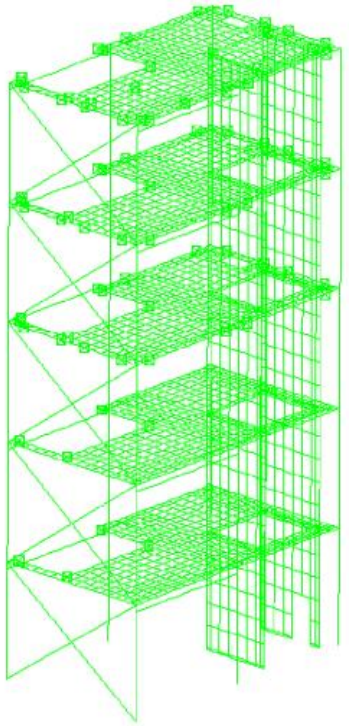
# Near-Real-Time Structural Health Monitoring with Multiple Sensors in a Cloud Environment (Leveraging NASA and NSF projects)




**Yehuda Bock[1], Michael Todd[2], Falko Kuester[2], Dara Goldberg[1], Eric Lo[2], Richard Maher[3]**

**[1]Scripps Institution of Oceanography**

**[2]Qualcomm Institute, UCSD**

**[3]KDM Meridian**



**IN22B Near Real Time/Low Latency Data for Earth Science and Space Weather Applications**

**2017 Fall AGU Meeting**

**December 12, 2017**

**New Orleans**

# Saving Lives Through Long-Term Structural Health Monitoring (SHM)

Collapse of the 5-story CTV building in Christchurch, New Zealand

(Photos: New Zealand Herald http://www.nzherald.co.nz)

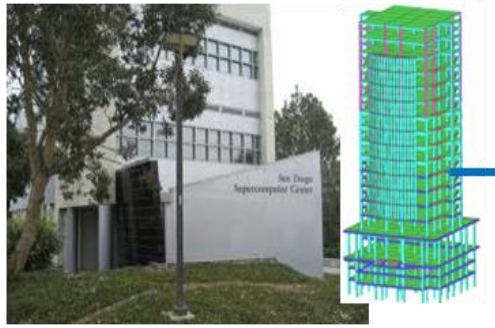
115 people died on February 21, 2011 during the Mw6.2 Christchurch earthquake. Most experts agree that the CTV building suffered significant damage during the September 3, 2010 Mw7.2 Canterbury earthquake.

If SHM had been in place any cumulative damage would have been monitored and loss of life may have been averted.

# Saving Lives Through Near-Real-Time Structural Health Monitoring (SHM)

Building Damaged

Sensor Data
Sent to Data Center



Structural Integrity
Models Run

Structural Integrity
Data Delivered

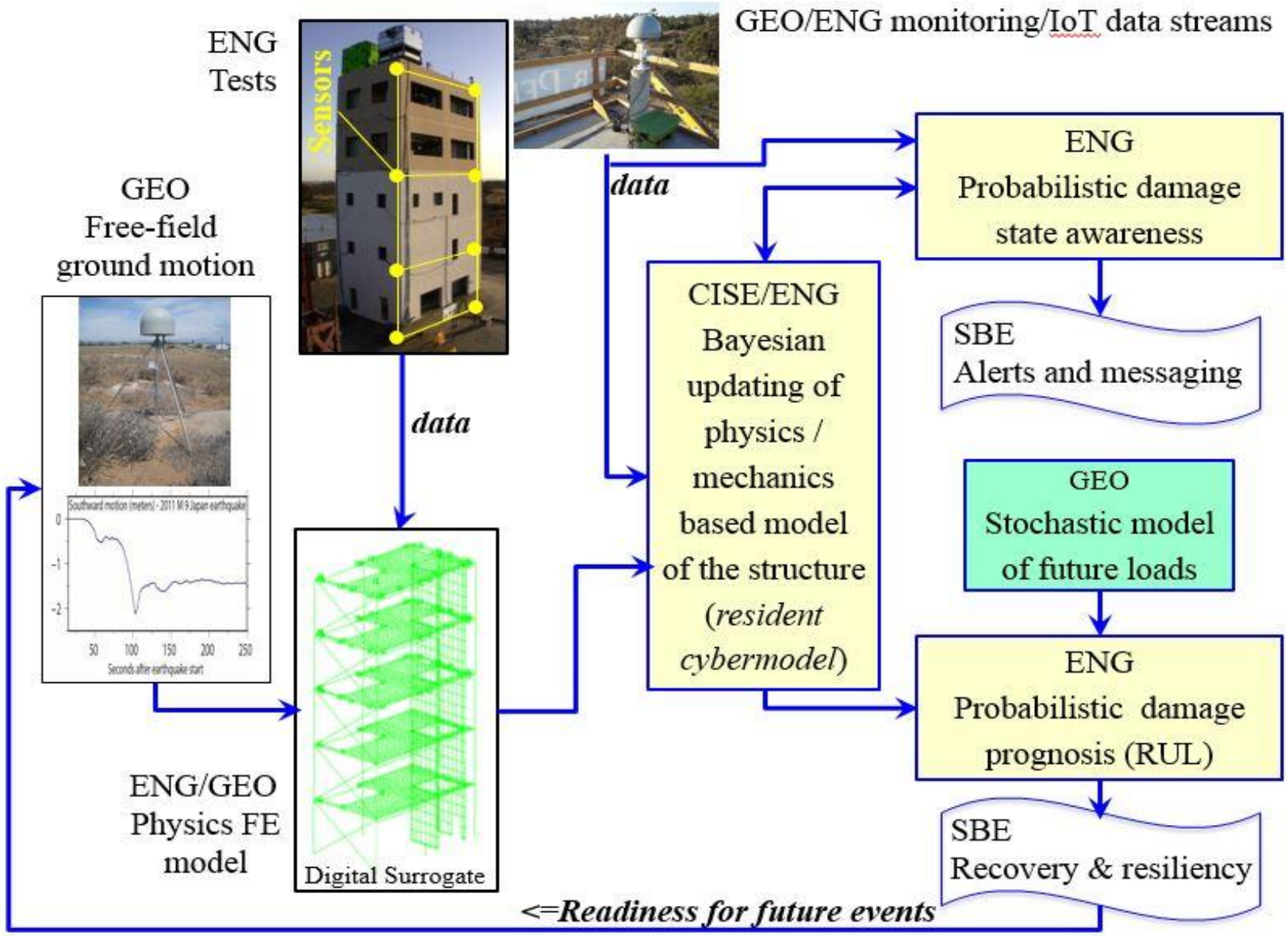
Battalion Chief
Tasks Rescue Team

Rescue Team Deploys

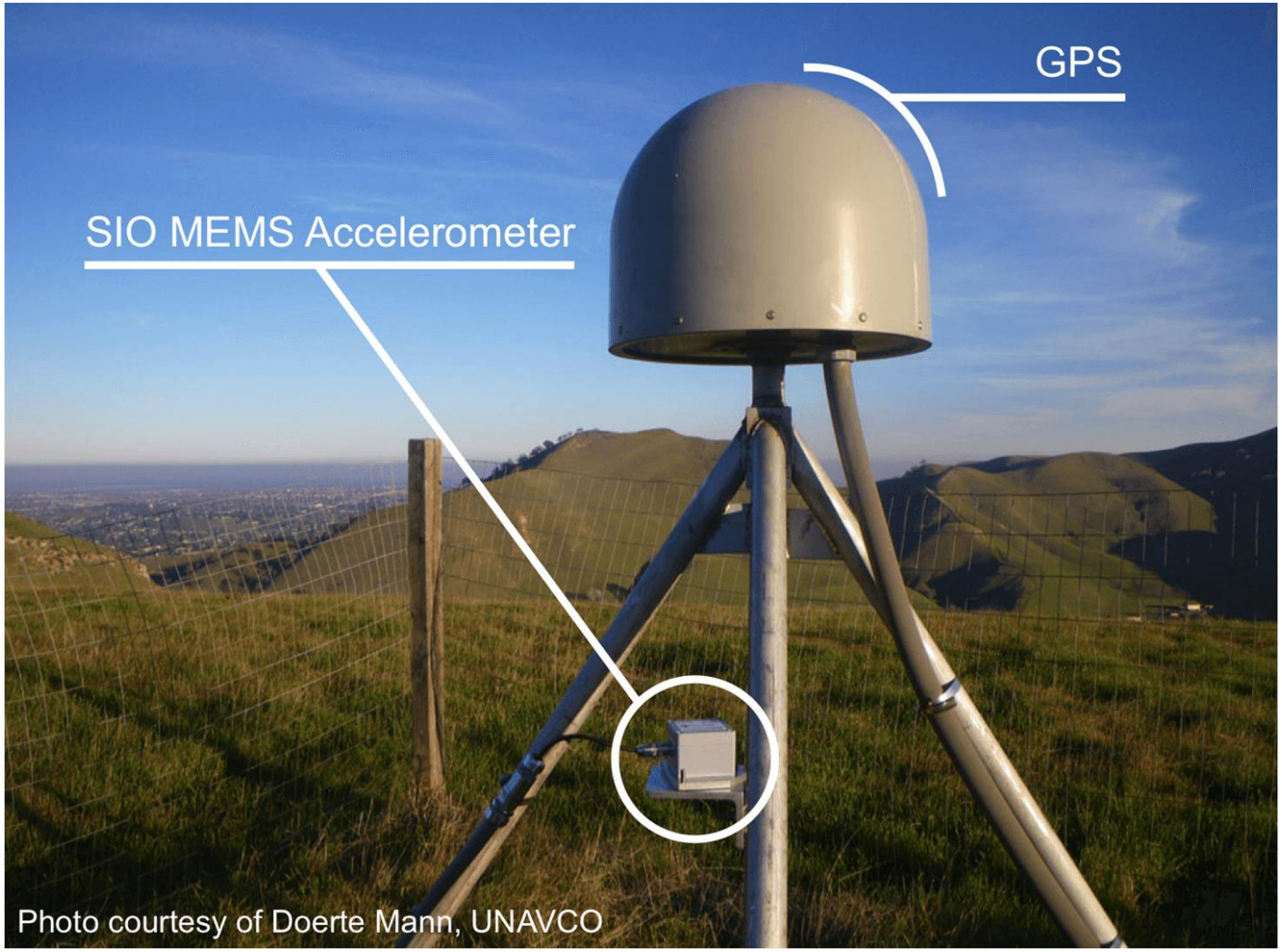
Victims Extracted
Via Safe Route

Safe Rescue
Accomplished

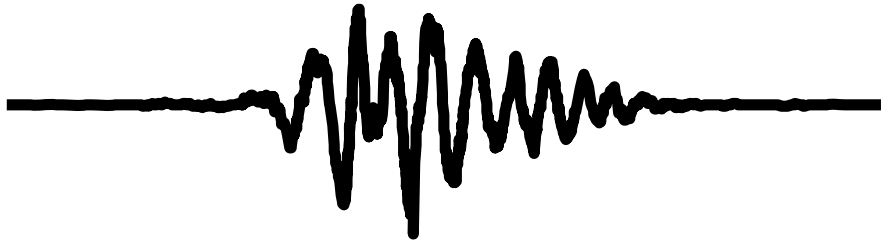
# Creation of a Resident Cybermodel for SHM Analysis



# Development of Seismogeodetic Instruments for Earthquake & Tsunami Monitoring (NASA/AIST and NSF IF/Earthscope Projects)

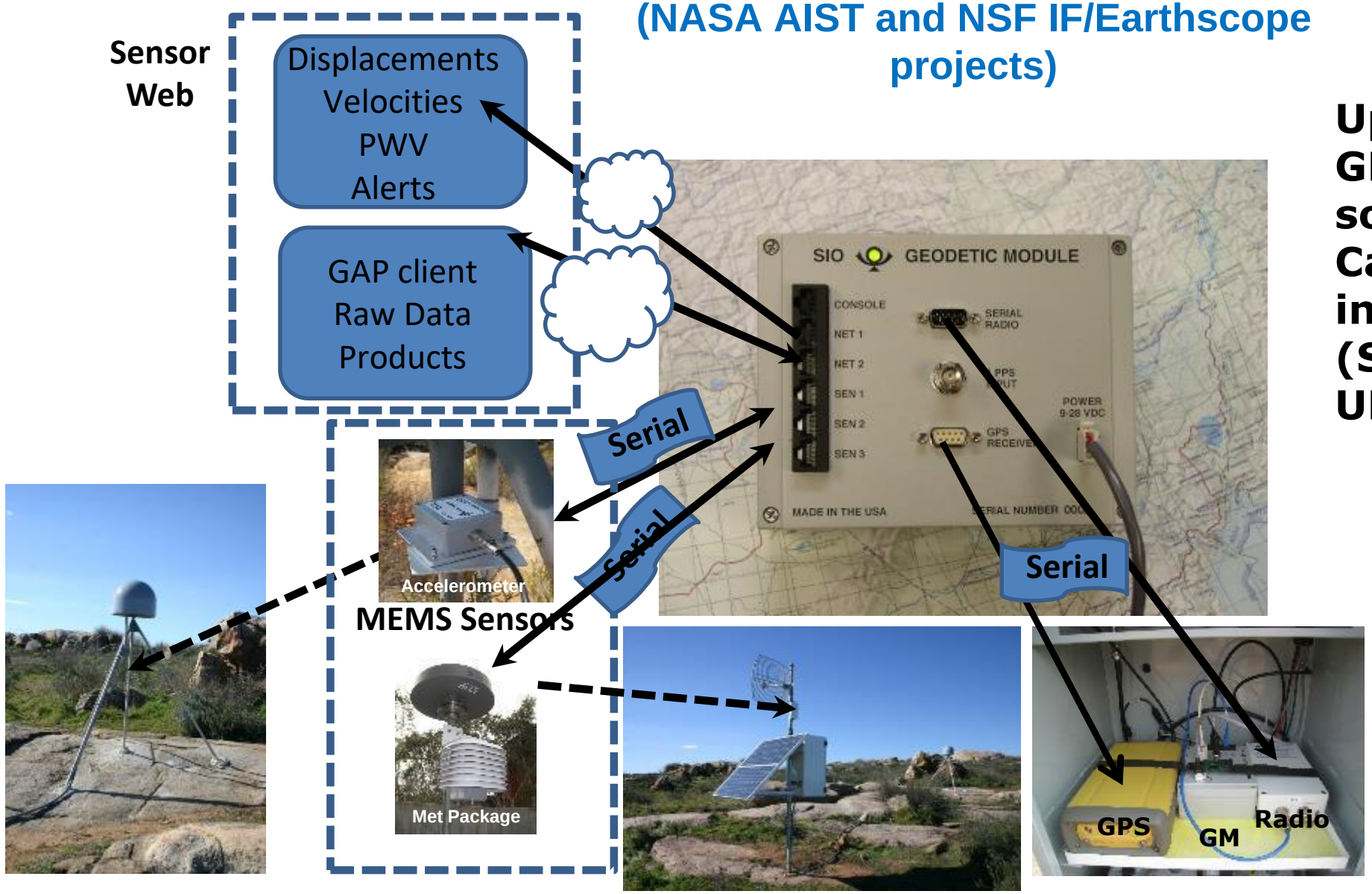



Seismogeodetic velocities, v(t)



Seismogeodetic displacements, x(t)

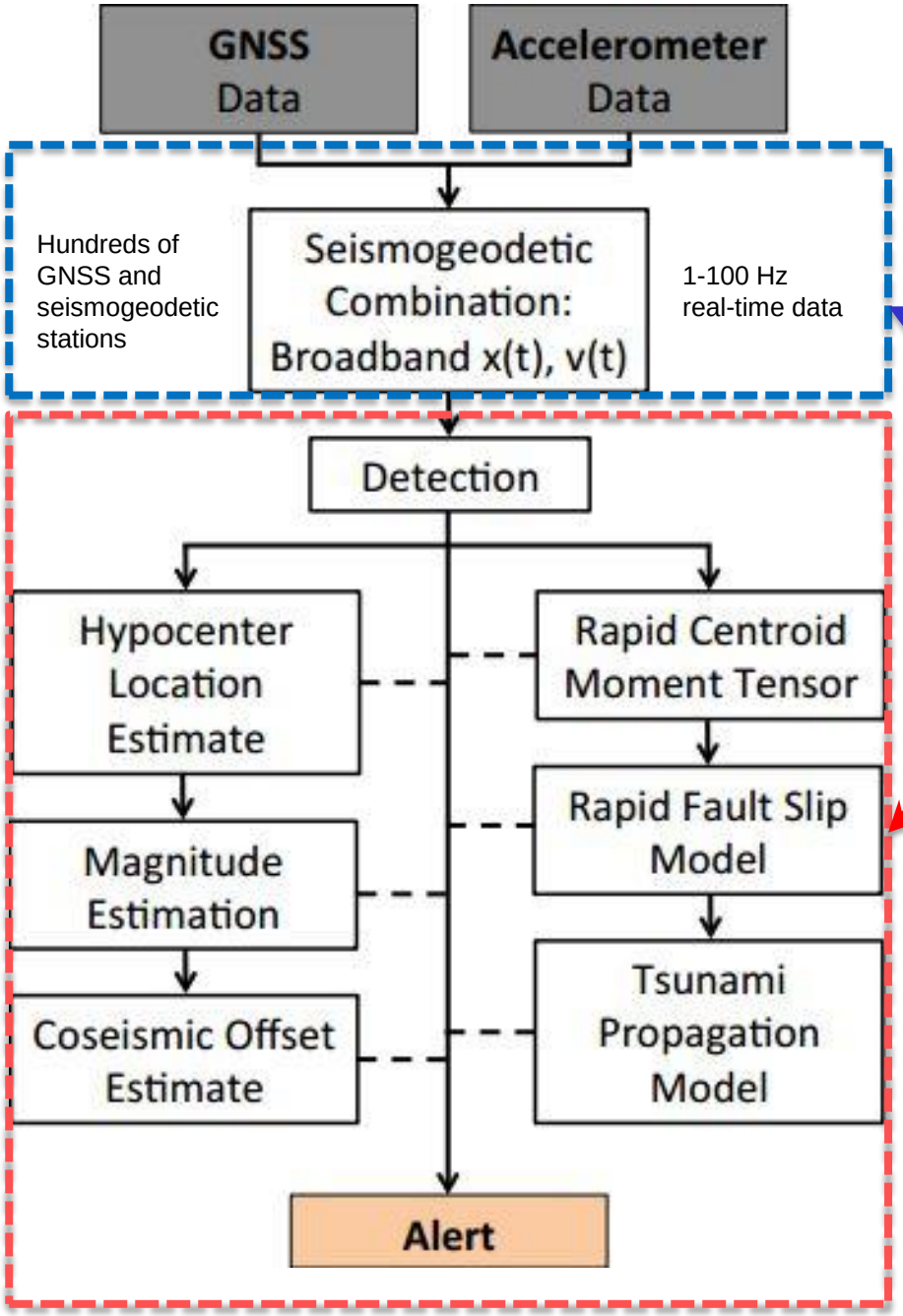
# GAP at GNSS Station (NASA AIST and NSF IF/Earthscope projects)




**Upgraded 15 GNSS stations in southern California and 10 in the Bay Area (SOPAC & UNAVCO)**

GAP – SIO Geodetic Module & MEMS Accelerometer

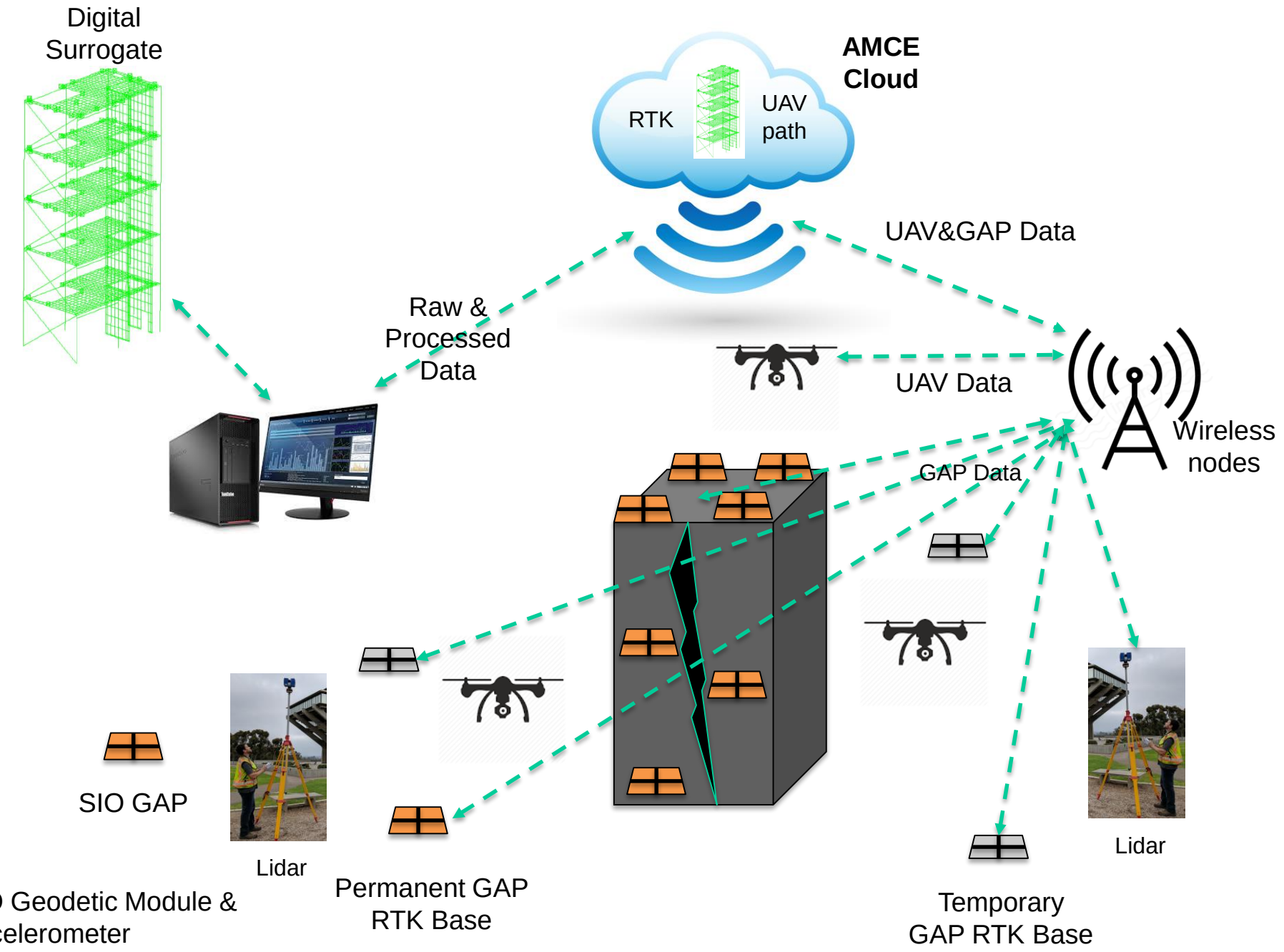
# Elements of near-real-time seismogeodetic earthquake and local tsunami warning system – Migrate from server to Cloud environment (NASA AIST and NASA/NOAA Local Tsunami Warning Disasters Project)





AIST Managed Cloud Environment (AMCE)
Amazon Web Services (AWS)

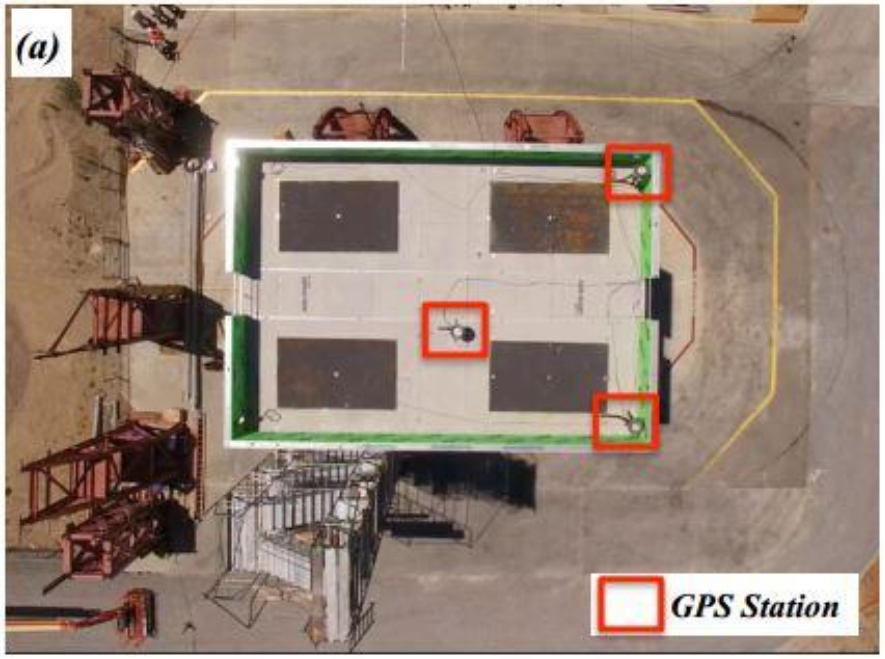
# Multi-Sensor Near Real Time Structural Monitoring




- Create baseline digital surrogate using all sensors
- GNSS/GAP continuous monitoring
- In emergency, fly UAVs with similar trajectory as baseline survey
- Cloud allows for heavy UAV image processing and emergency response to be controlled from any location

GAP – SIO Geodetic Module & MEMS Accelerometer

# UCSD LHPOST Experiments
# UAV Imaging and Roof GNSS Estimation of Tilt
# (NASA Disasters program)





UAV images of a 6-story wall-braced mid-rise CFS building on UCSD's LHPOST shake table subjected to full-scale earthquake shaking and live thermal (fire) testing

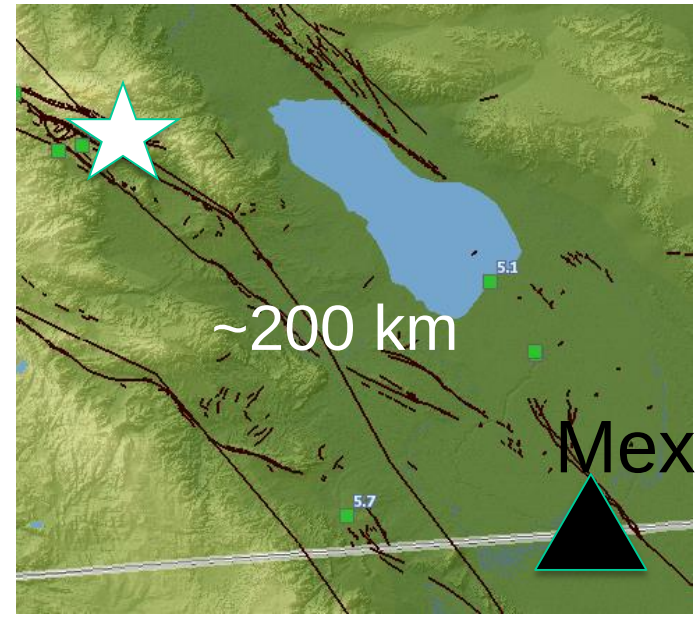
Source: Tara Hutchinson, USCD Structural Engineering Department.

# Mexicali Parking Garage Project:
# Effects of 2016 Mw5.2 Borrego Springs Earthquake
# (NASA Disasters Project)

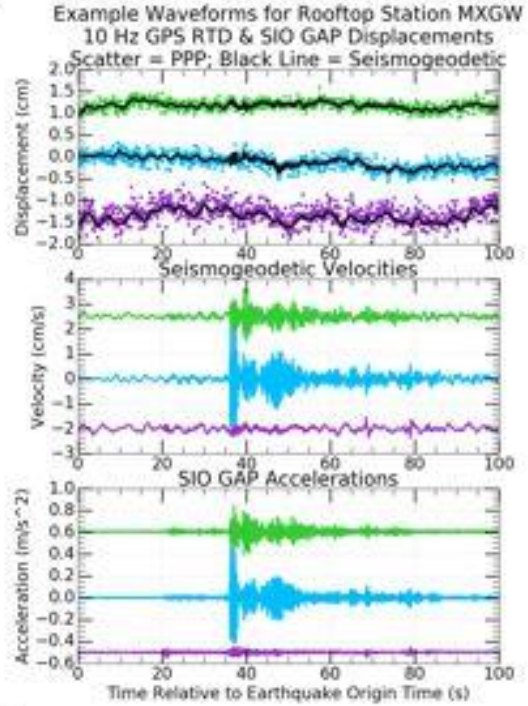
a)


b)

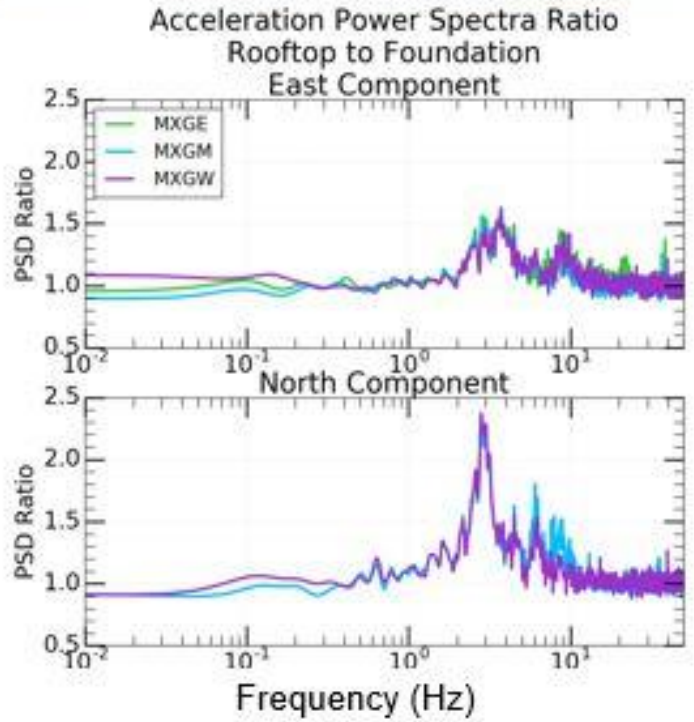
c)




d)



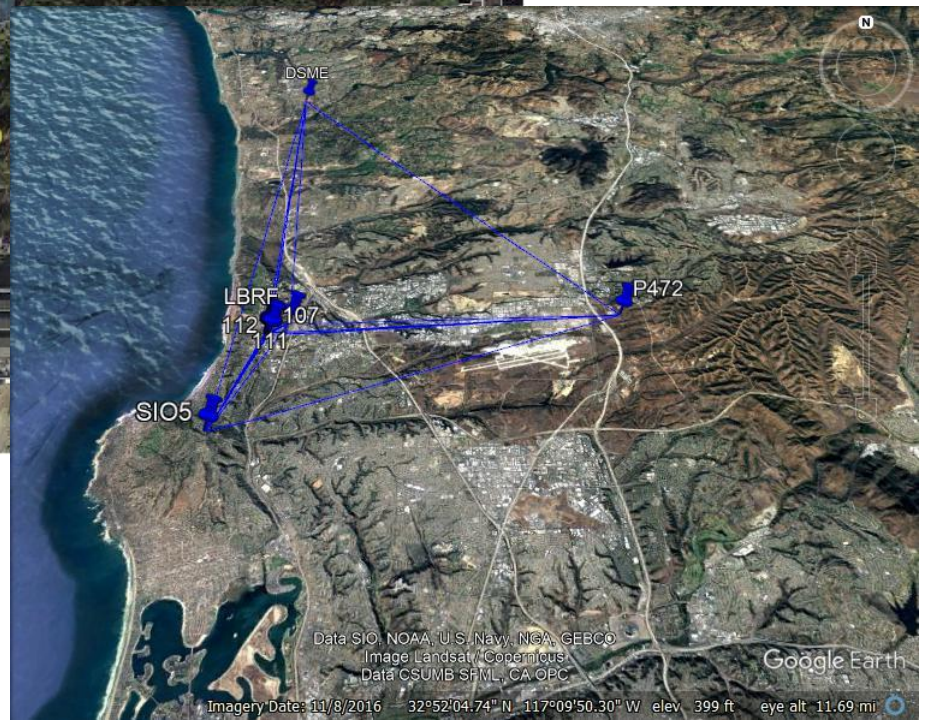

e)



# UCSD Geisel Library Multi-Sensor Baseline Survey July 28, 2017 (NASA Disasters)

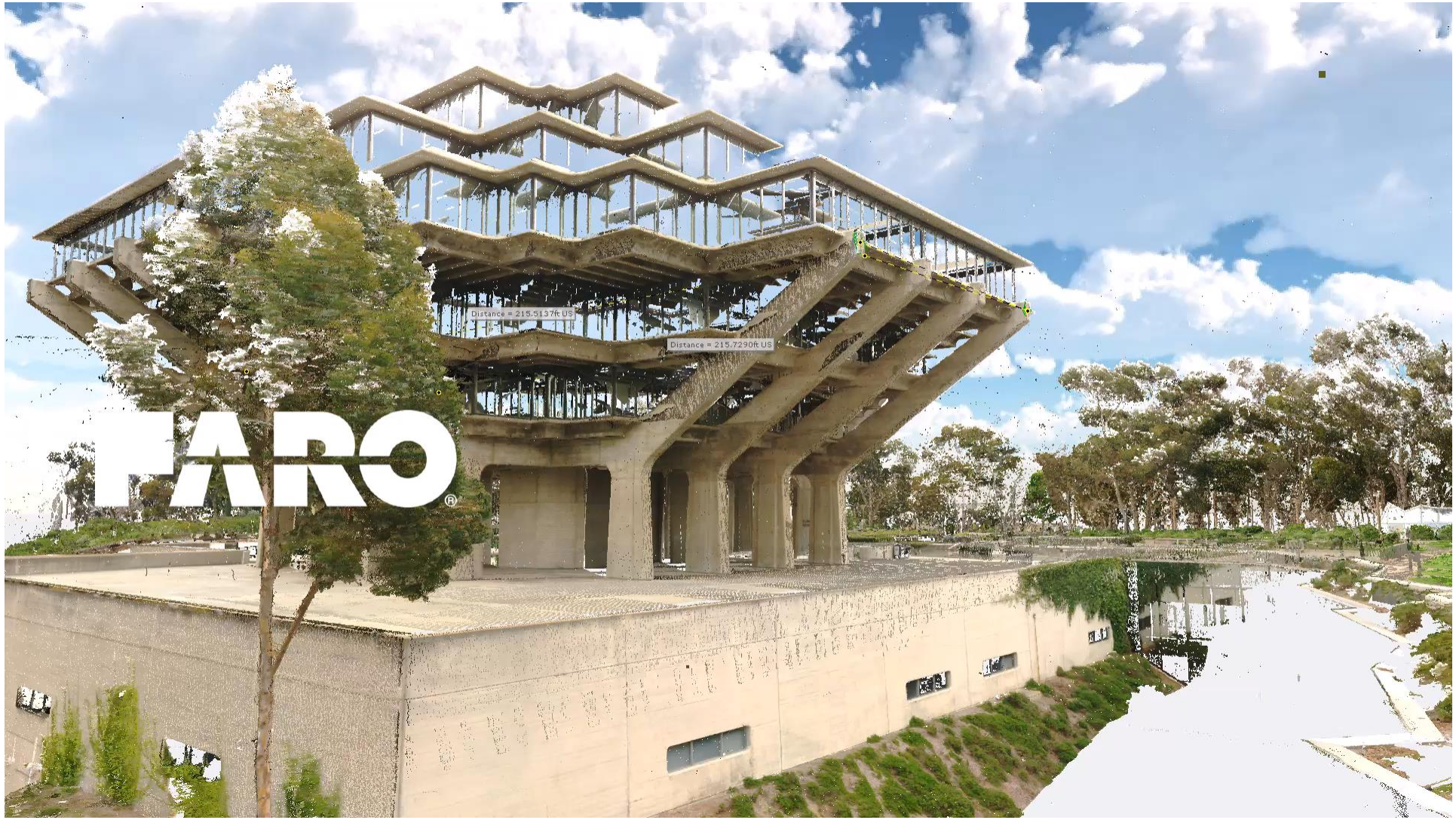
# Geo-Referencing Lidar

## Ground survey: GNSS, total station, differential leveling

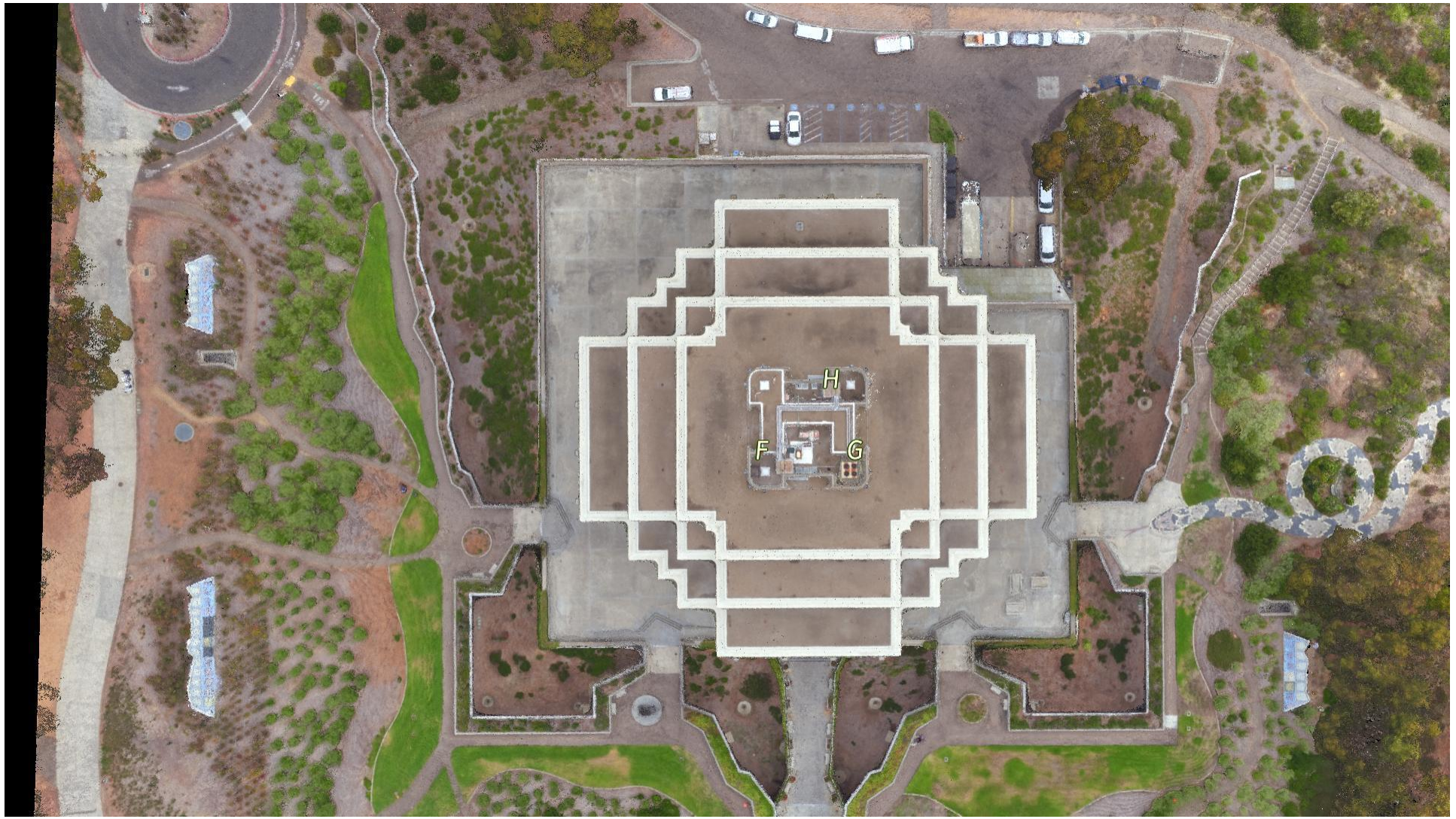




**UCSD Geisel Library Survey**
**July 28, 2017**

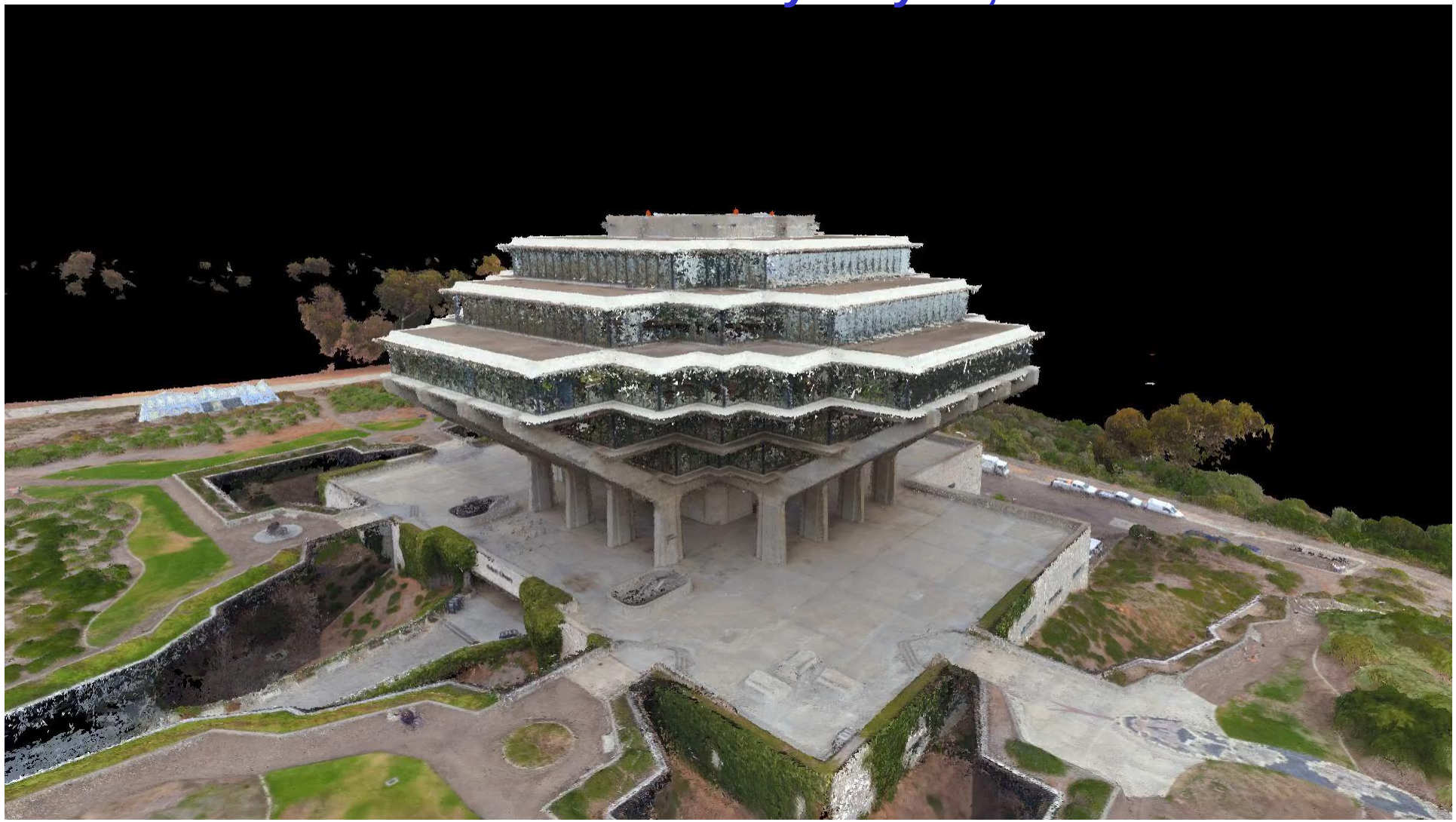
# Lidar Imaging
# UCSD Geisel Library July 28, 2017



# UAV Imaging
# UCSD Geisel Library July 28, 2017

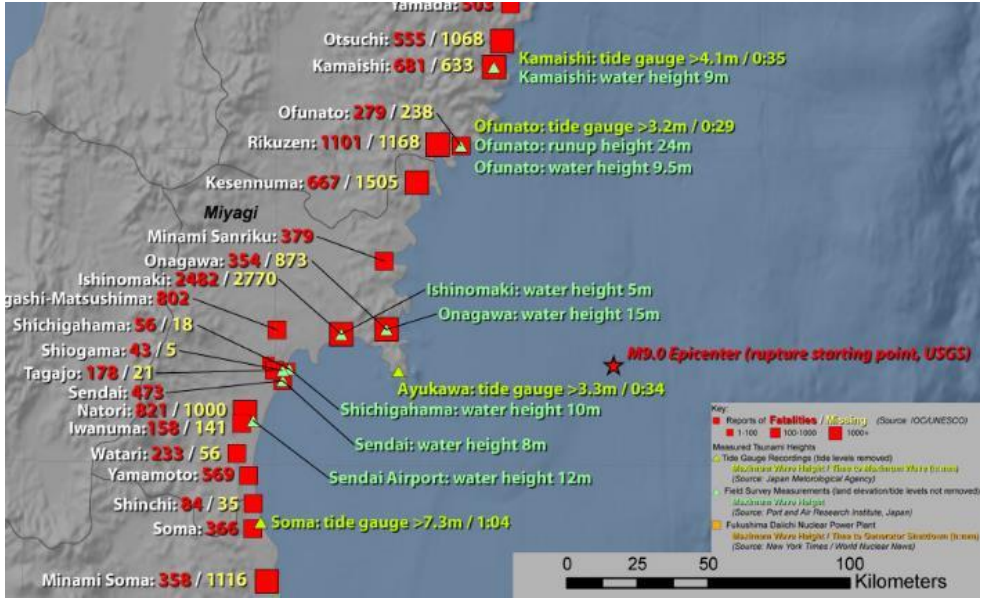


# UAV Imaging
# UCSD Geisel Library July 28, 2017



# Next Steps

- **Produce baseline digital surrogate**
  - **Align UAV with georeferenced Lidar imagery**
  - **Use GNSS positions on roof to assess accuracy**
- **Simulate near-real-time digital surrogate in AMCE**
- **Assess possible upgrade of UAV with geodetic-quality GNSS receiver and inertial sensor**
- **Repeat Geisel survey using AMCE**
- **Assess accuracy compared to baseline survey**
- **Identify target of opportunity with U.S. Army Corps of Engineers – dam, bridge, …**

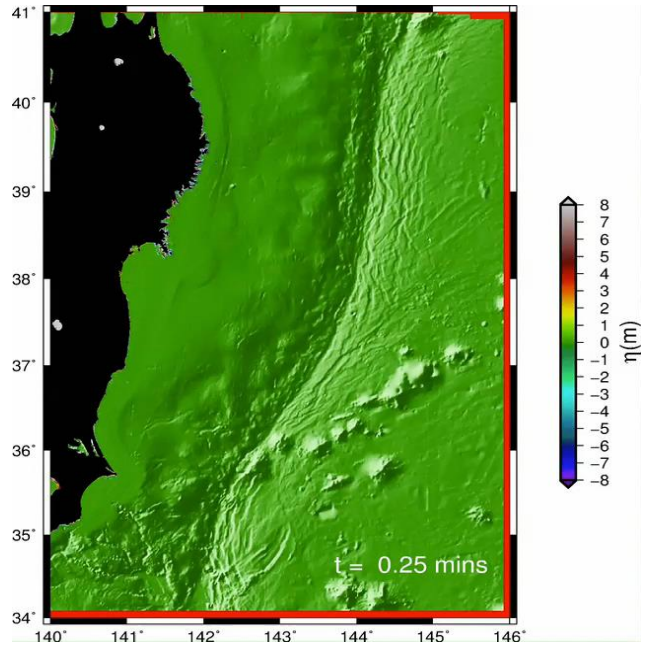



# Rapid Local Tsunami Warning with Complementary Data

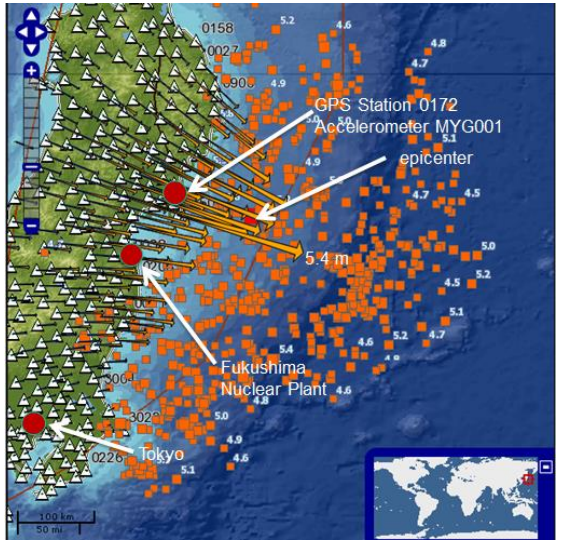
## (NASA ESI and ACCESS projects)

Kinematic GPS

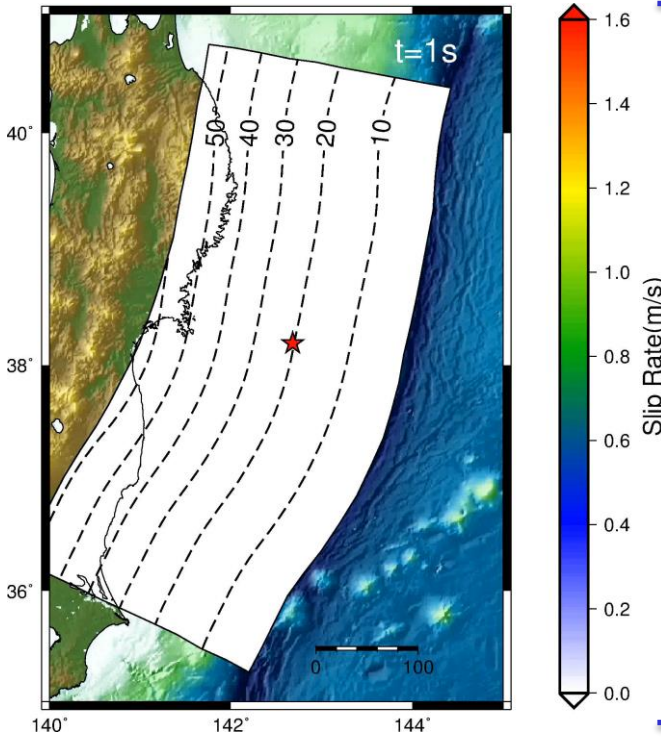
Tsunami Prediction




Seismogeodetic Network

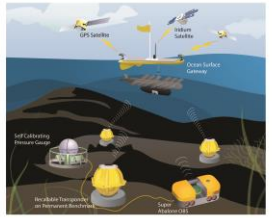



Earthquake Models




Seafloor deformation

Topography Bathymetry



Ocean-bottom sensors

Melgar & Bock, JGR, 2015