Comments on the Emerging Role of Remote Sensing in Post-Disaster Response

M. Shinozuka
University of California, Irvine

The 3nd International Workshop on Remote Sensing for Post Disaster Response

Chiba, Japan, September 12 - 13, 2005

Safety and Security of Civil Infrastructure Systems (1)

Prevention

Protection & Security of Individual Facilities

Preparedness

Monitoring for System Integrity

- Real-Time Monitoring and Damage Localization
- Distributed Optical Fiber Sensor Systems
- NDE Technology for Local Damage Assessment

Assessment of System Vulnerability

- Lifeline Networks - Electric Power Network, Water Distribution Network, and Transportation Network

Retrofit and Rehabilitation to Enhance Safety and Security

- Cost-effectiveness

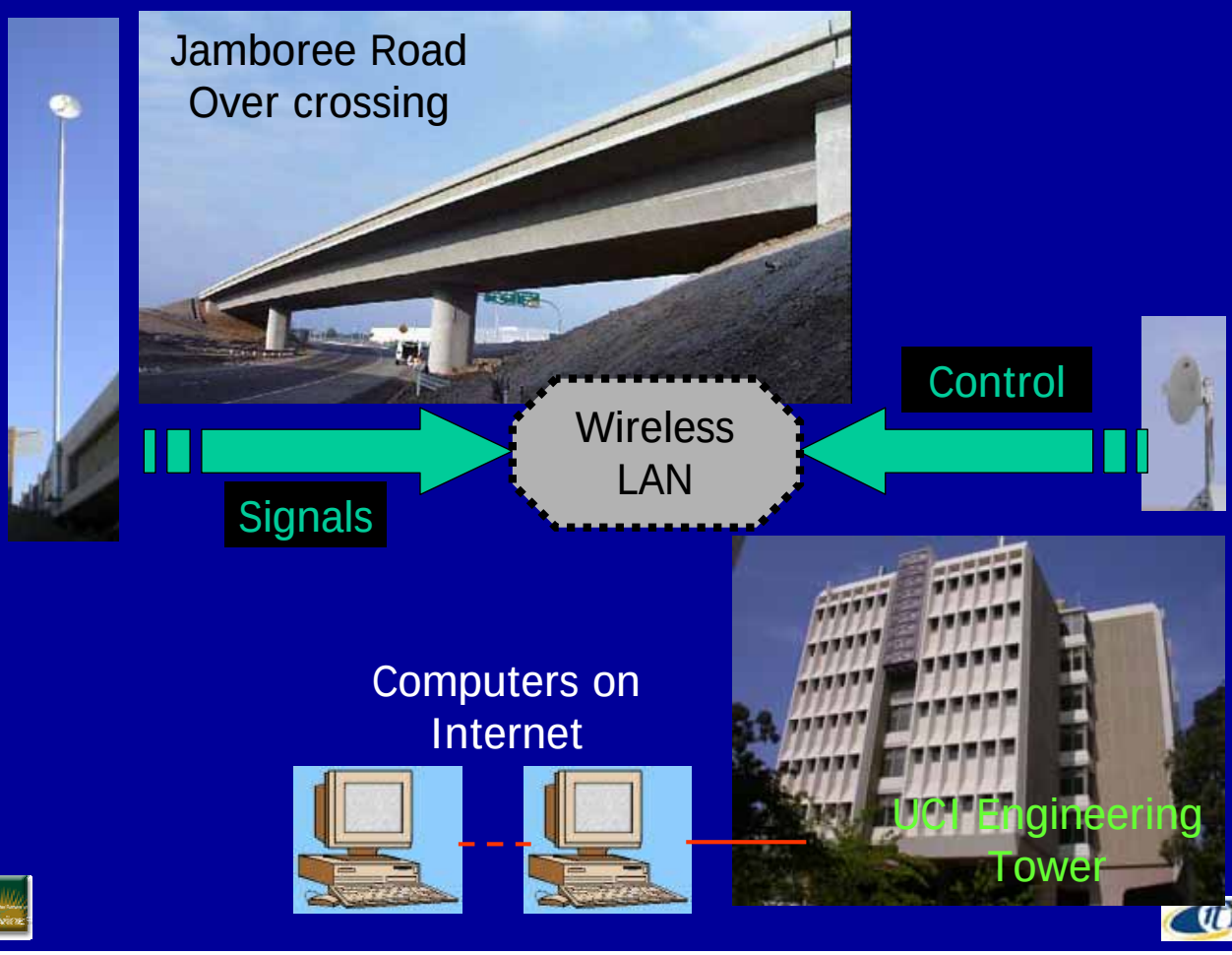
Safety and Security of Civil Infrastructure Systems (2)

Emergency Response

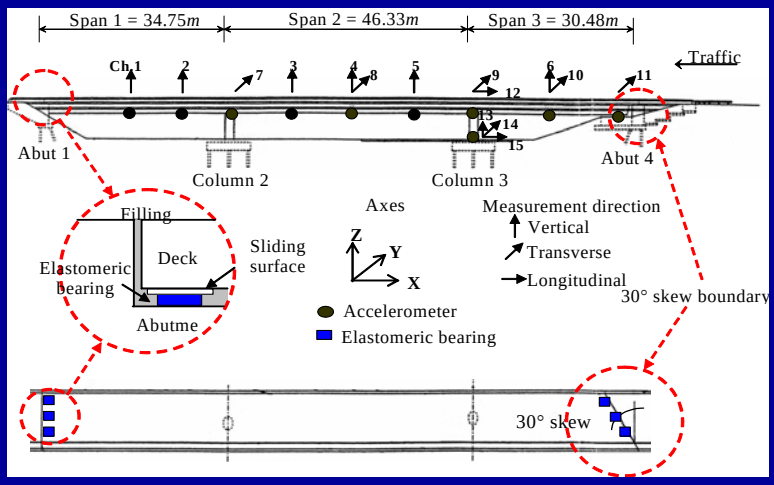
- **Remote Sensing for Rapid Urban Damage Assessment**
- **Data Fusion for Remote Reconnaissance**
- **Rapid Search / Rescue / Triage and Near Real-Time Transportation of the Injured**

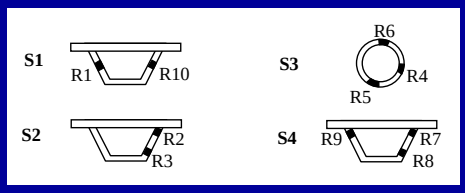
Restoration

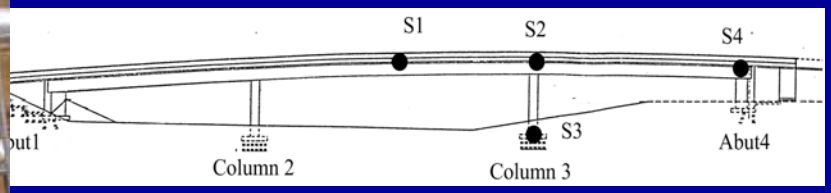
- **Repair Priority**
- **Time Required for Emergency Repair**
- **Economic Loss due to Repair and Service Interruption**
- **Restoration Strategy for Minimizing Indirect Cost**



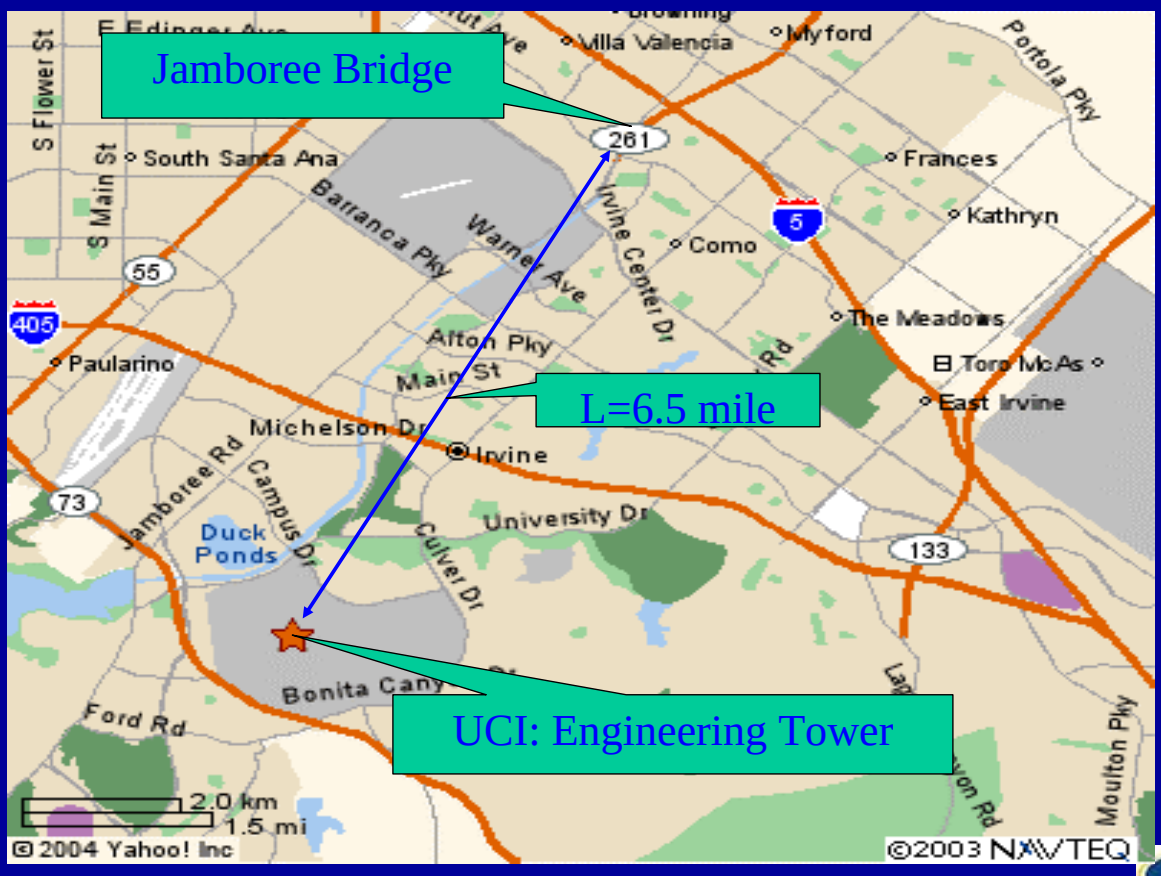
Instrumentation of Highway Bridges for Real-Time Monitoring

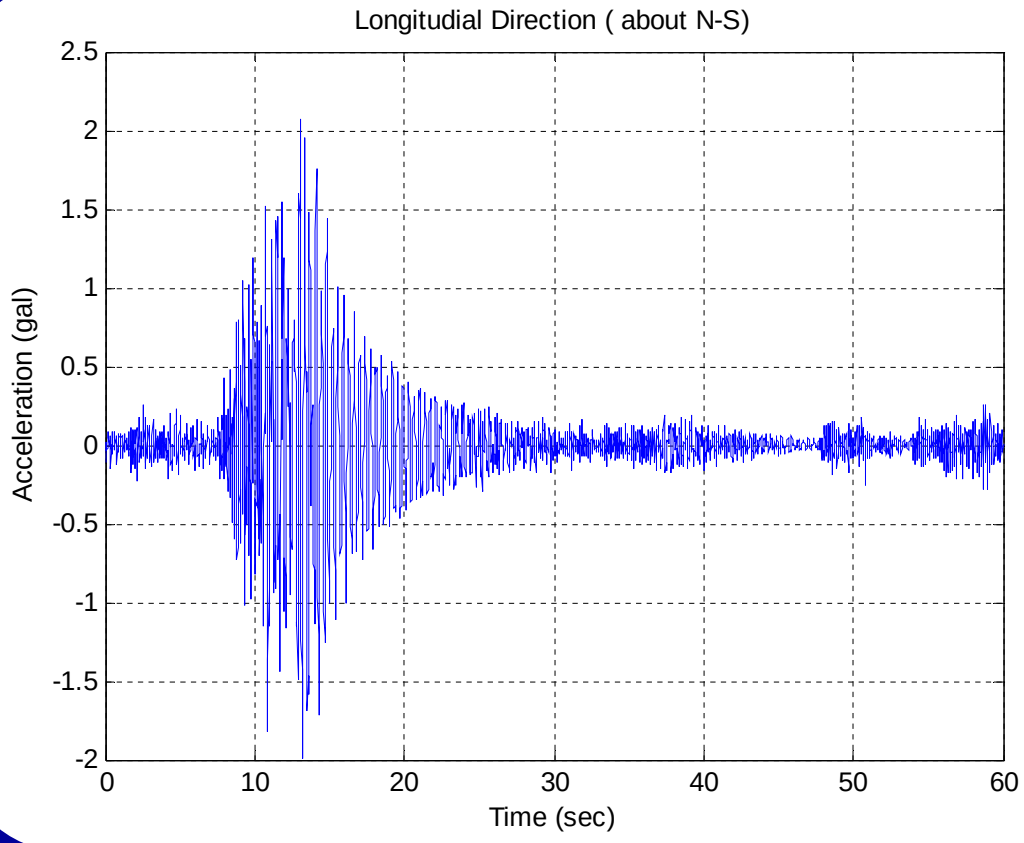






Jamboree Wireless DAQ System





New and Innovvative

Department of Civil and Environmental Engineering at University of California, Irvine posted a web site, http;/mfeng.eng.uci.edu, through which you can see at any time the response acceleration of Caltrans' Jambolee overpath under external disturbances such as passing traffic, earthquake, and wind. This is the first web display in the world of continuous monitoring of a dynamic response of an operational bridge by means of wireless transmission of sensor data (nine channels) installed on an operational bridge. What you see is what is happening in real time. The data refleshes every 10 seconds. Relative locations of the campus and bridge site are shown below.

Micro Electro Mechanical Systems

Real Time Data

Internet

RS232C

Server

Laptop Computer

Sensor Node

- DuraNode
  - 3-Axis Accelerometer
  - 802.11b Wireless
  - 2000mAh Battery

    + Solar and Wind Panel

Flexibility for alternative interfaces, including BlueTooth, ZigBee, fiberoptics in addition to 802.11b and other WLAN interfaces.

- Eco
  - 2-Axis Accelerometer
  - 2.4GHz GFSK Wireless
  - Ultra-Compact (<1 cm^3)
  - Low Power

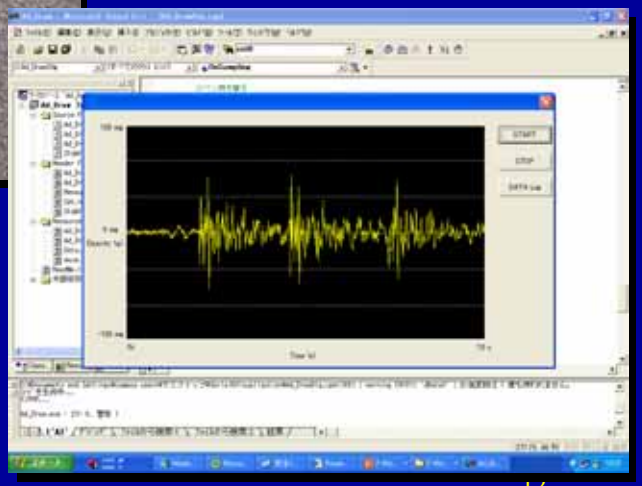
Steel Truss Bridge at UCI

Real-time Data Acquisition System

Data Acquisition System

Hardware

- ✓ 1Axis; ±2g
- ✓ Transmit Range up to 400 ft
- ✓ Powered by 9V Battery
- ✓ Connected by RS232C Cable



Software

- ✓ Read the Serial Port
- ✓ Real-time Visualization
- ✓ 200Hz Sampling
- ✓ Data Logger system

Experimental Results Frequency Domain

Seismic Piezoelectric Accelerometer PCB 393C

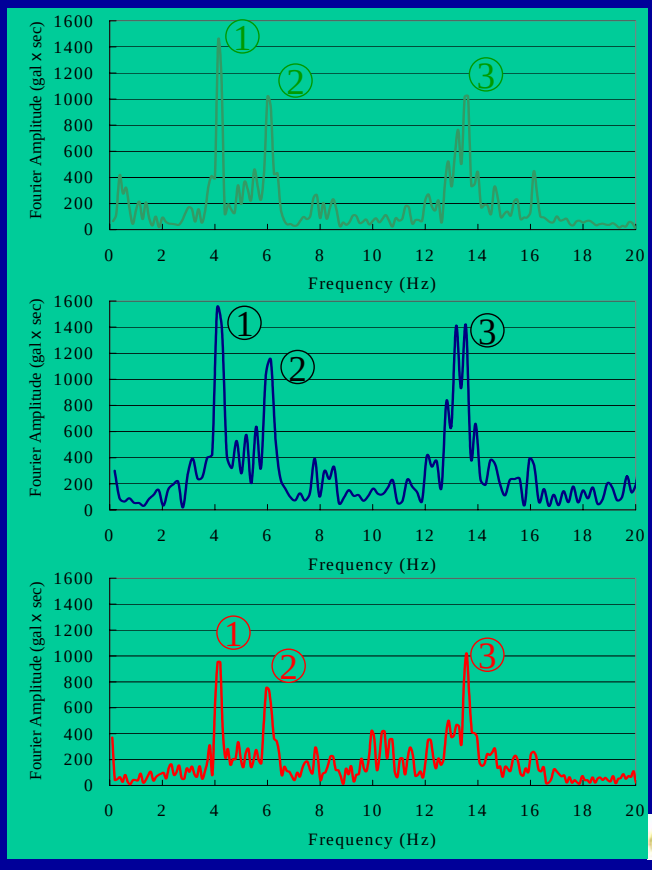
	Frequency (Hz)
1	4.12
2	6.00
3	13.63

Silicon Design

	Frequency (Hz)
1	4.08
2	6.12
3	13.17

ADXL 202E

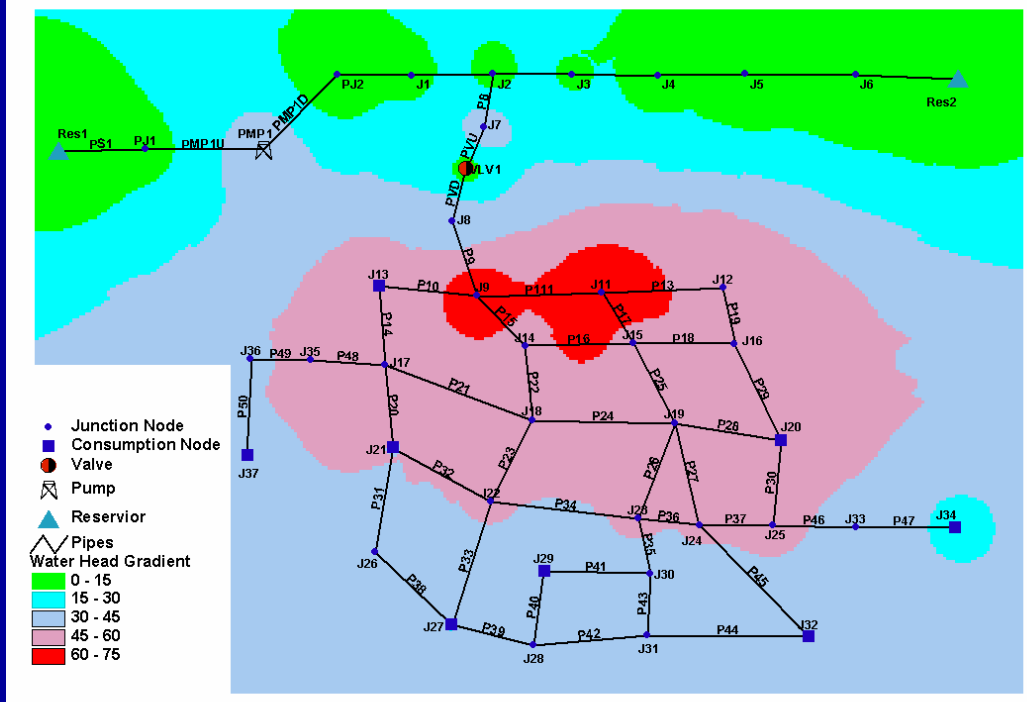
	Frequency (Hz)
1	4.20
2	5.96
3	13.57



New and Innovative

For the first time in the world, Department of Civil and Environmental Engineering at University of California, Irvine succeeded in real-time visualization of MEMS-Based sensor data of high reslution only available with tradsitional electical sensors. Data are transmitted by wireless through DuraNode.

Contour of Water Head Gradient



P111 Damage

New and Innovative

For the first time in the world, Department of Civil and Environmental Engineering at University of California, Irvine succeeded in proof of concept experiment to use weireless MEMS sensors in real-time identification of pipe damage location in a network of water distribution system. Data are transmitted by wireless through DuraNode.

Real Time Displacement Measurement of a Flexible Bridge Using Digital Image Processing Techniques

Jong-Jae Lee, Yoshio Fukuda, Masanobu Shinozuka

Department of Civil and Environmental Engineering,
University of California, Irvine

Real Time Displacement Measurement Using Image Processing Techniques

Digital Video Camcorder
- **30x optical zoom**
- **720 by 480 pixels**
- **30 fps**

$500

Telescopic Lens
- **8x optical**

$150

IEEE 1394 Firewire

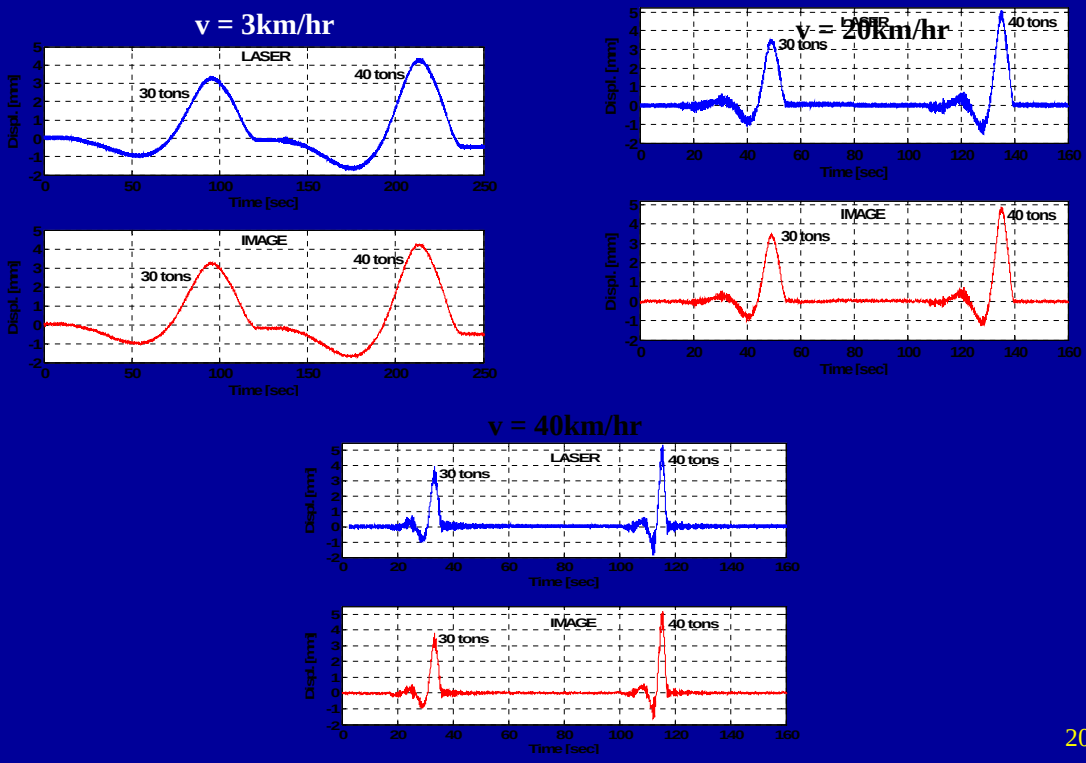
$20

Laptop

$1200

highly cost-effective

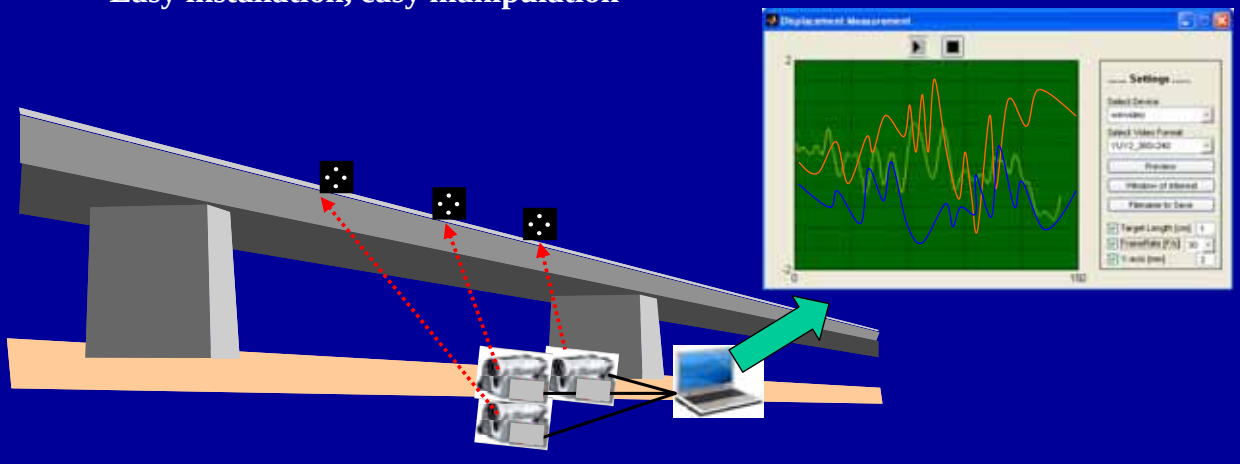
Application on a steel-box girder bridge



Further Developments

Synchronous multi-location measurement

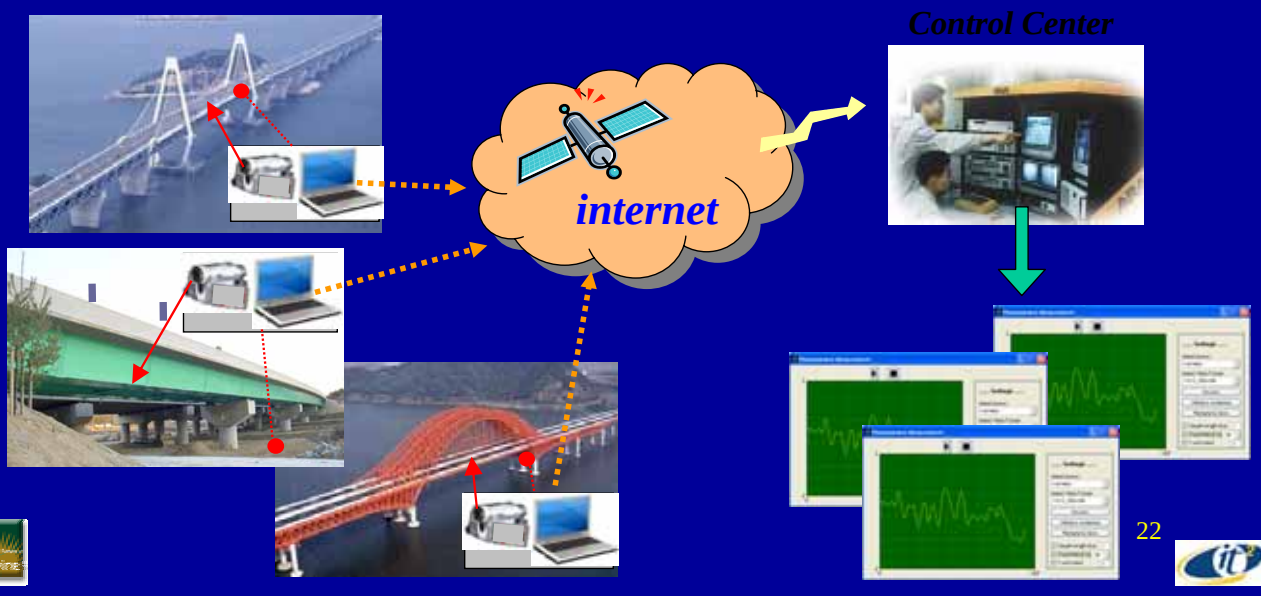
- ✓ Dynamic measurement with high resolution and cost-effectiveness
- ✓ Multi-points measurement
- ✓ Real-time measurement and visualization
- ✓ Easy installation, easy manipulation



Further Developments

Integrated monitoring system

- ✓ **Wireless data transmission**
- ✓ **Internet, Satellite**



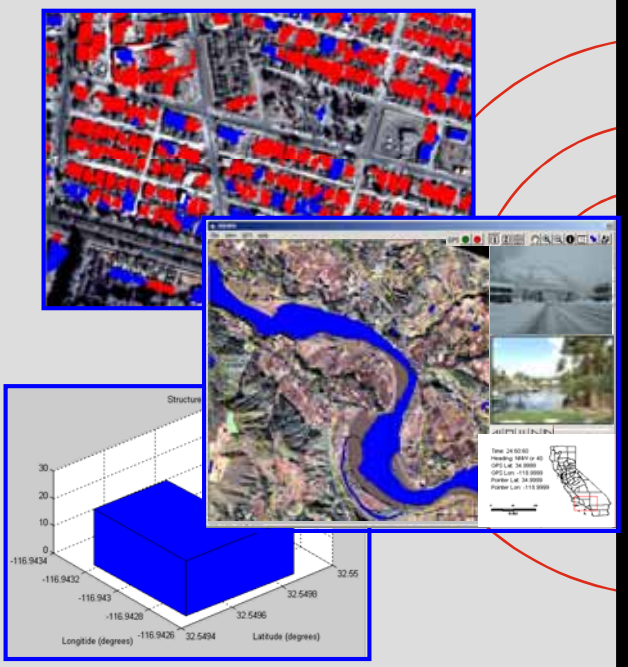
MCEER's Remote Sensing Program

Masanobu Shinozuka

University of California, Irvine

Year 8 Accomplishments

1. Post-disaster damage & situation assessment
2. Field reconnaissance - damage data collection & visualization
3. Building inventory for loss estimation



3rd International Workshop on Remote Sensing and Disaster Response, Chiba, Japan, September 12-13, 2005

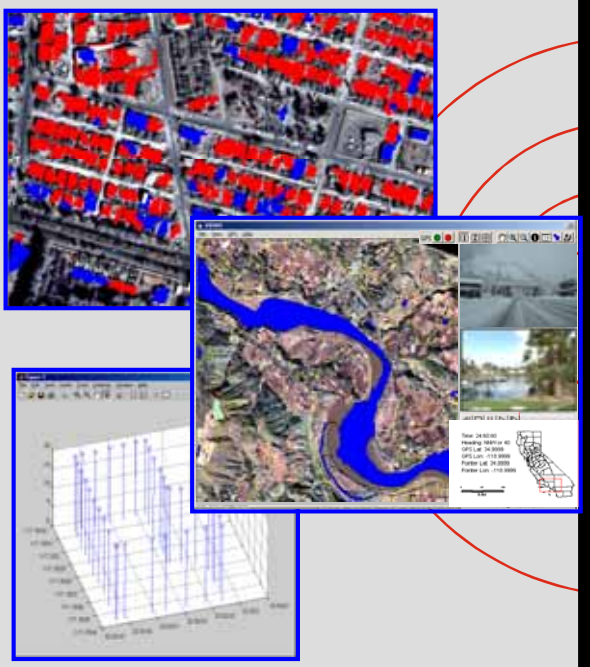
MULTIDISCIPLINARY CENTER FOR EARTHQUAKE ENGINEERING RESEARCH

Research Collaborators

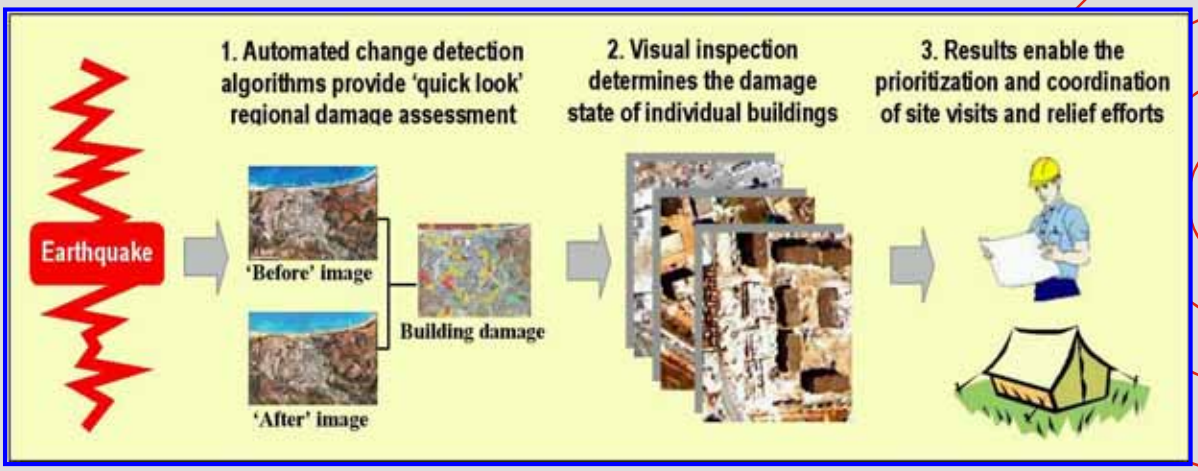
- Damage detection algorithms
  - *Chiba University*
  - *Earthquake Disaster Mitigation Research Center*
  - *University of Bologna*
- VIEWS deployment
  - *Earthquake Engineering Research Institute (EERI)*
  - *Wind Science Engineering (WISE) & Research Center at Texas Tech University*
- Building inventory
  - *Stanford University*

Year 8 Accomplishments

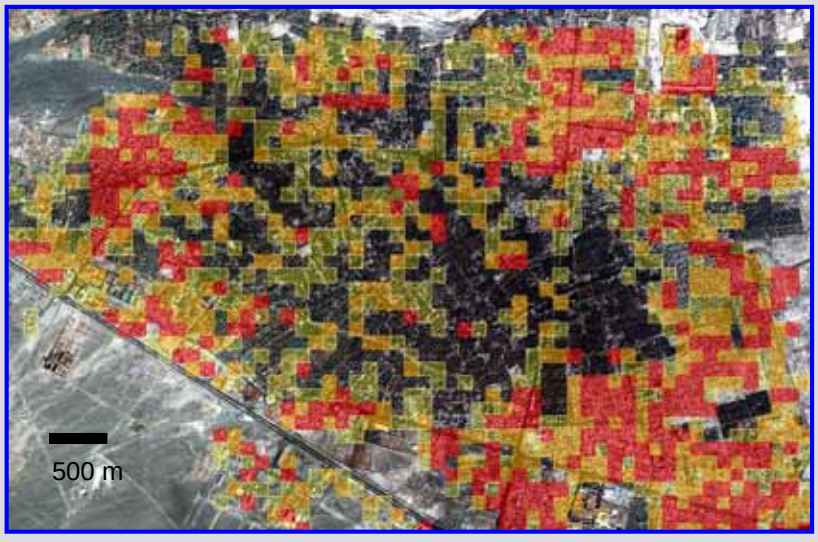
1. Post-disaster damage & situation assessment
2. Field reconnaissance - damage data collection & visualization
3. Building inventory for loss estimation



Tiered Reconnaissance System



City-wide Damage Assessment



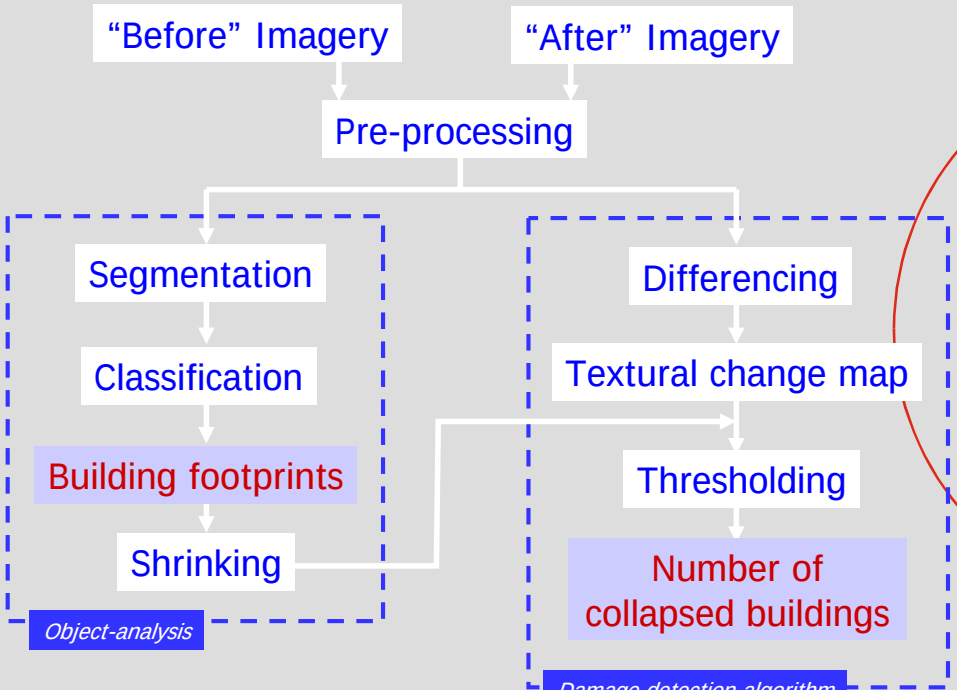
Extreme change
Complete building collapse

Widespread change
Building collapse widespread

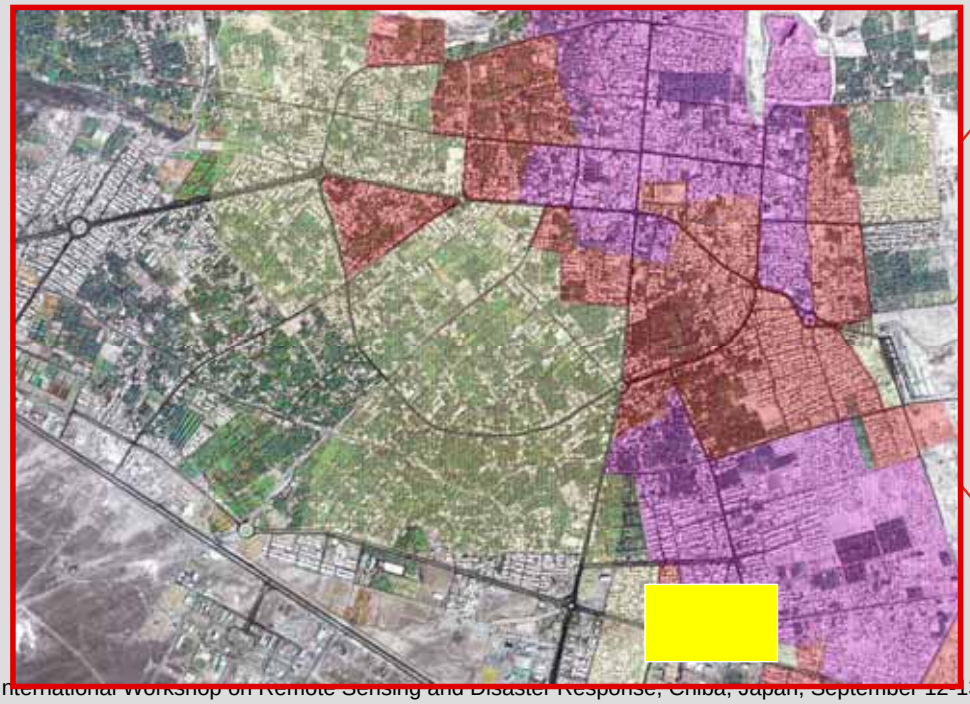
Some damage
Localized pockets of collapse

Object-based Damage Assessment

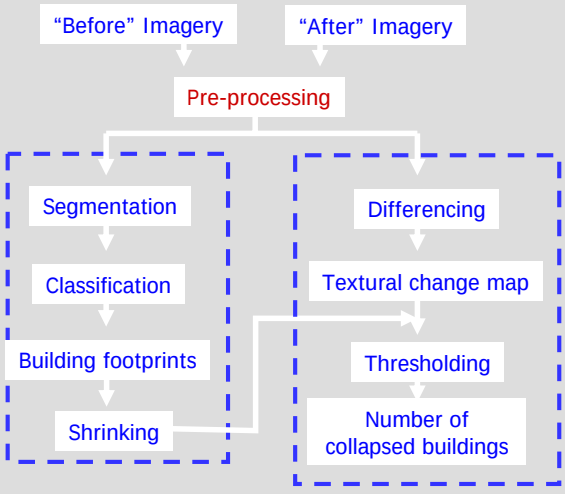
Counting Collapsed Buildings



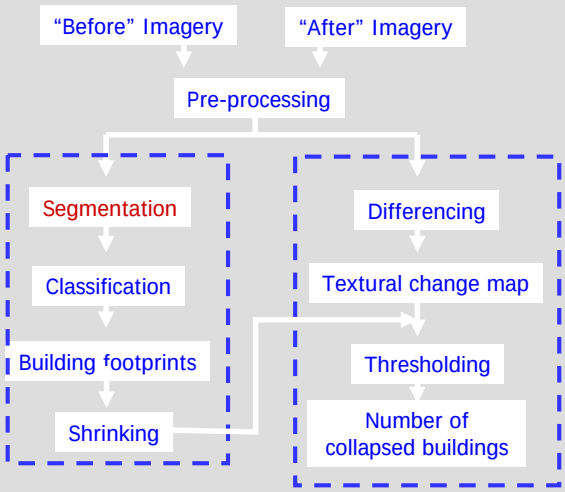
Illustrative Neighborhood



Pre-processing

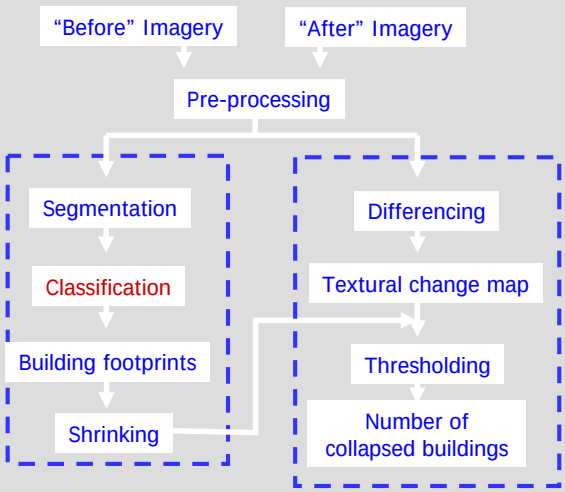


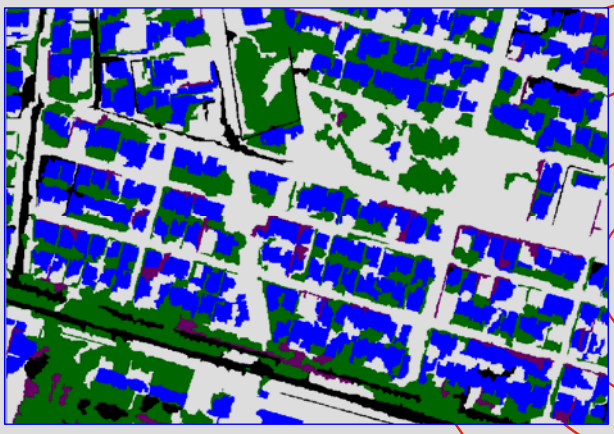
Segmentation



Scale = 30
Color = 0.1
Smoothness = 1.0

Classification



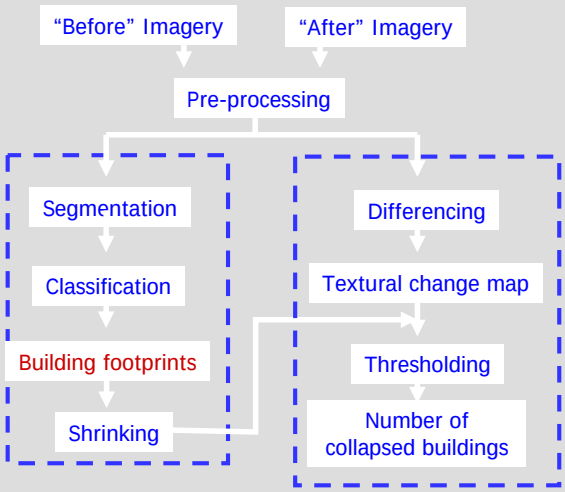


900 training objects

Building
Vegetation
Shadow
Other

Accuracy = 75%

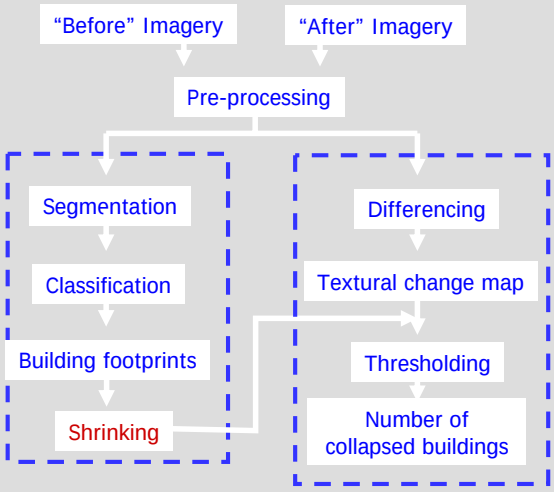
Building Footprints

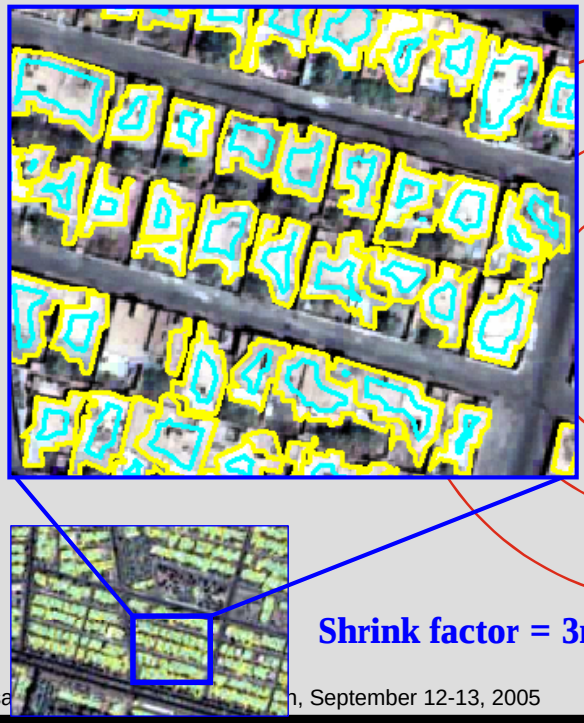


Buildings

Total estimated buildings = 19,211

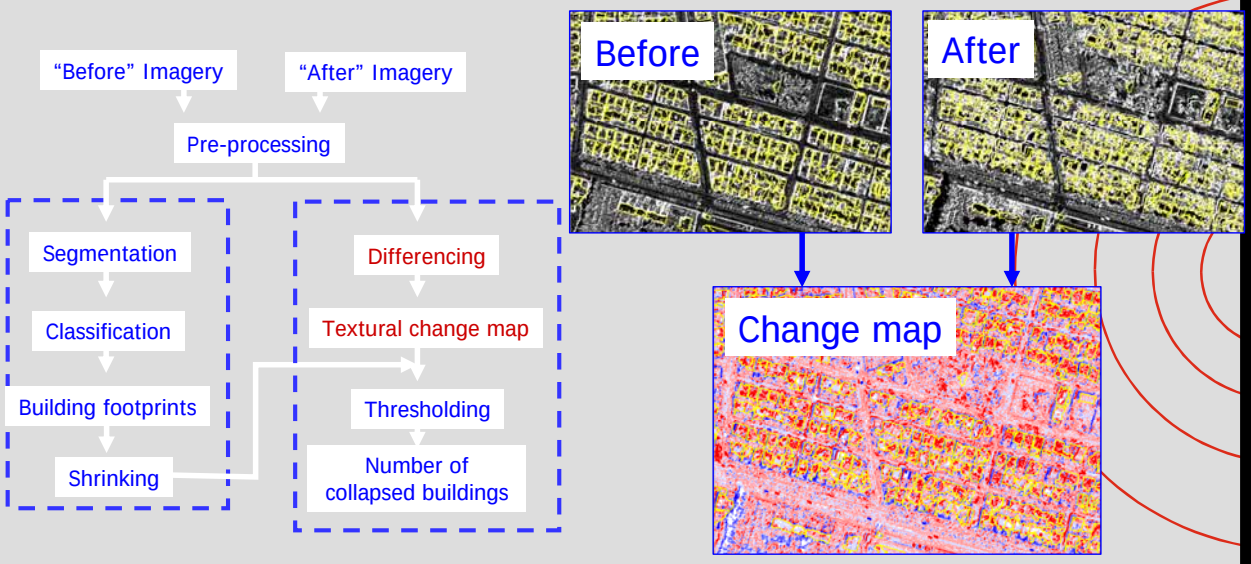
Shrinking



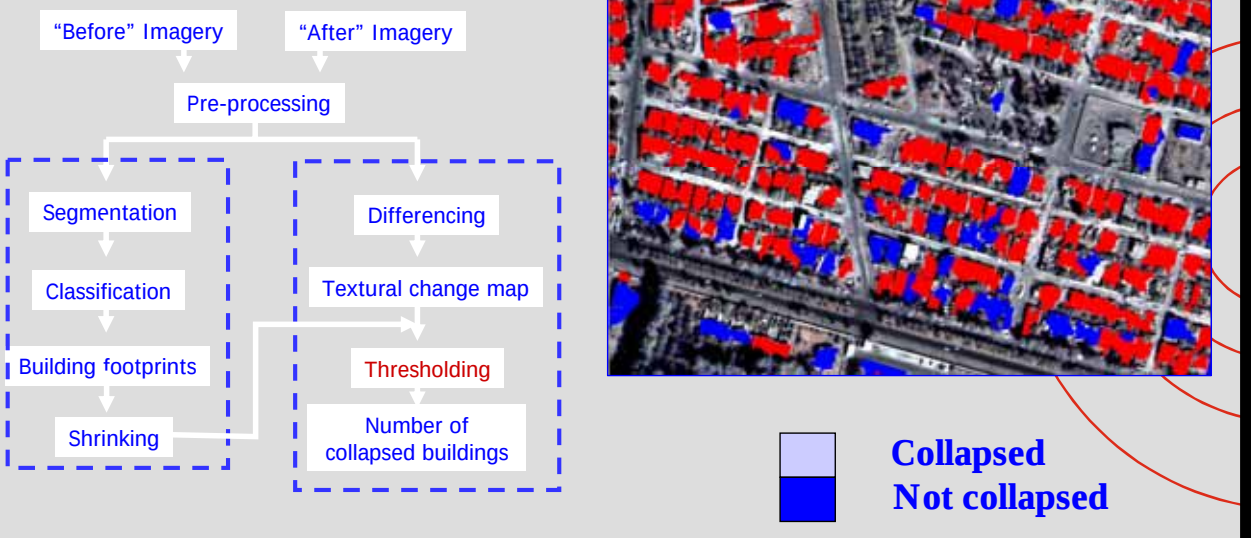


Shrink factor = 3m

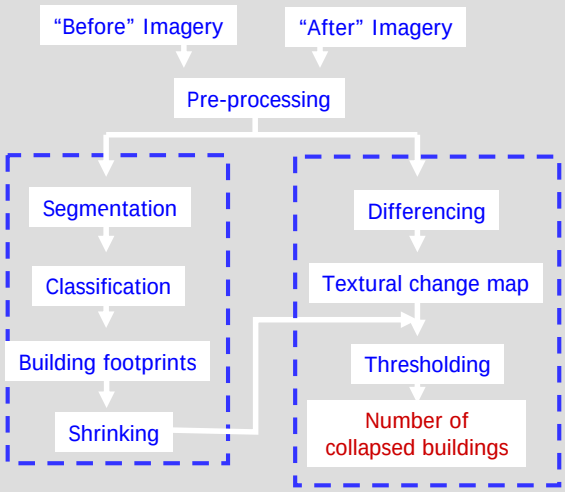
Differencing (Texture)



Thresholding



Number of collapsed buildings



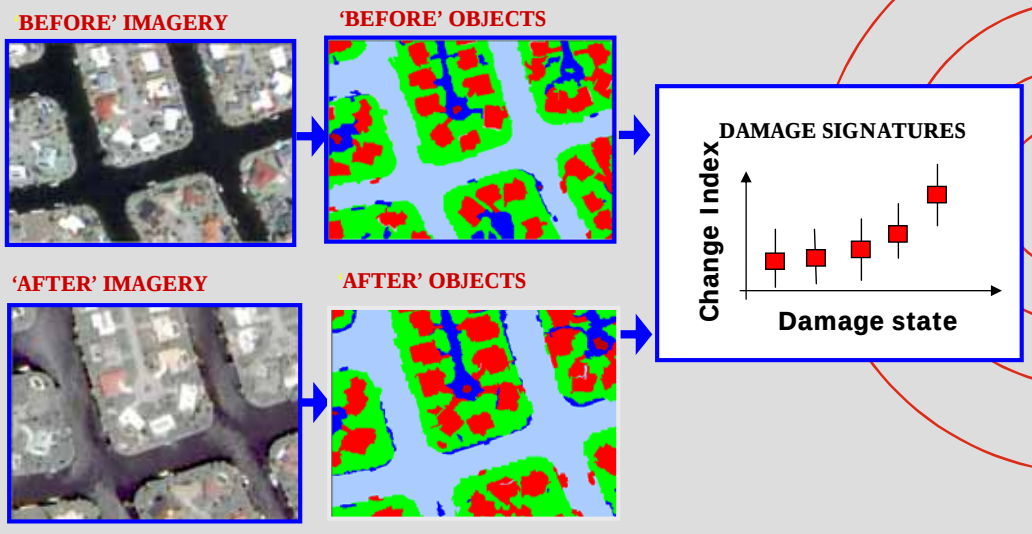
Collapsed buildings = 6,481
Not collapsed buildings = 9,021
Not classified = 3,709

Accuracy = 79%

Hurricane Damage Detection

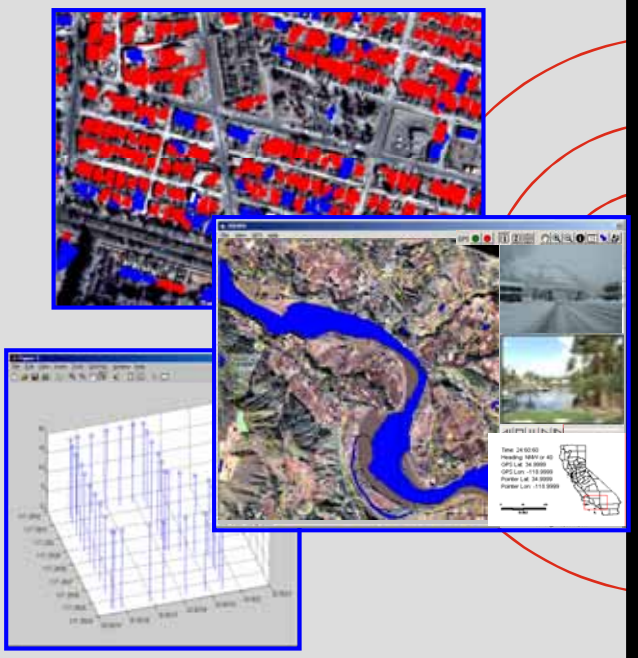
(a) USE 'OBJECT-ORIENTED' IMAGE PROCESSING TO LOCATE BUILDINGS IN 'BEFORE' and 'AFTER' IMAGERY

(b) QUANTIFY BUILDING DAMAGE



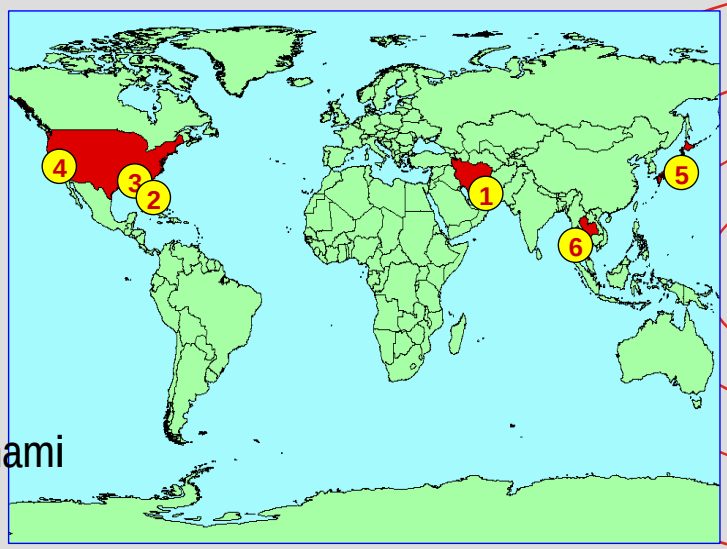
Year 8 Accomplishments

1. Post-disaster damage & situation assessment
2. Field reconnaissance - damage data collection & visualization
3. Building inventory for loss estimation



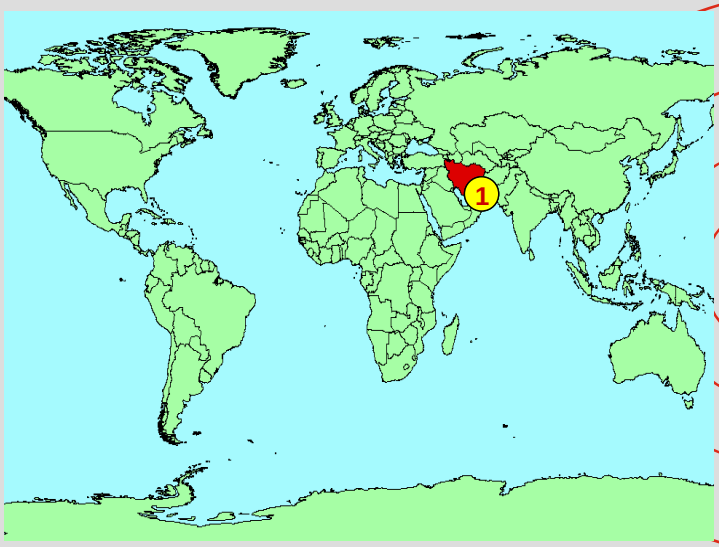
2004-2005 VIEWS Deployments

1. Bam, Iran earthquake
2. Hurricane Charley
3. Hurricane Ivan
4. Parkfield earthquake
5. Niigata, Japan earthquake
6. Thailand, Indian ocean tsunami



1. Bam (Iran) Earthquake

1st VIEWS deployment



1. Bam (Iran) Earthquake

Deployed by
EERI reconnaissance team

Data collected
Geo-referenced photographs

Other uses
Navigating
Identifying hard-hit areas

Remote sensing imagery
Quickbird 60cm before & after

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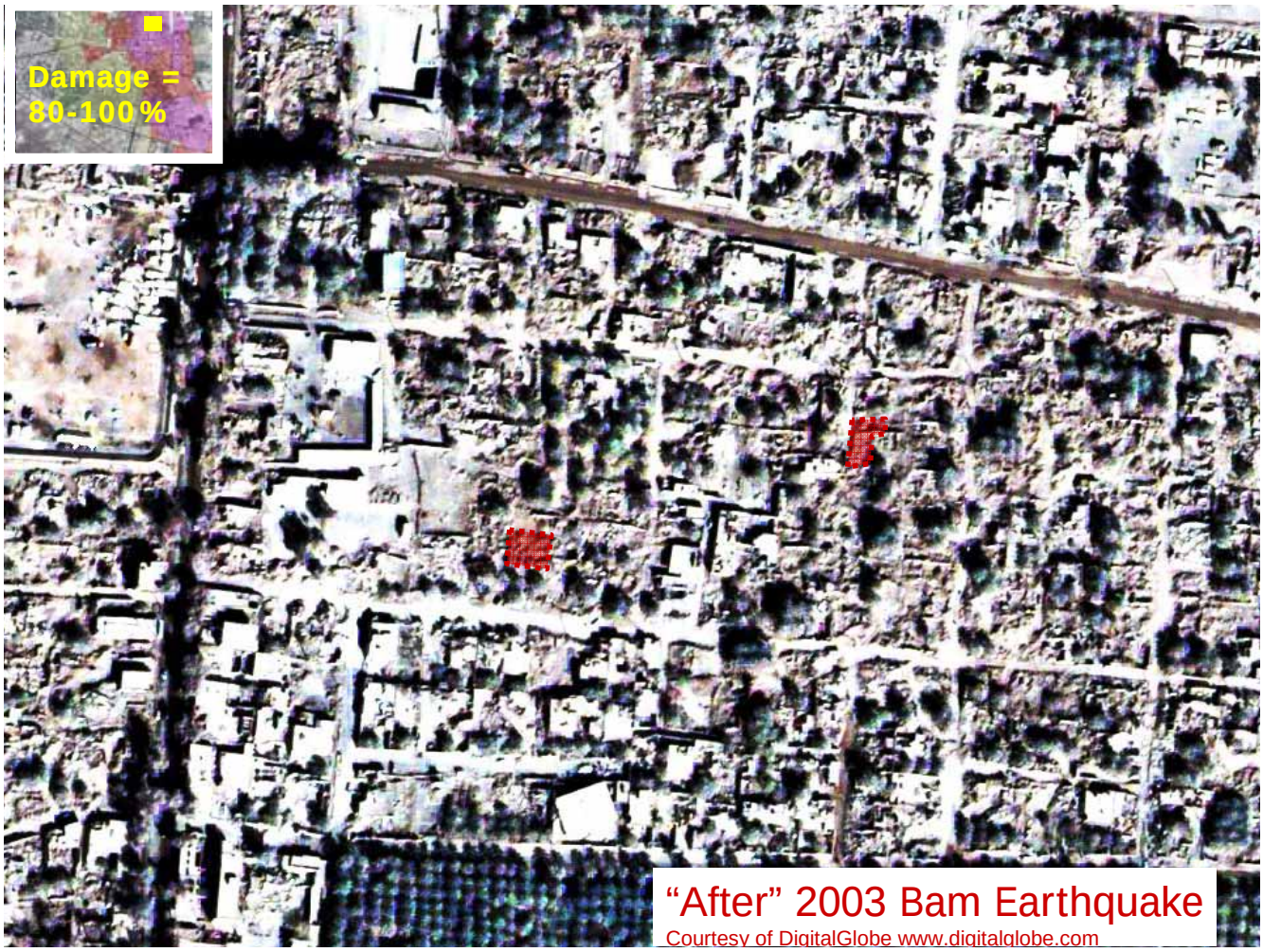
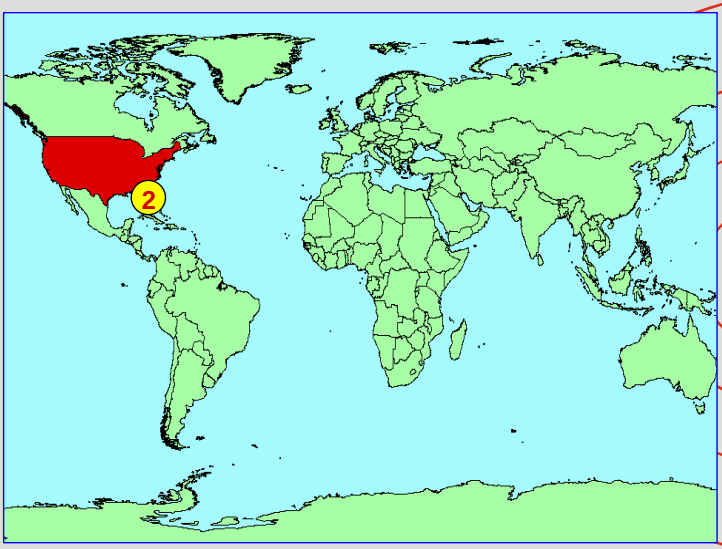
MULTIDISCIPLINARY CENTER FOR EARTHQUAKE ENGINEERING RESEARCH



2. Hurricane Charley

1st VIEWS deployment for hurricane

New geo-referenced video



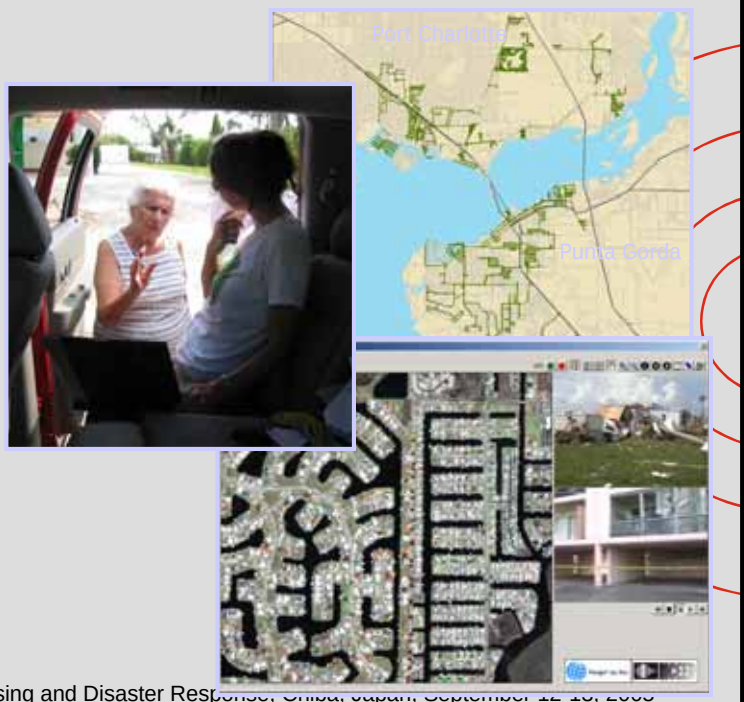
2. Hurricane Charley

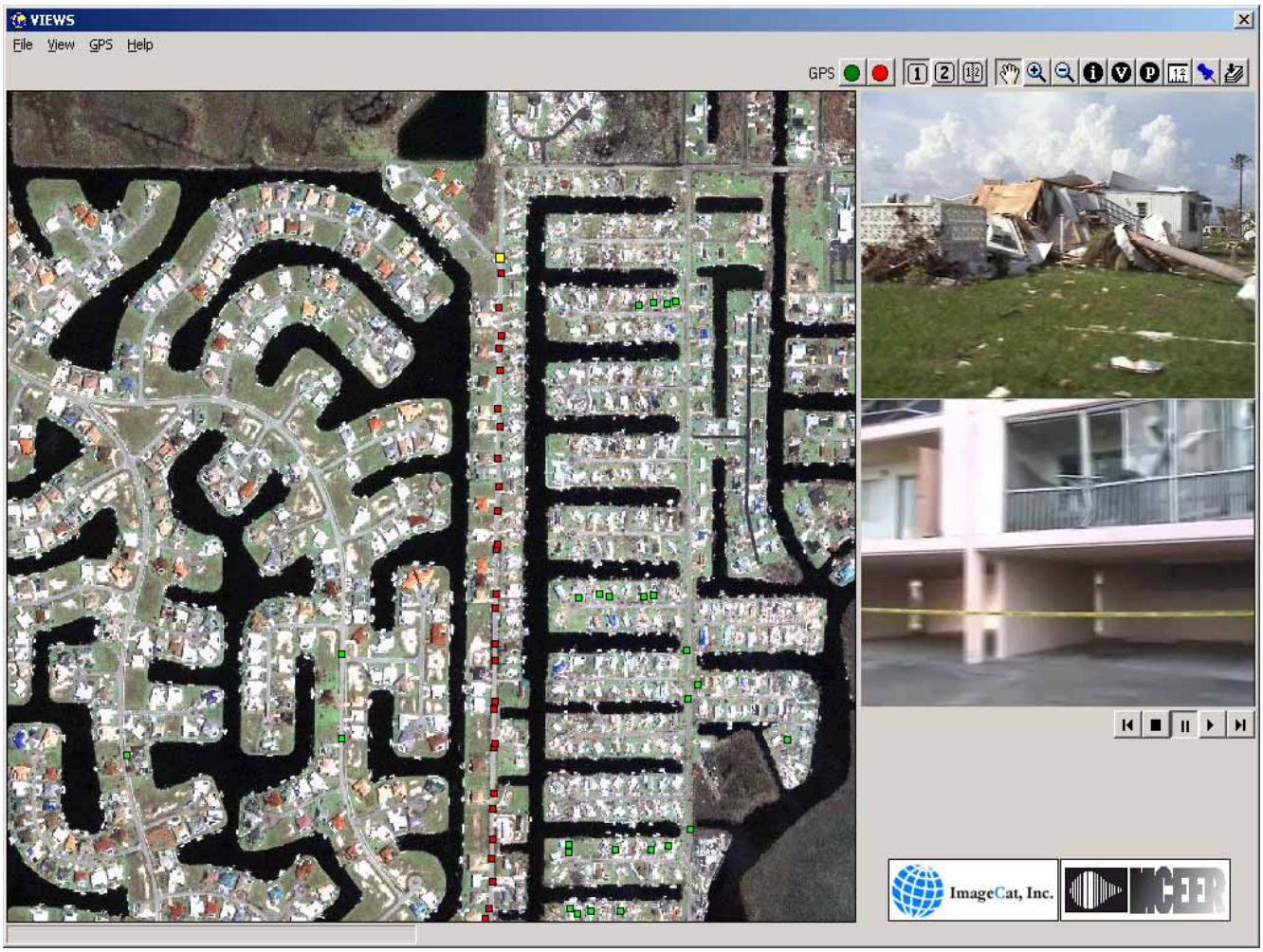
Deployed by
WISE Center, Texas Tech

Data collected
21 hours digital video
930 geo-referenced photographs
~10,000 buildings surveyed

Other uses
Navigating
Identifying hard-hit areas

Remote sensing imagery
Quickbird 60cm before & after



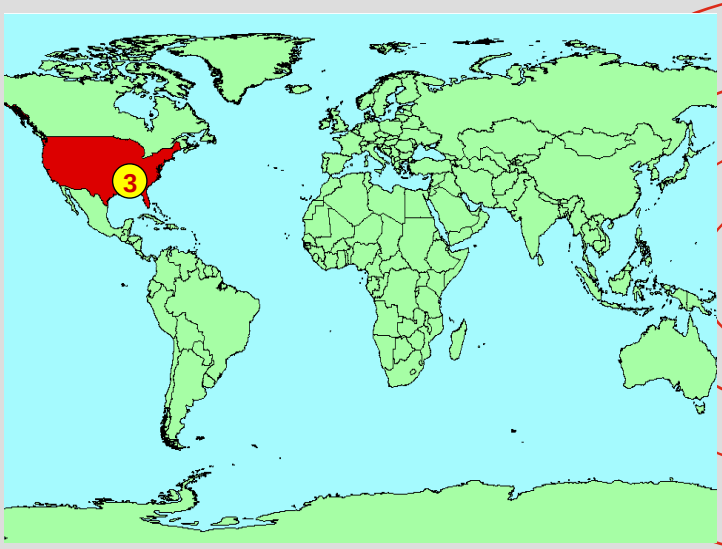


"After" 2004 hurricane Charley

Courtesy of DigitalGlobe www.digitalglobe.com

3. Hurricane Ivan

1st VIEWS deployment for flood damage



3. Hurricane Ivan

Deployed by

WISE Center, Texas Tech

Data collected

13 hours digital video

1,200 geo-referenced photographs

~7,500 buildings on geo-referenced video

Other uses

Navigating

Identifying hard-hit areas

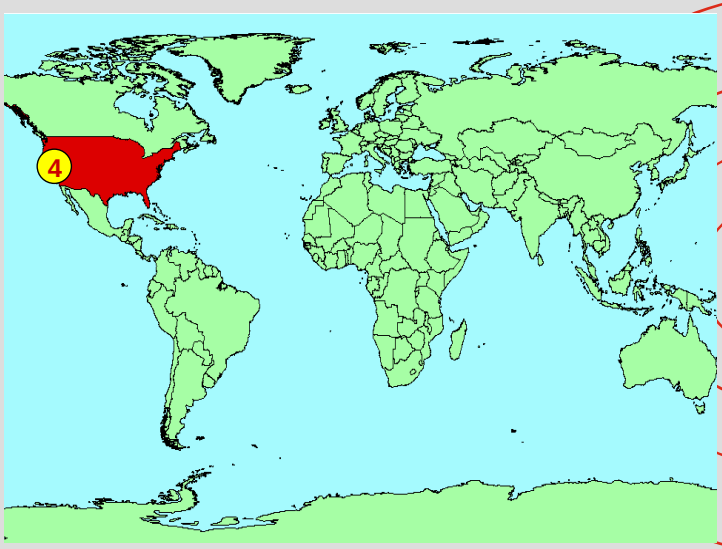
Remote sensing imagery

Quickbird before & after

NOAA aerial photography

4. Parkfield Earthquake

Investigating on-foot survey requirements



4. Parkfield earthquake

Deployed by
EERI reconnaissance team

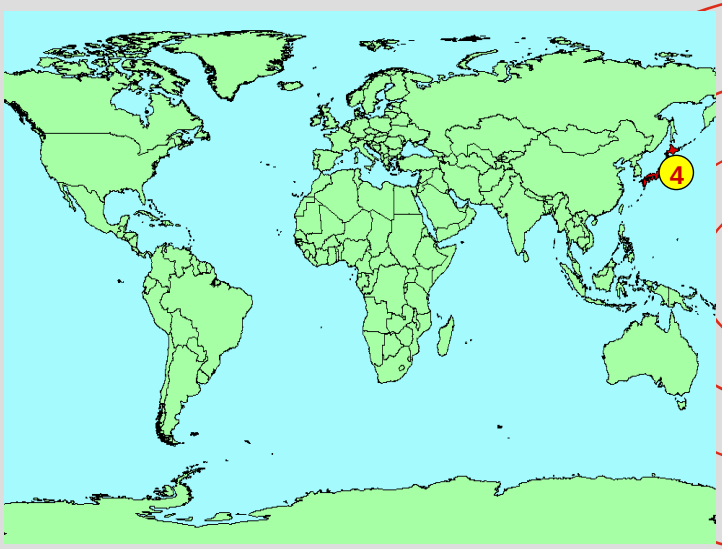
Data collected
2 hours digital video
100 digital photos

Other uses
Inventory damage assessment

Remote sensing imagery
USGS DOQQ

5. Niigata (Japan) Earthquake

1st VIEWS deployment for landslide



5. Niigata (Japan) Earthquake

Deployed by
EERI reconnaissance team

Data collected
10 hours digital video

Other uses
Navigating
Mapping landslides

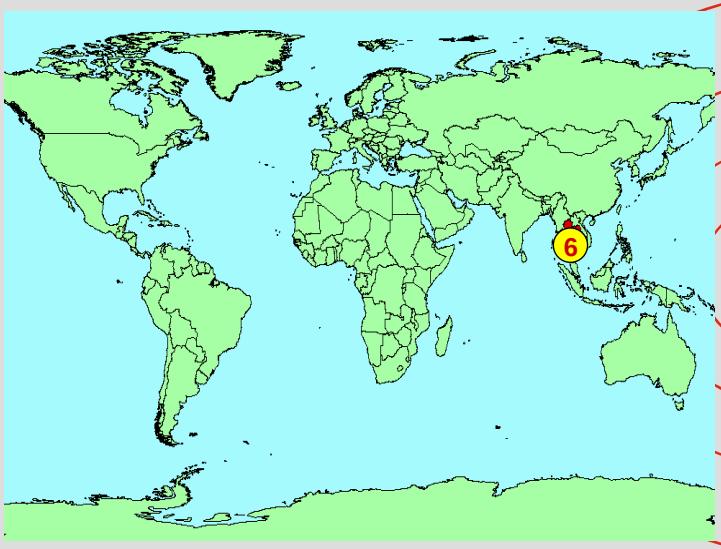
Remote sensing imagery
Quickbird after
IKONOS after

6. Indian Ocean Tsunami

1st VIEWS deployment for tsunami

New 'panoramic' video capture

Hand-held GPS used during on-foot survey



6. Indian Ocean Tsunami

Deployed by
MCEER
Chiba University (Japan)
Asian Institute of Technology

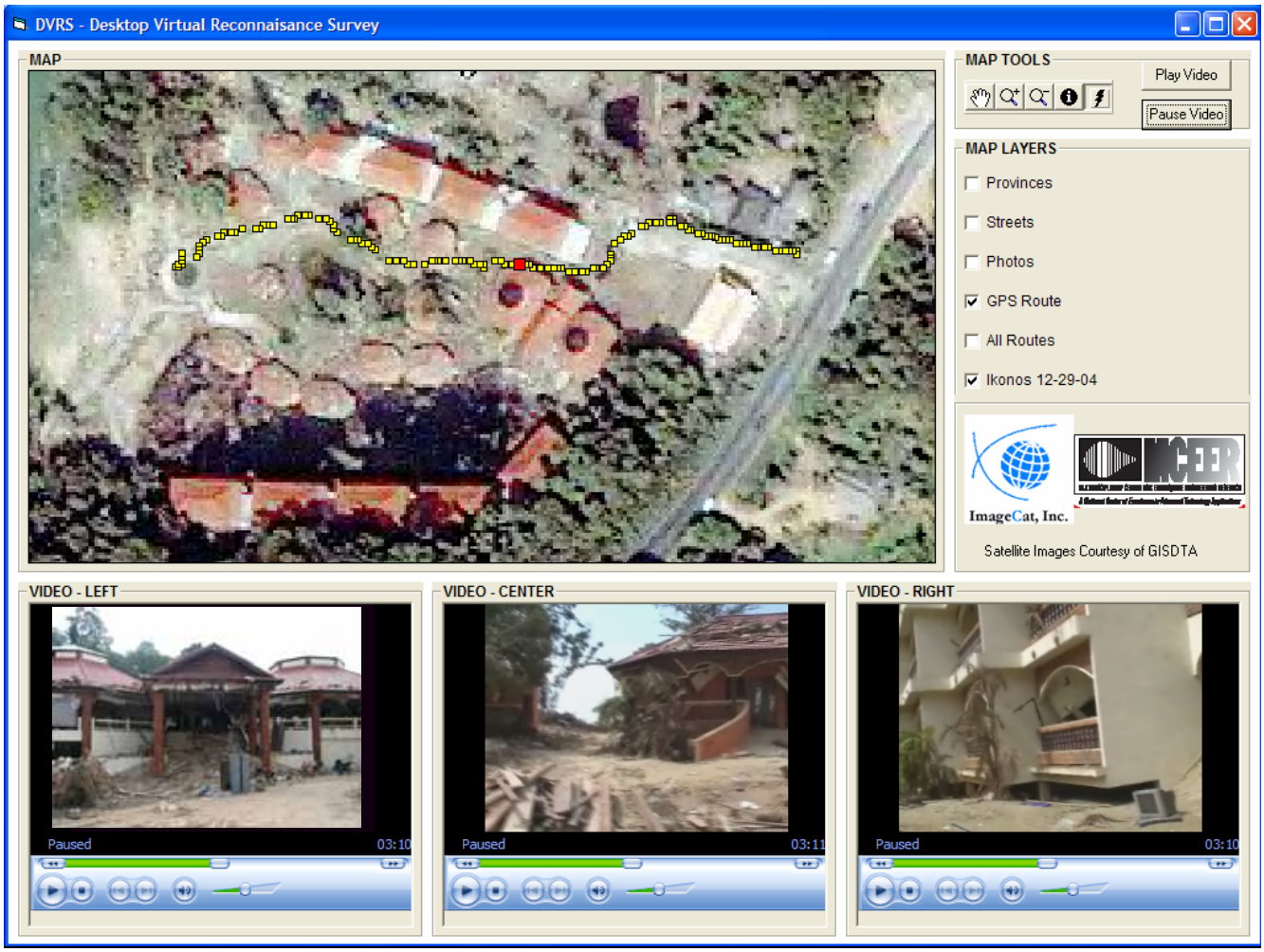
Data collected
11 hours digital video
5 hours panoramic video
1,500 digital photographs

Other uses
Recording flood levels
Navigating

Remote sensing imagery
Quickbird before
Quickbird after
IKONOS after
Landsat after

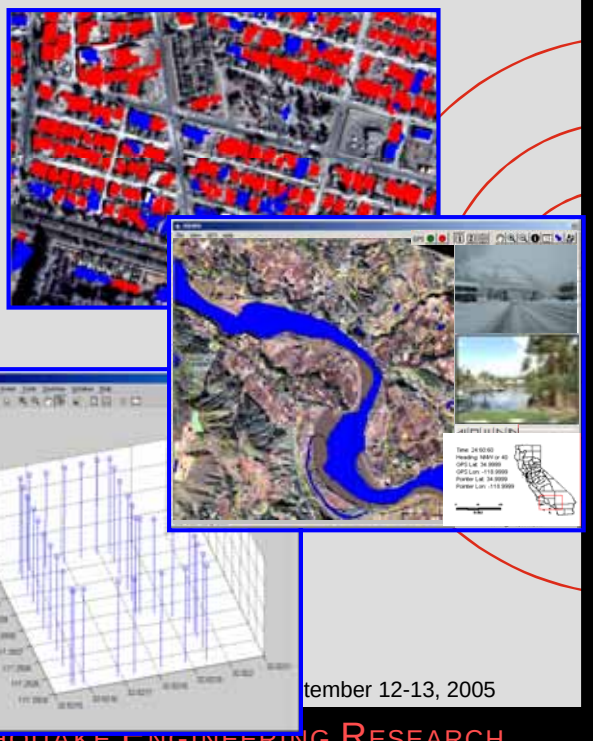
"After" 2004 tsunami - Thailand
Courtesy of Space Imaging / CRISP-Singapore


SURVEY ROUTE: 8 January, 2005
a
b
c
d
KHAOLAK, THAILAND
IKONOS Image 29 December, 2004
courtesy GISDTA, Thailand
a
Completely destroyed Pakarang Cape area resort, Khao Lak, Thailand
b
Heavily damaged Pakarang Cape area resort, Khao Lak, Thailand
c
Heavily damaged Pakarang Cape area government building, Khao Lak, Thailand
d
Heavily damaged mid-Khao Lak area resort, Thailand
Resp
er 12-13, 2005
QUAKE ENGINEERING RESEARCH


DVRS - Desktop Virtual Reconnaisance Survey
MAP
MAP TOOLS
Play Video
Pause Video
MAP LAYERS
Provinces
Streets
Photos
GPS Route
All Routes
Ikonos 12-29-04
ImageCat, Inc.
MCEER
Satellite Images Courtesy of GISDTA
VIDEO - LEFT
VIDEO - CENTER
VIDEO - RIGHT
Paused
03:10
Paused
03:11
Paused
03:10

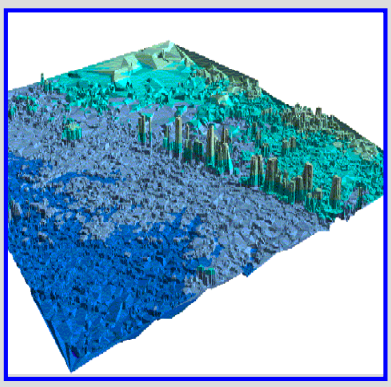
Year 8 Accomplishments

1. Post-disaster damage & situation assessment
2. Field reconnaissance - damage data collection & visualization
3. Building inventory for loss estimation



Theoretical Approaches

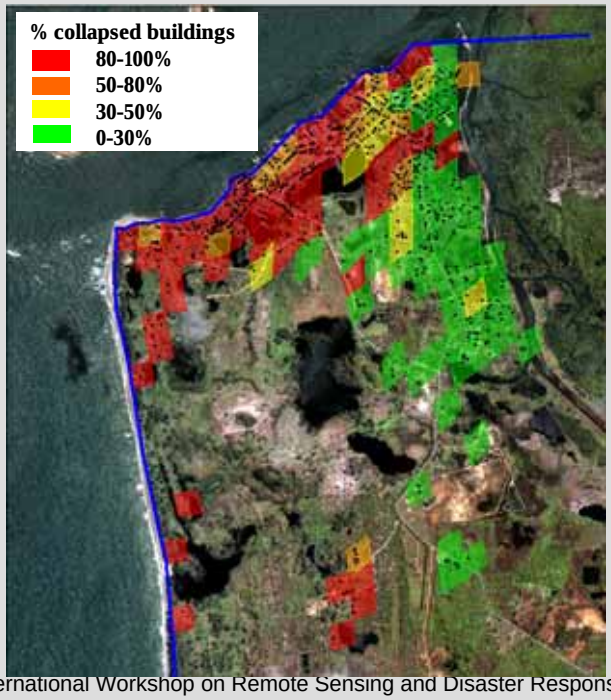
1. IfSAR



2. Stereo satellite imagery

3. Mono satellite imagery

Thailand Damage Mapping



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ImageCat Investigates Tsunami Damage Using DigitalGlobe Satellite Imagery

Longmont, Colo. – Feb. 7, 2005 – DigitalGlobe® announced that ImageCat Inc. is using DigitalGlobe's QuickBird satellite imagery to assess damage resulting from the massive Indian Ocean tsunami that was triggered by an earthquake on Dec. 26, killing more than 226,000 people.

On Jan. 7, ImageCat and the MultidisciplinaryCenter for Earthquake Engineering Research (MCEER) traveled to Phuket, Thailand with engineers from Japan's ChibaUniversity and Bangkok's Asian Institute of Technology to document and analyze the tsunami damage. In Thailand, more than 5,300 people were killed, important tourist destinations were devastated, and the shrimp industry suffered US$500 million in damage.

The team deployed ImageCat's custom-built Visualizing Impacts of Earthquakes with Satellites (VIEWS), a portable notebook-based reconnaissance system that links high-resolution QuickBird imagery, digital photographs and digital video footage to a real-time GPS feed. The team used 60-centimeter QuickBird imagery collected over PatongBeach in Phuket on Jan. 2, 2005, and for comparison purposes, imagery collected in March 2002.

VIEWS is operated with a digital video recorder and digital camera from either a moving vehicle or on-foot, and produces a permanent visual record of damage.

"QuickBird imagery helped identify key landmarks so that we could orient ourselves and navigate the area," said ImageCat's Shubharoop Ghosh, transportation systems analyst, who joined Japan's Professor Fumio Yamazaki and Thailand's Dr. Pennung Warnitchai on the expedition. "By essentially freezing events in time, VIEWS and the imagery helped us reconstruct the site after we returned to our home offices," Ghosh added.

A field report detailing ImageCat's findings is located at:
https://mceer.buffalo.edu/research/tsunami/page1.asp

ImageCat has used QuickBird imagery and the MCEER-funded VIEWS extensively for evaluating disasters, including the Oct. 2004 earthquake in Niigata, Japan; Florida's Aug. 2004 Hurricane Charley and Sept. 2004 Hurricane Ivan; and the Dec. 2003 Bam, Iran earthquake.

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Longmont CO (SPX) Feb 08, 2005

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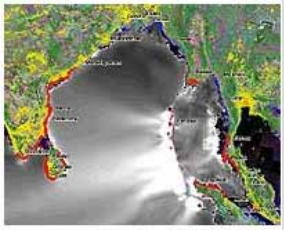

In the image above, areas of potential devastation have been identified by cross referencing population data from NOAA's DMSP sensor (in yellow and orange) with wave height modeled by Vasily Titov at NOAA and proximity to the coastline. The resulting areas (in red) are being used to prioritize the acquisition of high-resolution images from DigitalGlobe.

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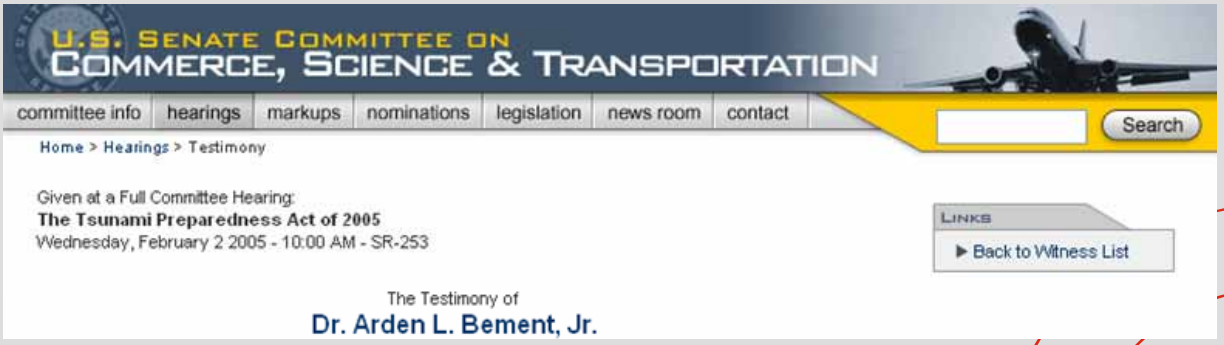

"NSF Earthquake Engineering Research Centers are undertaking work on damage assessment. **The Multidisciplinary Center for Earthquake Engineering Research (MCEER)** sent a team of researchers to Thailand in partnership with the Asian Institute of Technology and the Earthquake Disaster Mitigation Research Center from Japan. Shubharoop Ghosh from ImageCat will join a team led by Prof. Yamazaki of Chiba University. The team is examining impacts of the earthquake and tsunami upon buildings and critical infrastructure. Research is also being supported by the earthquake centers on validating the potential of remote sensing data to accurately assess damage and impacts".

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