Structures and Data Collection

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Nepal RAPID Reconnaissance Team

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- **U. Roma-La Sapienza:** Dr. Rosario Gigliotti, Dr. Marco Faggella
- **U. Nebraska:** Dr. Richard Wood
- **Tufts U.:** Dr. Babak Moaveni

Unique Features of this Effort

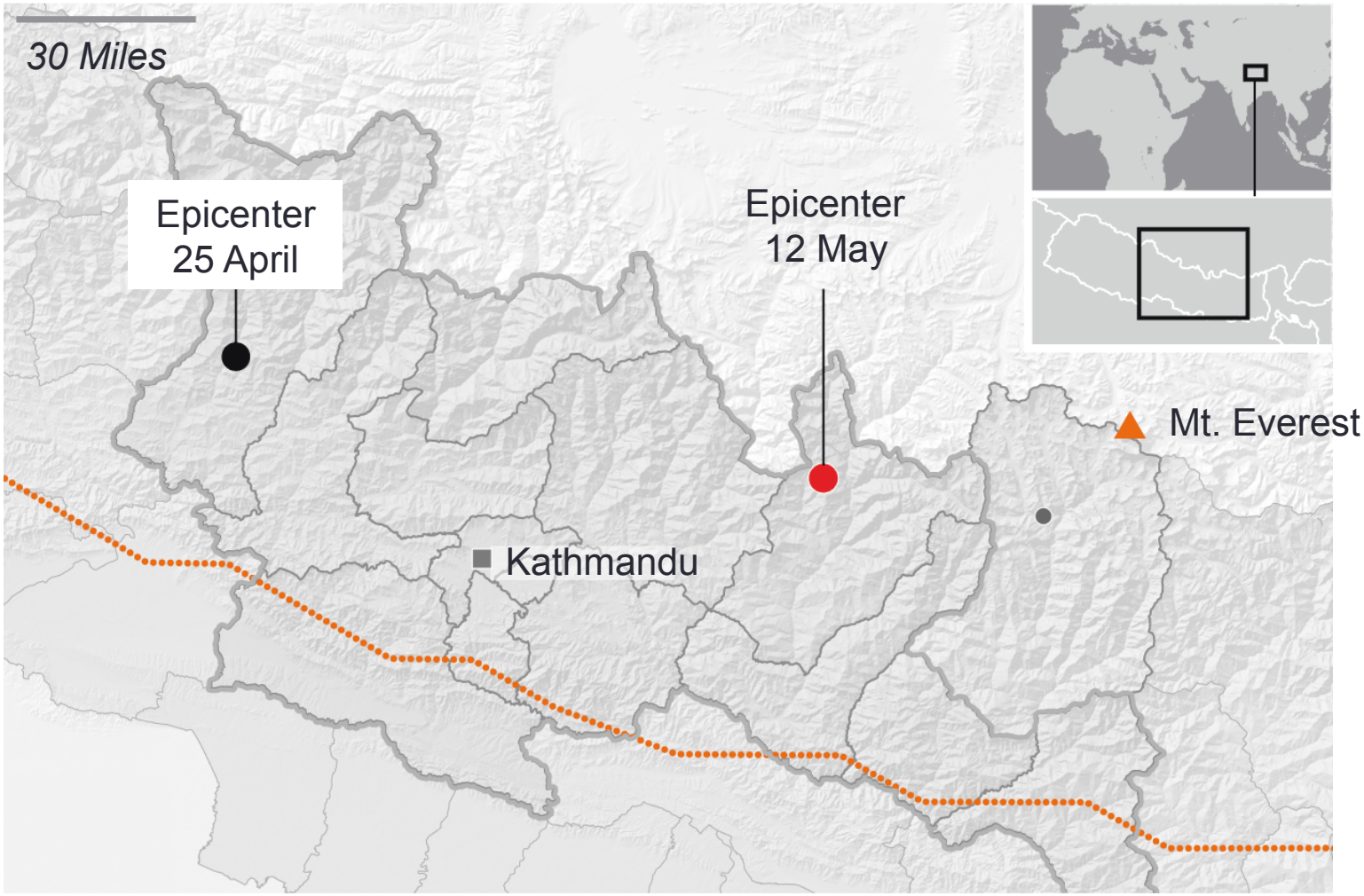
NSF RAPID

1. Survey of RC buildings with masonry infill
2. Quantitative damage measurements obtained using 3D, ground-based lidar (GBL) scans, Structure from Motion (SfM), i.e. 3D reconstructions from 2D photographs, and 360^{o} panoramic camera

Additional work

A. Dynamic system identification of RC infilled buildings
   a) Non-engineered buildings (with and without damage)
   b) Well designed buildings (with and without damage)
   c) Identification of frequency of infill walls (with and without damage)
B. Damage assessment of urban/rural areas using visual damage assessments (rapid and detailed) unmanned aerial systems (UAS)
C. Inform local agencies in Nepal on suggested rebuilding and recovery guidelines.

Geographical Extent



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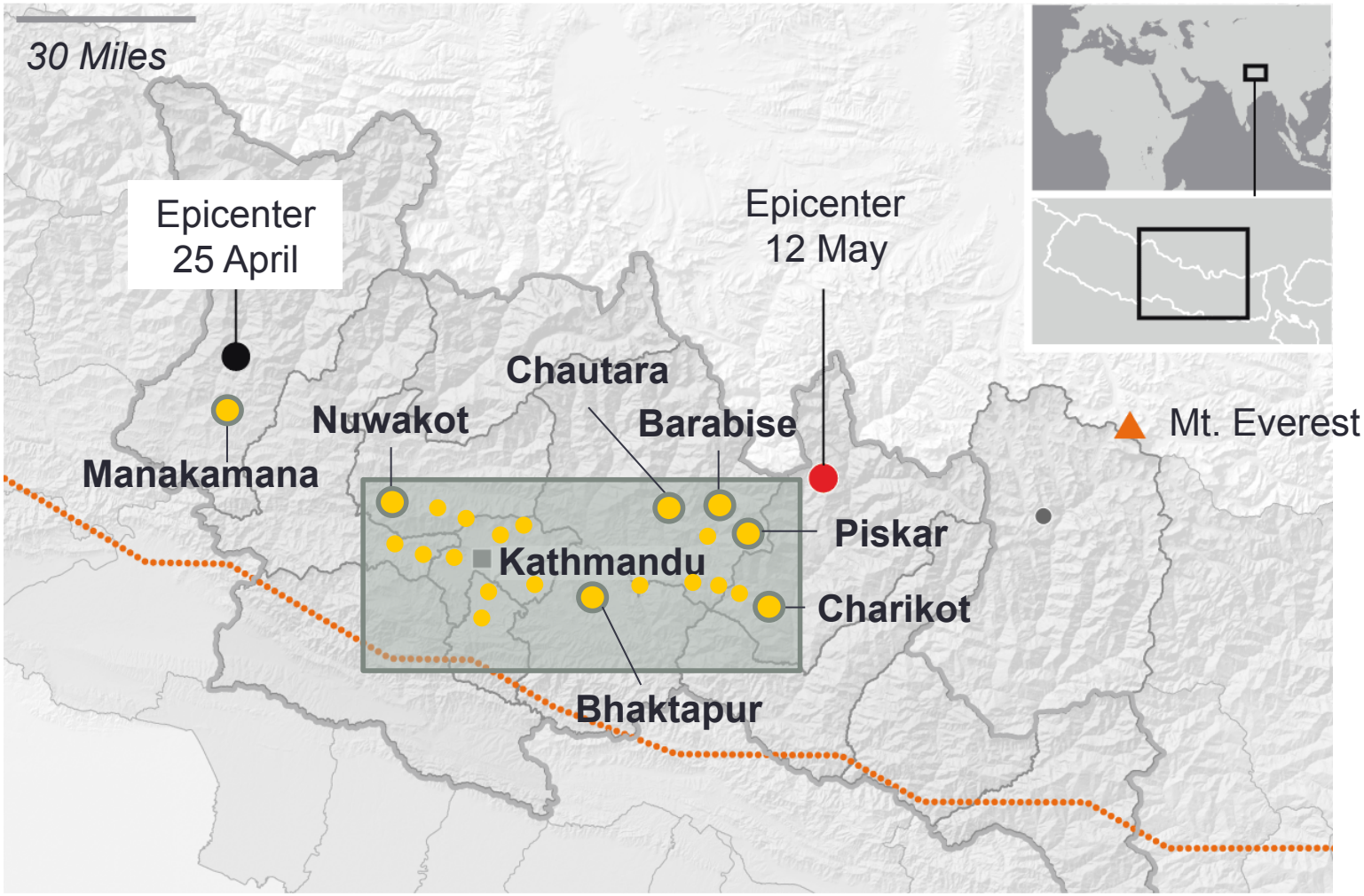


Towns and areas visited

Team Effort

Structures

- **RC structures with infills**
  - Three (3) tall buildings
  - Six (6) school buildings
  - Two (2) hospitals
  - 25 residential buildings
- **Two (2) Historic Centers**
  - Bhaktapur and Bungmati
- **Seven (7) Urban and Rural Areas**
  - Kathmandu – Gongabu, Sitapaila
  - Sindhupalchowk – Chautara, Barabise, Charikot, Piskar
  - Ghorkha – Manakamana
- **Three (3) historical URM structures**
- **Landslides and liquefaction**

Type of Assessment

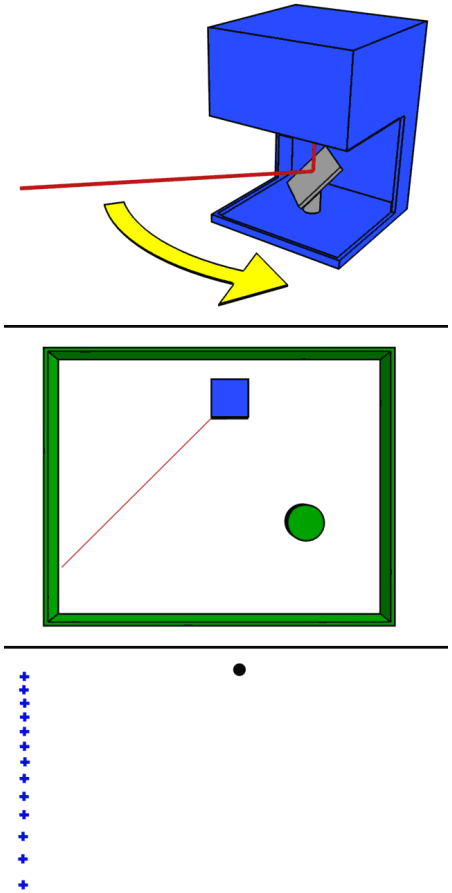
- **ATC-20 Rapid Evaluations**
- **ATC-20 Detailed Evaluations**
- **Non-destructive Testing**
  - Schmidt Hammer Testing
  - Rebar Scanner
  - Ultrasonic testing
- **LiDAR (laser scanning)**
- **Unmanned Aerial Vehicles**

Full list available at: http://web.engr.oregonstate.edu/~barbosa/NEPAL/

Laser Scanning Basics

- Lidar (light detection and ranging) is used to determine surface geometries of various structures
  - Traditionally a pulse of light is sent and “time of flight” calculated
  - Uses an exterior camera to capture RGB color indices
- Creates a point cloud
  - Vertices in 3D space
  - Measures distance, compute area and volume
  - Mesh or surface creation
- Advantages include:
  - Fast and easy to deploy
  - Limited to no contact
  - High quality data

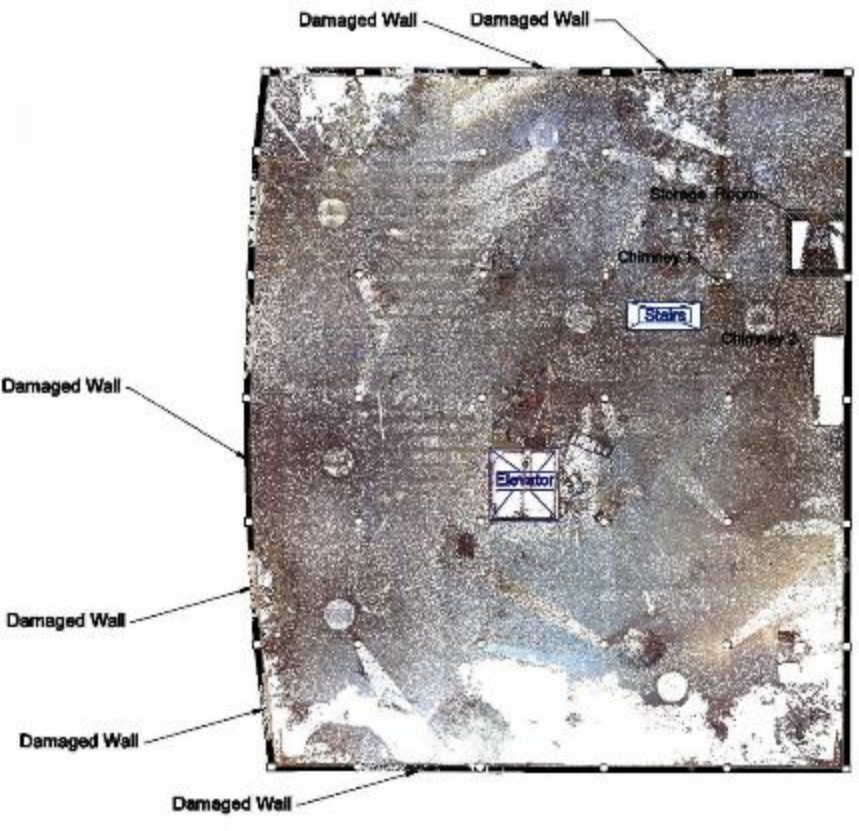
Lidar Mechanism



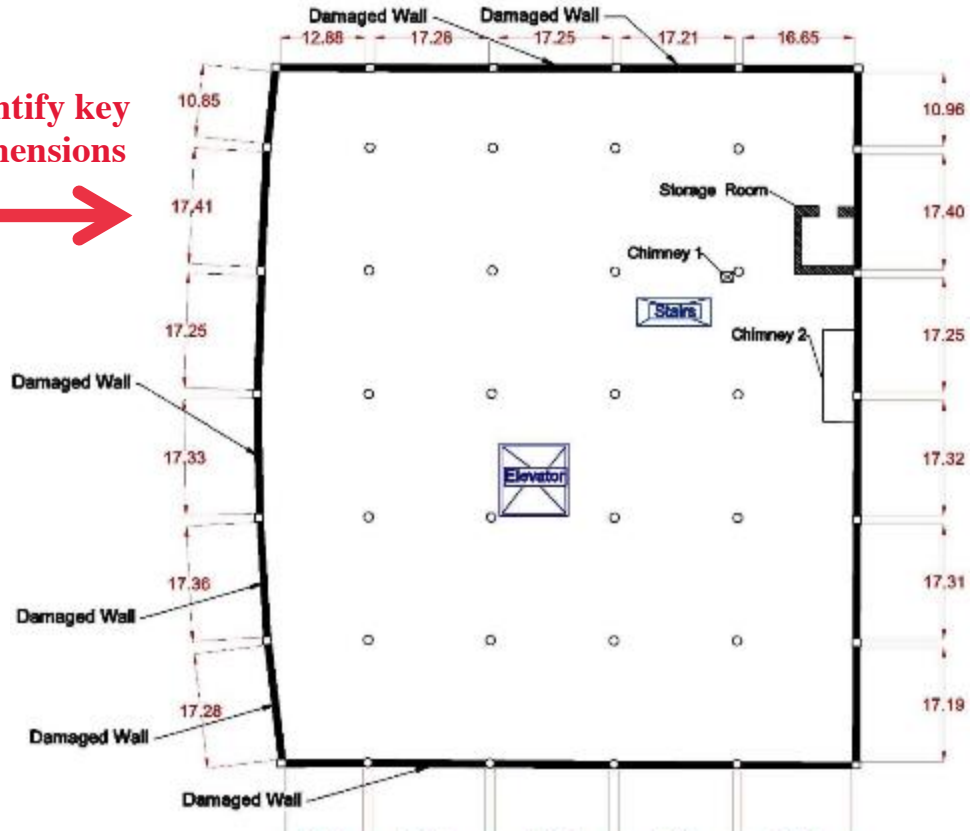
http://en.wikipedia.org/wiki/File:LIDAR-scanned-SICK-LMS-animation.gif

Ability to Construct CAD Drawings

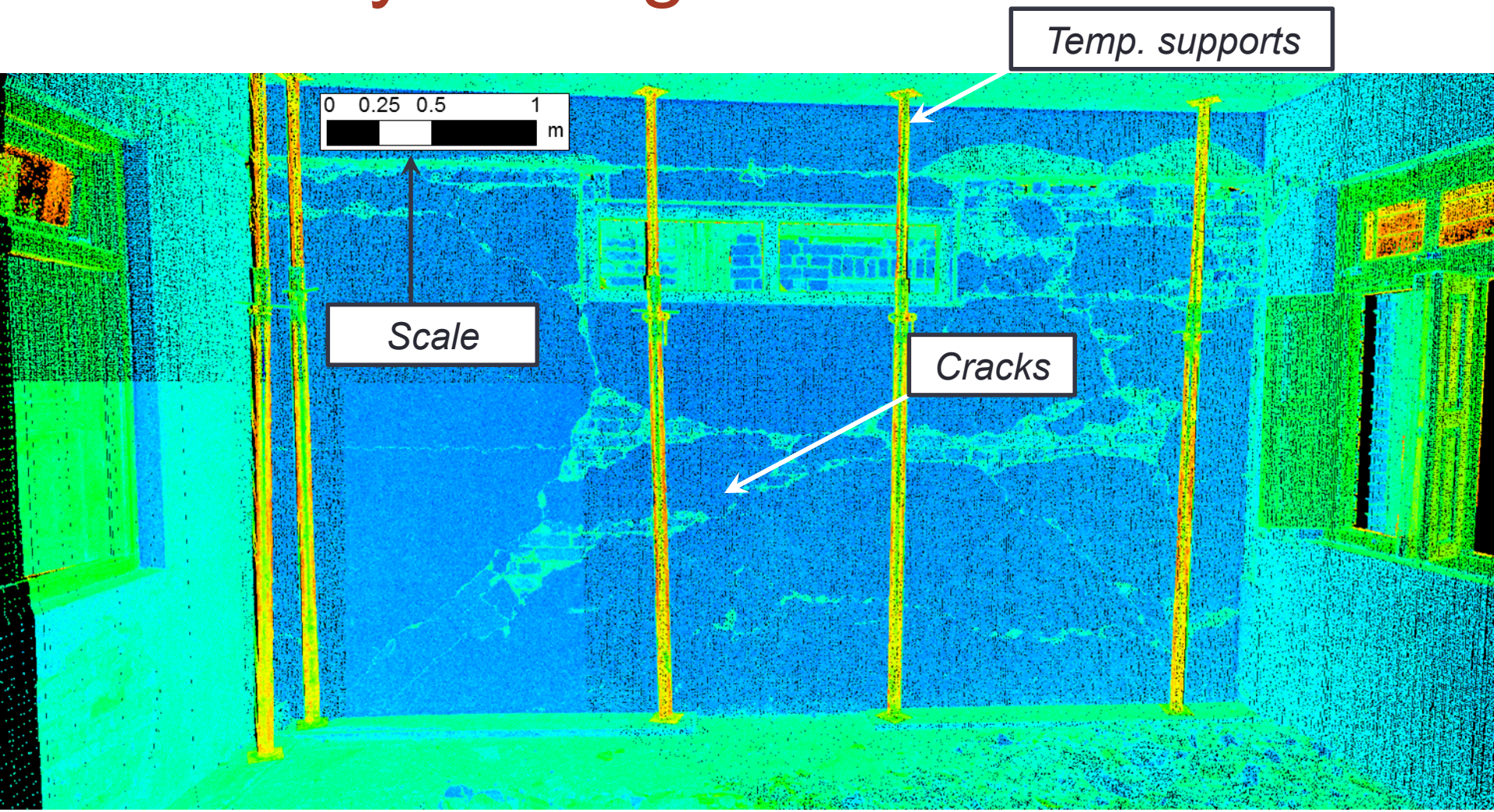
- Convert point cloud or (x, y, z) vertices to detailed dimensioned drawings of the structural members
- Example illustrated for interior scan data from the first floor (top level) at Imperial Cabinets Building in El Centro, California (Dr. Wood, Dr. Stavridis)



identify key dimensions



Quantify Damage



Unmanned Aerial Vehicles

- Bird's eye view
- Low flying heights provide high-resolution data
- Cheap flights
- Repeat flights for time series analyses/change detection
- Inexpensive vehicles and cameras are available
- Requires training

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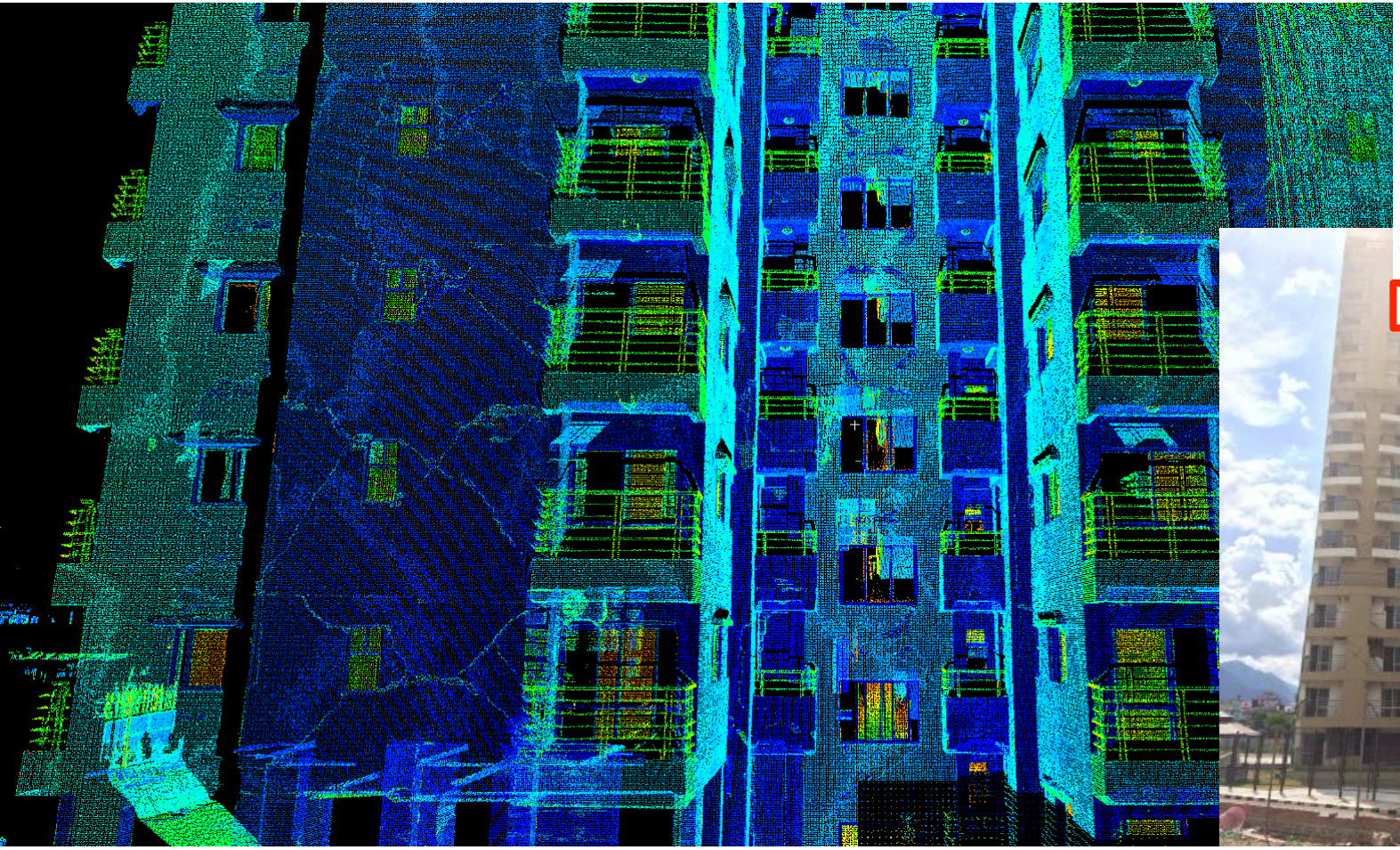
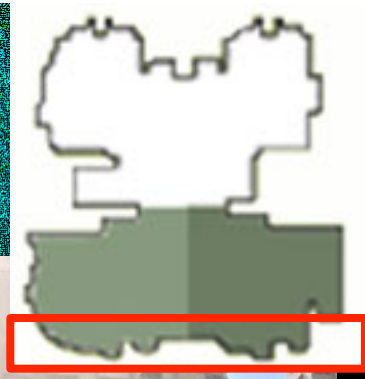
Performance of Tall Buildings

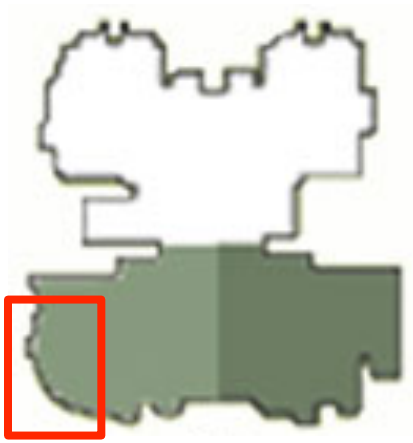
- **Hatiban, Kathmandu**
- **4 Towers (T1 – T4) on the same site**
- **T1 and T4 are 18 story towers**
- **T2 and T3 are 12 story towers**
- **Slight non-structural damage on T2/T3.**
- **Extensive non-structural and moderate structural damage on T1/ T4**





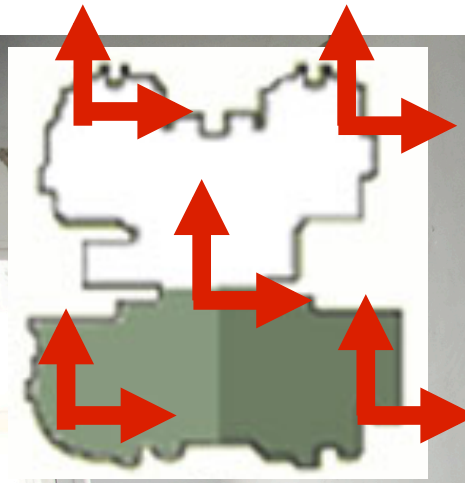
- **Buildings were designed for shaking intensities larger than experienced**
- **In general, buildings performed “well” (life-safety)**
- **Buildings are repairable, but significant losses, mostly to be covered by insurance**
- **Misinformation by media**

- **Vertical irregularity (stiffness)**



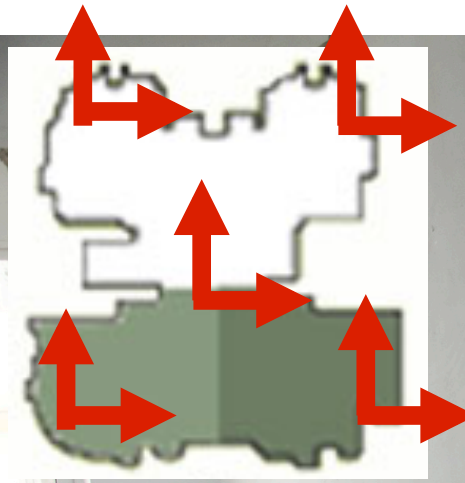
- **Good construction practice**
- **Beam-column joint cracks and shear cracks visible in coupling beam and short beams**
- **Flexural cracks on beams propagated to the 6” slabs**

Dynamic system identification – system 1



ACCELEROMETERS

Portable DAQ



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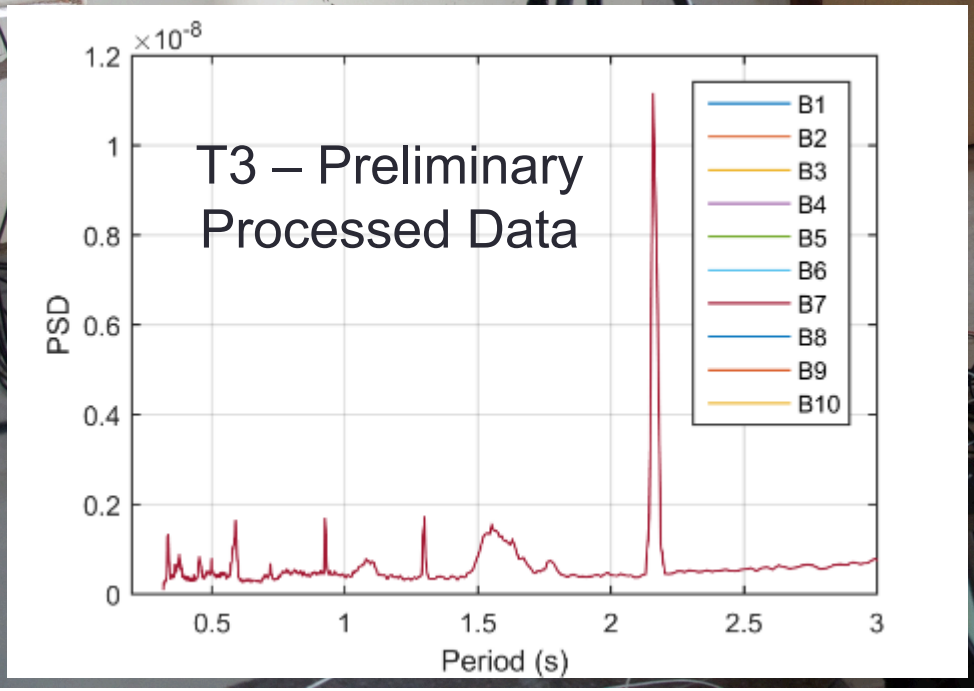
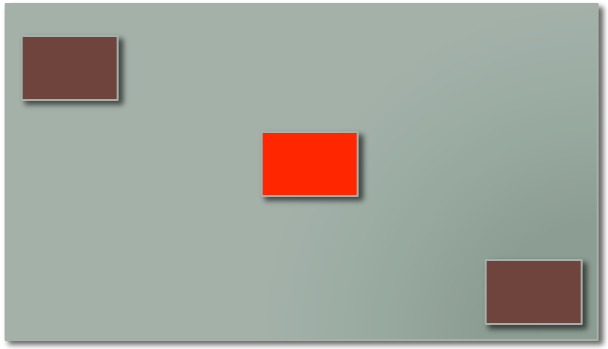


PORTABLE DAQ

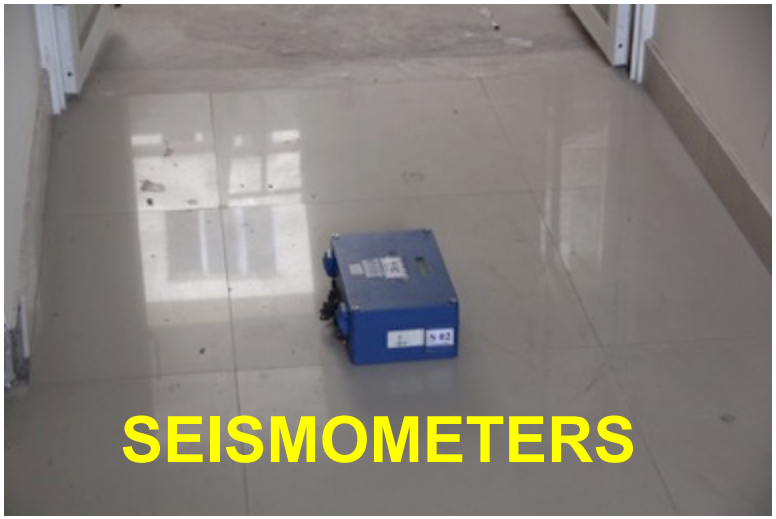
Portable DAQ

Dynamic system identification – system 2 (U. Porto)



Top story

other stories



Dynamic system identification – system 3 (U. Porto)

- **Dynamic identification of infill walls**
- **Useful for identifying and calibrating model parameters for infills**

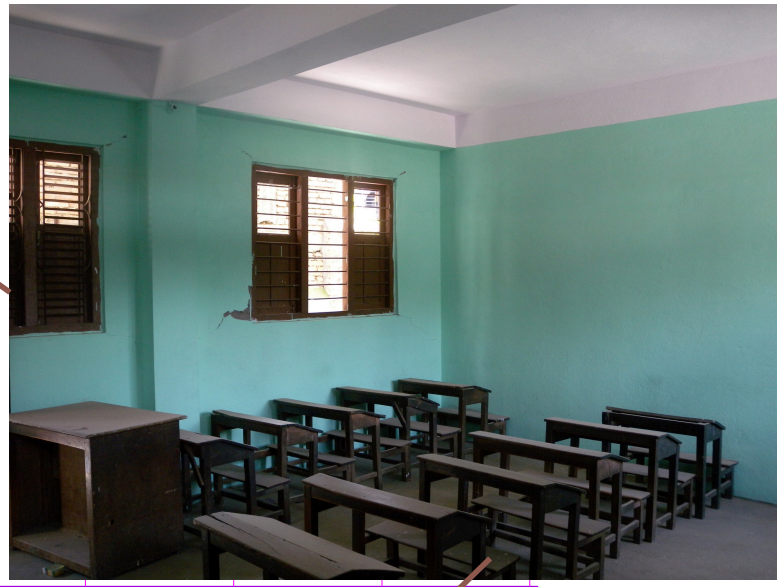
Site Characterization

- **Micro-tremor equipment used to estimate shear wave velocities of near-surface soil at two tall building sites**

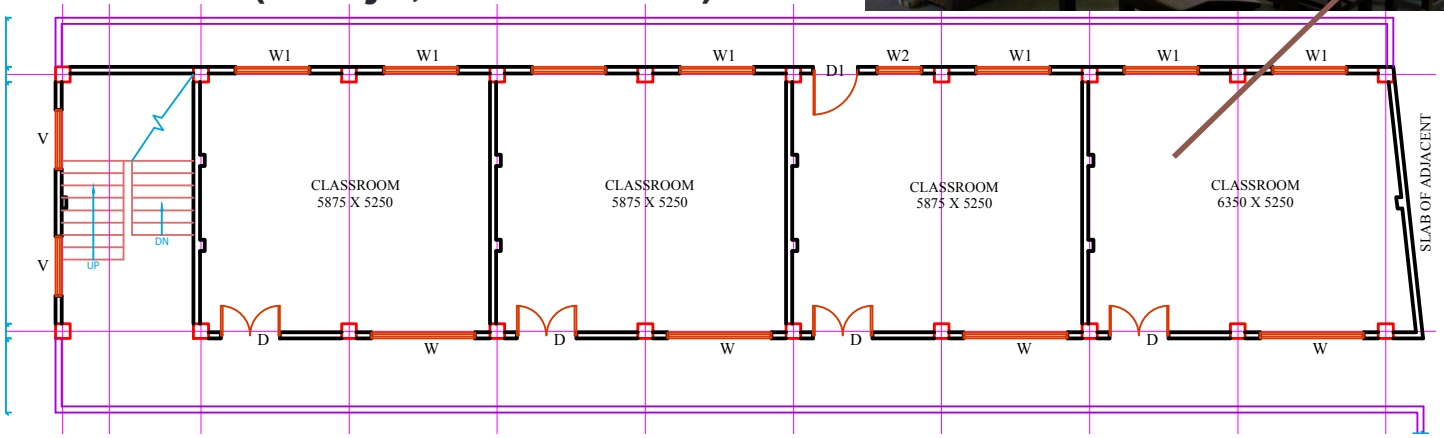
- Courtesy: Dr. Ben Mason, Dr. Domniki Asimaki, and Dr. Deepak Rayamajhi, and faculty and students from Khowpa Engineering College

School Buildings

- Torsional irregularity (stair case)
- Vertical irregularity (infill walls and column size)



- **Tarun ma vi (Balaju, Kathmandu)**



6.4 m (~21ft)

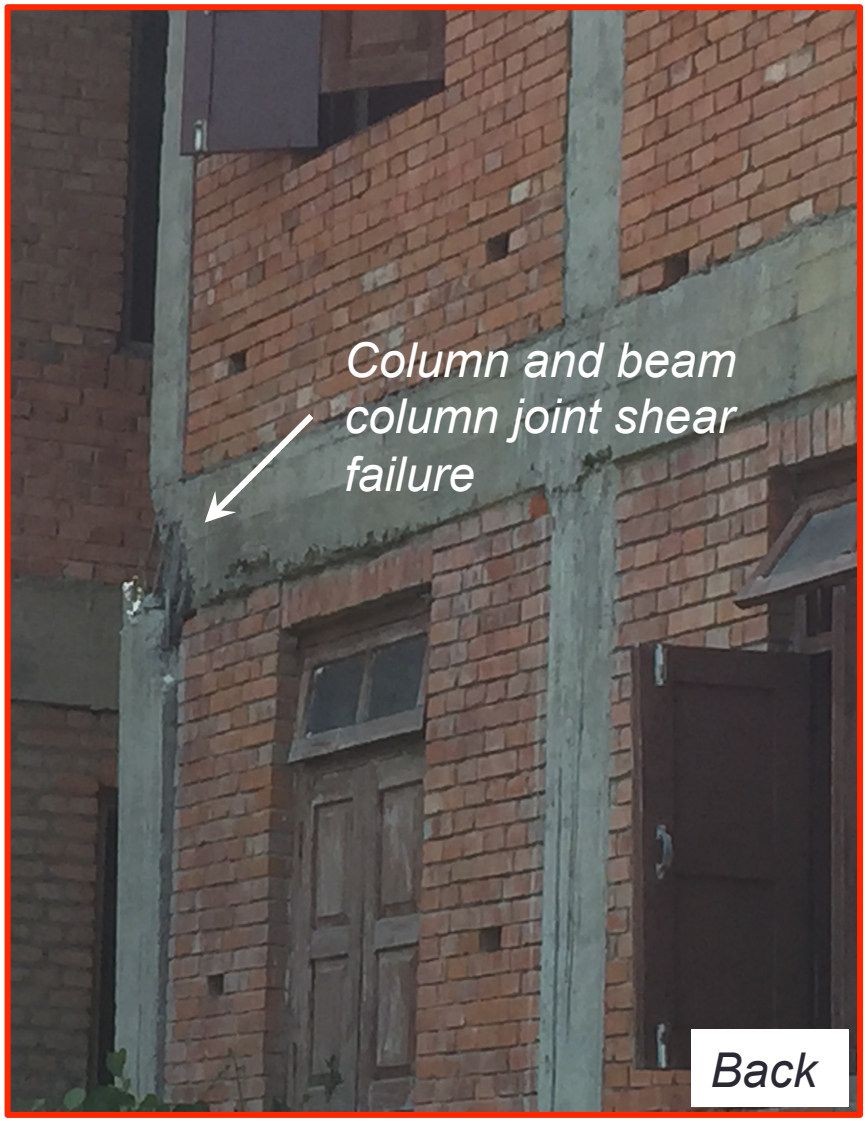
Plan View (Level 2)

27.1 m (~90 ft)

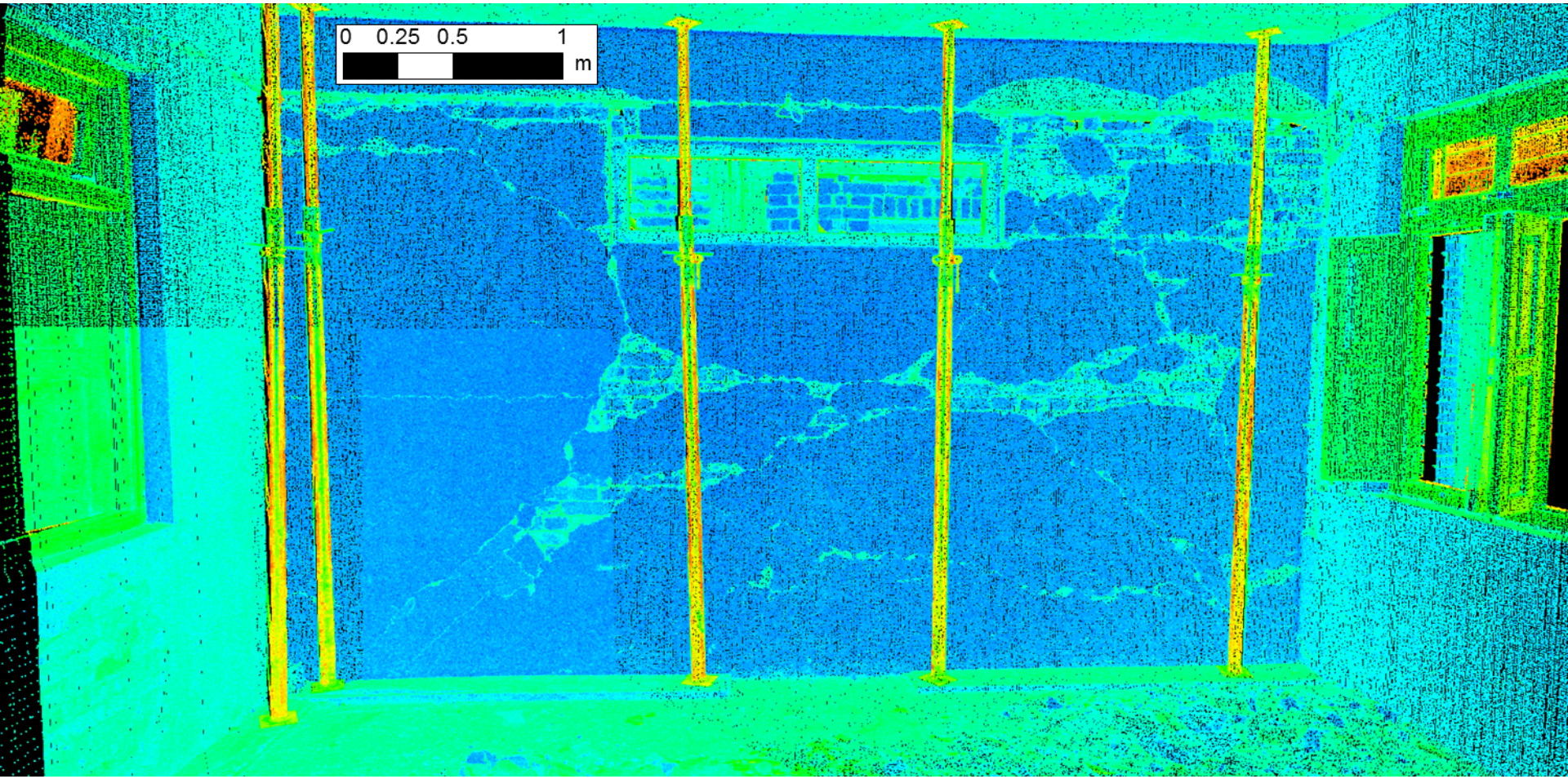
- **Level 3 – reduction of the number of infill walls and section of columns**

School Buildings (2)

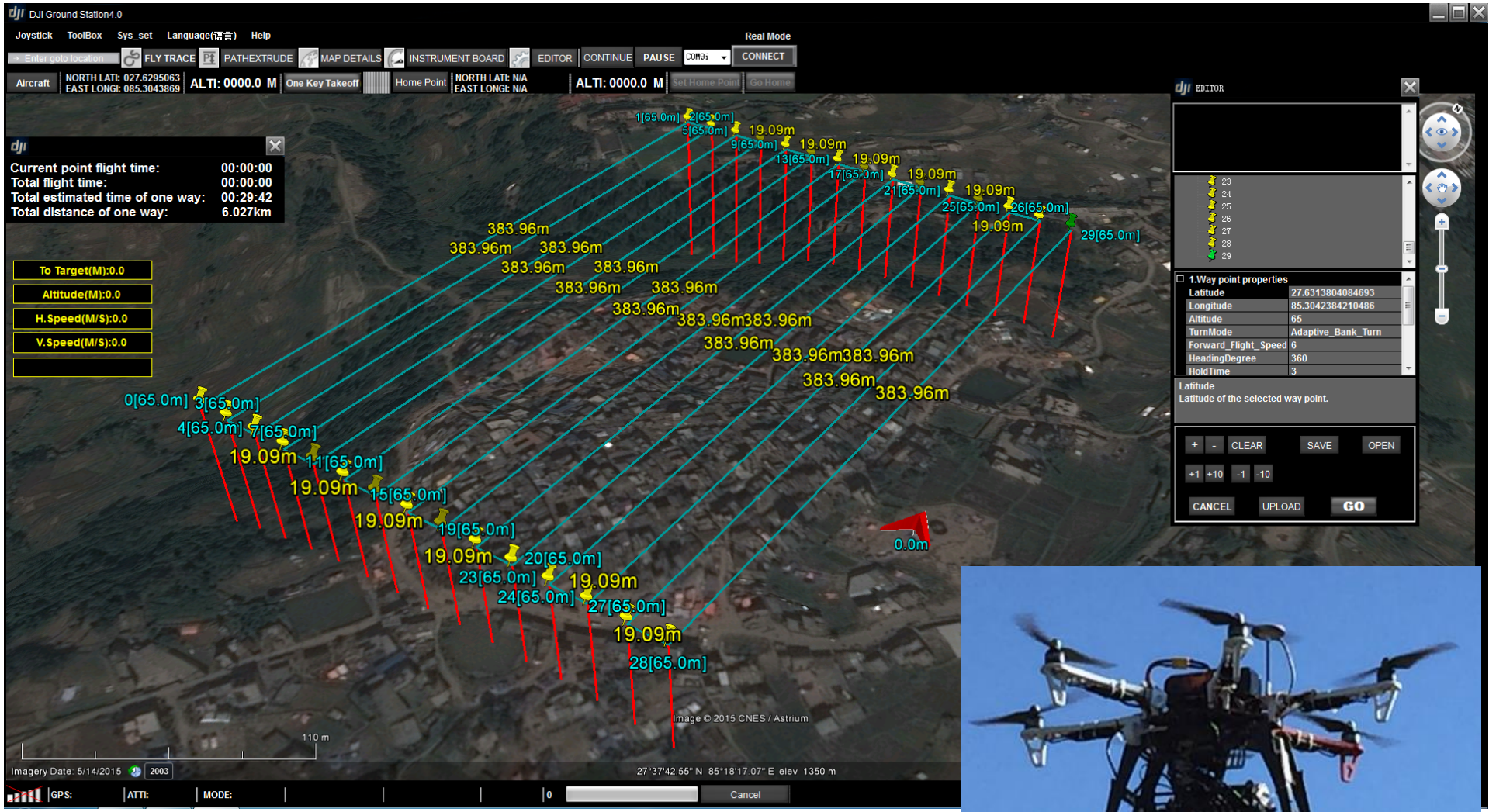
- Reinforced concrete (RC) frame plan irregular/asymetric building



- **Damage in Story 1**



Damage Assessment to Urban Centers



- **UAV flight plan for damage assessment**

- **Correlation of UAV based damage assessment with visual damage assessment**

- **1600 overlapping photos were taken with Sony A5000 and Go-Pro Hero cameras mounted on multi-rotor UAVs. The photos were processed in Structure-from-Motion software to output 3D models and ortho-rectified aerial imagery. These outputs were geo-referenced to real-world coordinates by establishing ground control points in the study area by a static differential GPS survey (Dan Gillins)**


OSU

Acknowledgements

- National Science Foundation Grant Number CMMI-1545632 “RAPID/ Collaborative Research: Post-Disaster, Reinforced Concrete Building Performance Data Collection following the April 25, 2015 Nepal Earthquake”
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- Cascadia Lifelines Program
- Dr. Manjip Shakya, Dr. Ganesh Ram Nhamafuki, Dr. Hemchandra Chaulagain, Principal Chandra Kiran, Principal Sujan Maun, Sharoo Shrestha
- Several building owners in Nepal that prefer to remain anonymous.
- Leica Geosystems and David Evans and Associates provided the Oregon State University laser scanning equipment and software used for this project

Thank You!

Q&A: email questions to peer_center@berkeley.edu

PEER

Reconnaissance briefing will be posted at:
http://peer.berkeley.edu/publications/earthquake_recon_reports.html

EERI

Maintain M7.8 Nepal Earthquake Clearinghouse:
http://www.eqclearinghouse.org/2015-04-25-nepal/

GEER

GEER Report: Gorkha (Nepal) Earthquake of April 25, 2015:
http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Nepal_2015/index.html