings by Advanced Earthquake Monitoring

Advanced Earthquake Monitoring System for U.S. Department of Veterans Affairs Medical Buildings—Instrumentation

http://earthquake.usgs.gov/monitoring/buildings/

UPCOMING DOCUMENTATION



Documentation for Structural Health Monitoring Website for Instrumented VA Hospital Buildings

Real-Time Structural Health Monitoring, Damage Detection System for VA Hospital Buildings

Thank you…