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Virtual Earthquakes

Jean-Pierre Bardet

GEER Workshop
UC Berkeley
May 18, 2009

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Acknowledgements

- Dedicated to the late Dr. Cliff Astill, NSF
- Thanks to
  - US National Science Foundation (NSF)
  - GEER, EERI, USGS, and many others
  - Contributors to post-earthquake surveys in Japan, Turkey, Taiwan, India and China
  - Julie Young, Princeton University.

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Outline

1. Past Reports on Earthquakes
2. Virtual Earthquakes
3. Conclusion

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Introduction

- Each time earthquakes strike, researchers, engineers, and scientists discover something they had overlooked in the past and make another successful step toward better understanding these complex natural phenomena.
- Earthquake engineering has evolved in concert with unexplained information collected from field surveys after major earthquakes.
  - 1906 San Francisco, California
  - 1964 Alaska, USA
  - 1964 Niigata, Japan
  - 1971 San Fernando, California
  - 1989 Loma Prieta, California
  - 1994 Northridge, California
  - 1995 Hyogoken Nanbu, Japan
- How did the reports of post-earthquake surveys have evolved with GPS and the Internet?

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1. Reports on Earthquakes
2. Virtual Earthquakes
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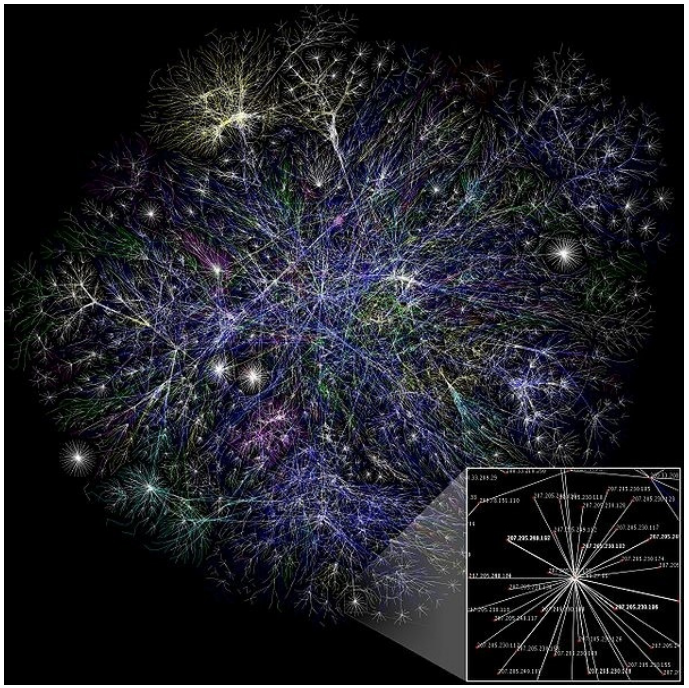
1993 Mosaic, 1994 WWW

- 1980: Born at CERN
- 1993: Mosaic web browser developed by a team at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC).
- April 1994: Mosaic Communications Corporation changed its name to Netscape, and the browser was developed further as Netscape Navigator.
- May 1994: First International WWW Conference,
- September 1994: the World Wide Web Consortium (W3C) is founded
- November 1995: HTML 2.0 was published
- January 1996: Google is a research project at Stanford.
- September 1998: Google Inc.



- Source: Wikipedia

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Evolution of Web Reports

- Prehistory: Hard copy reports
- Early Age: GPS, Mosaic and HTML
- Middle Age: GIS and IMS
- Renaissance: Google, Wikipedia & Photo Metadata
- Future: Virtual earthquakes

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Web reports on GEES website

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- GEER website
- ROSRINE project
- Velacs project
- Useful links

Mw 7.9 earthquake in Sichuan, China on May 12, 2008
Post-earthquake reconnaissance of EERI-GEER team (August 4-8, 2008)

Mw 6.6 earthquake in Japan on October 23, 2004
The preliminary reports of EERI/NSF-GEER released on November 5, 2004.

Mw 7.7 earthquake in India on January 26, 2001
The preliminary report of the National Science Foundation geotechnical reconnaissance team (March 1, 2001).
It includes videos and a GIS/IMS database of photos.

Mw 7.1 earthquake in Turkey on November 12, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (November 25, 1999)

Ms 7.6 earthquake in Taiwan on September 21, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (October 8, 1999).

Ms 7.8 earthquake in Turkey on August 17, 1999
The preliminary report of the National Science Foundation geotechnical reconnaissance team (September 3, 1999).

The Great Hanshin Earthquake Disaster.
The January 17, 1995 South Hyogo Prefecture, Japan, Earthquake
One of the first reports over the Internet sponsored by the National Science Foundation,
originally released in Mosaic on February 5, 1995.

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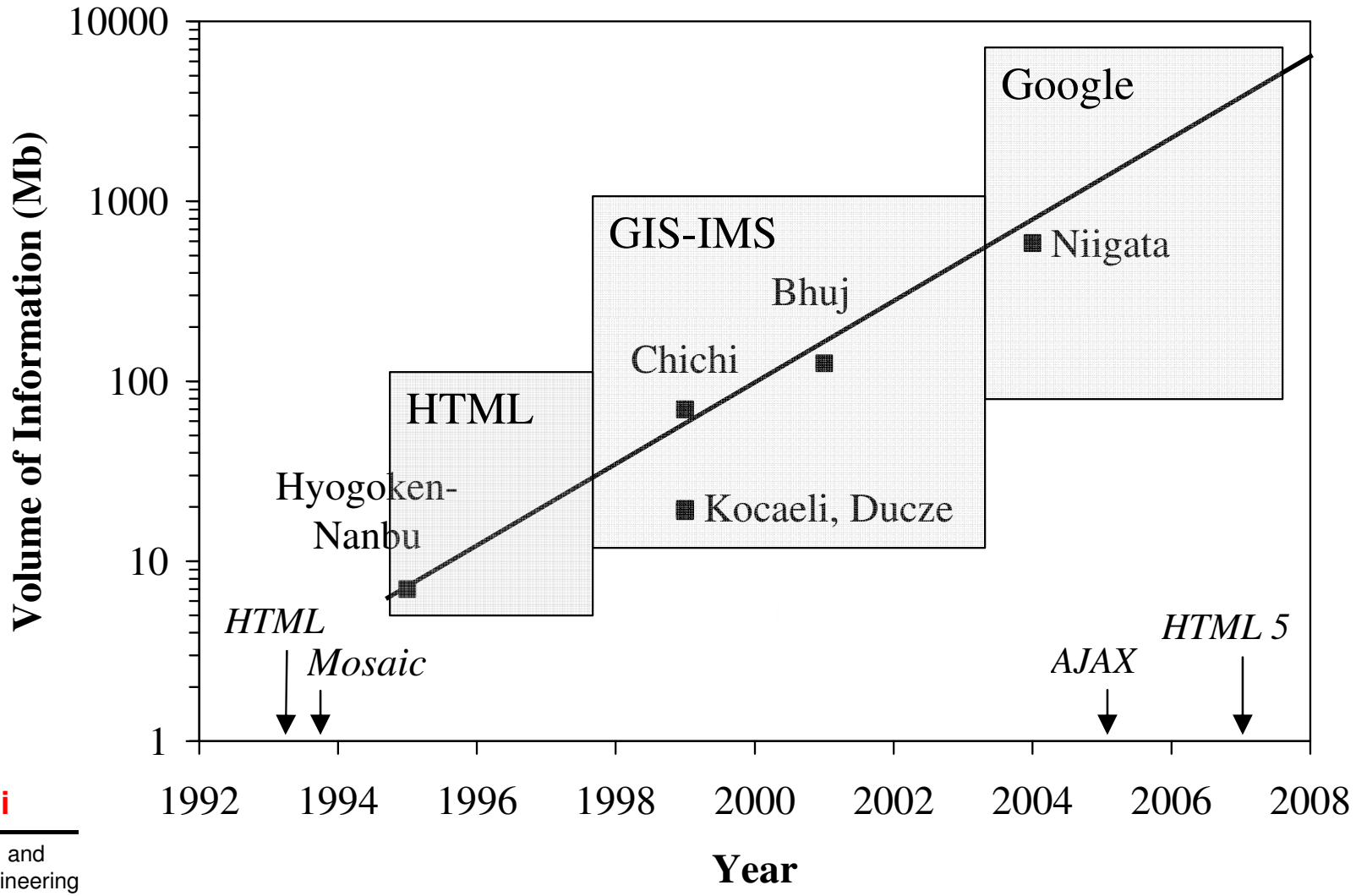
Growth of information on GEES



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Early Internet Documents

The Great Hanshin Earthquake Disaster
The January 17, 1995
South Hyogo Prefecture Earthquake

Preliminary Investigation Report
February 5, 1995

J.P. Bardet
Civil Engineering Department
University of Southern California, Los Angeles, California

and

F. Oka, M. Sugito, and A. Yashima,
Department of Civil Engineer
Gifu University, Gifu, Japa

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5. DAMAGE TO INFRASTRUCTURES, AND RESIDENTIAL AND INDUSTRIAL BUILDINGS

The general location of all the observations (i.e, photographs) made during the earthquake investigation are referred to by using letter A f Fig.5.1.

Residential dwellings and buildings

About 170,000 houses were destroyed or severely damaged in Hyogo Prefecture and Osaka Prefecture (Photo.J2, Photo.J3, Photo.J4, Photo.P3, and Photo.P4). Many office and apartment buildings were also severely damaged. The number of refugees is reported to be in excess of 300,000.

Industrial buildings and factories

A large number of 7-12 floor reinforced concrete office buildings were damaged at middle or top floors (Photo.E1, Photo.E2, Photo.E3, Photo.E4, Photo.E5, Photo.E6, Photo.E7, and Photo.E8). A large number of factories have been rendered inoperative by the earthquake, either directly by the destruction of their facilities, or indirectly by the interruption of their supply lines. The port of Kobe, which is the second largest port of Japan, was shut down. In Kobe, in contrast to Los Angeles, supplies are difficult to move through alternate routes. The damage to the traffic network in that small and narrow area where the mountains close in on the sea cannot be compared with Los Angeles where detours were possible when expressways collapsed during the 1994 Northridge Earthquake. The earthquake has been called Japan's greatest postwar disaster. At the present, it is difficult to assess the total amount of damage to the Japanese economy.

Railways lines and bridges

There are four major railways companies that operate in the Hyogo Prefecture. Their lines are referred to as Sanyo Shinkansen line, Japan Railways (JR) line, Hankyu line, and Hanshin line. Railway lines, including the fast train (Shinkansen) line, were severely damaged. Many b decks and girders of railway lines moved transversely or dropped down to the ground (Photo.E9, Photo.J1, Photo.J5, Photo.J6). A large nu of reinforced concrete bridge piers were destroyed or severely damaged (Photo.L1, Photo.L3, Photo.L5, Photo.P1, and Photo.P2). These damaged piers severely deformed the railway tracks above them (Photo.J1). At 5:46 AM on January 17, 1995, most trains were fortunately yet moving. However, derailment still took place at Sumiyoshi Station of Hanshin railway line. At least 500 m of railways were damaged between Shukugawa Station and Nishinomiya-Kitaguchi Station of Hankyu line. The Sanyo Shinkansen line was damaged in the Kamioich area in Nishinomiya and Ashiya City (Photo.L1, Photo.L2, Photo.L3, Photo.L4, Photo.L5, Photo.L6, Photo.L7, and Photo.L8).

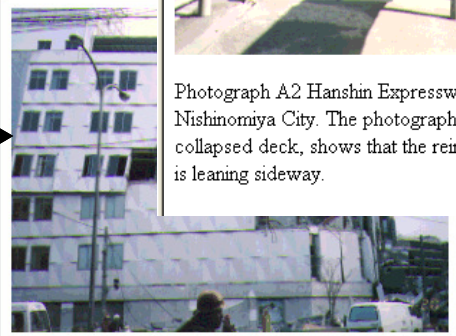
Highway bridges

Highway bridges sustained severe damage during the South Hyogo Prefecture Earthquake. The locations of representative bridge failures a shown in Fig.5.2. The main failures are summarized in the following section.

1. Route 43 (Iwaya Viaduct-Kobe, Nada district). Reinforced Concrete columns of Iwaya Viaduct collapsed, and the superstructure fell dow (Photo.I1, Photo.I2, Photo.I3, and Photo.I4).
2. Route 171 (Mondo Viaduct, Nishinomiya). Mondo Viaduct is a long span bridge which overpasses an Hankyu Railway line. The upper de the crossover fell down onto the railway (Photo.K1, Photo.K2, and Photo.K3).
3. Route 2 (Hamate Bypass). The upper deck of this double deck bridge shifted transversely to the north, and almost fell down (Photo.D5).
4. Hanshin Expressway Route 5, Wangan Line (Nishinomiya-Harbor Bridge, east closure span, Nishinomiya). The span length of the Nishinomiya Harbor bridge is 252 m. The closure span on the eastern side of the bridge collapsed, the bridge support failed, and the girder partially buckled (Photo.5.1, Photo.C1, Photo.C2, Photo.C3, Photo.C4, Photo.C5, Photo.C6, Photo.C7, Photo.C8 and Photo.C9).
5. Hanshin Expressway Route 3, Kobe line (Kobe, Nada district, Fukae-Honmachi-Ashiya, Hirata) In the Fukae-Homachi area, a 500 mete section of Route 3 completely collapsed in the transverse direction onto National Road Route 43.
6. Hanshin Expressway Route 3, Kobe line (Nishinomiya, Tateishi junction). A steel bent buckled during the earthquake.
7. Hanshin Expressway Route 3, Kobe line (Nishinomiya, Hamawaki-cho, Satsuba area). The restrainer of the girder failed, and two spans between Bents P40 and P42 collapsed.
8. Hanshin Expressway Route 3, Kobe line (Nishinomiya, Koshien Takashio-cho). A reinforced concrete Bent P267 collapsed (Photo.A1,

Photograph I3 Route 43 Iwaya overpass. Viewed from the north, the deck north.

Photograph A2 Hanshin Expressway Bridge in Nishinomiya City. The photograph, taken under the collapsed deck, shows that the reinforced concrete pier is leaning sideway.



Photograph E7 Vicinity of Sannomia Station. The fourth floor of this six-storey building partially failed.

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1999 Kocaeli, Turkey, Earthquake

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The August 17, 1999, Kocaeli, Turkey, earthquake

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Preliminary Reports of the Turkey-US Geotechnical Earthquake Engineering Reconnaissance Team
Sponsored by the National Science Foundation

Reconnaissance Report (View/Download PDF version, 14 MB)

- Summary
- Aerial survey over Izmit, Adapazari, Lake Sapanca, Golcuk, Yalova and Lake Iznik (August 24, 1999)
- Adapazari and its southern vicinity (August 25, 1999)
- Southern coast of Marmara Sea including Yalova, Karamursel and Halidere (August 26, 1999)
- Sapanca lake and Adapazari (August 27, 1999)
- Golcuk and its vicinity (August 28, 1999)
- Avcilar (August 29, 1999)

Map Server

Useful links

Maps

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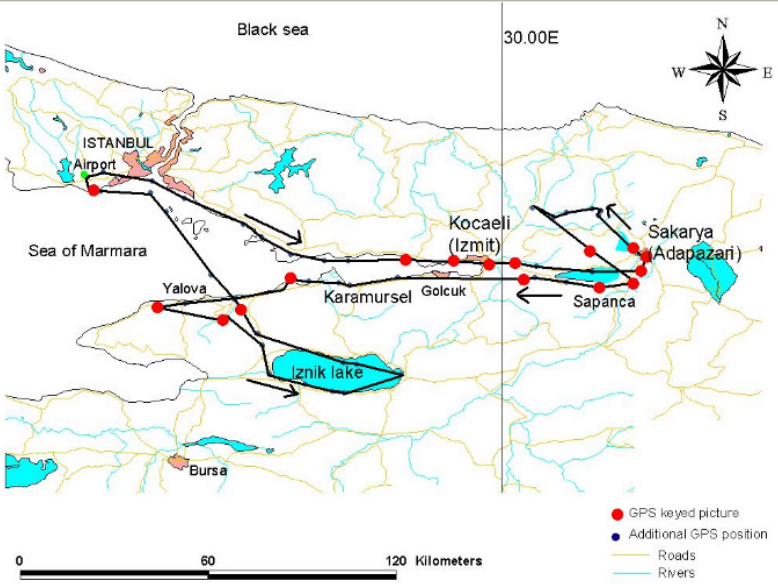

The flight path initiated from the Istanbul airport to the west and went over the Izmit and Derince areas, Adapazari, Sapanca Lake, Golcuk, Karamursel, Yalova, and the Iznik lake.

Izmit and Derince areas

Overview of the TUPRAS refinery along the Izmit Bay after the fire that started right after the earthquake on August 17, 1999 (N40°45.938', E29°33.684', 8/24/99, 15:23:17).

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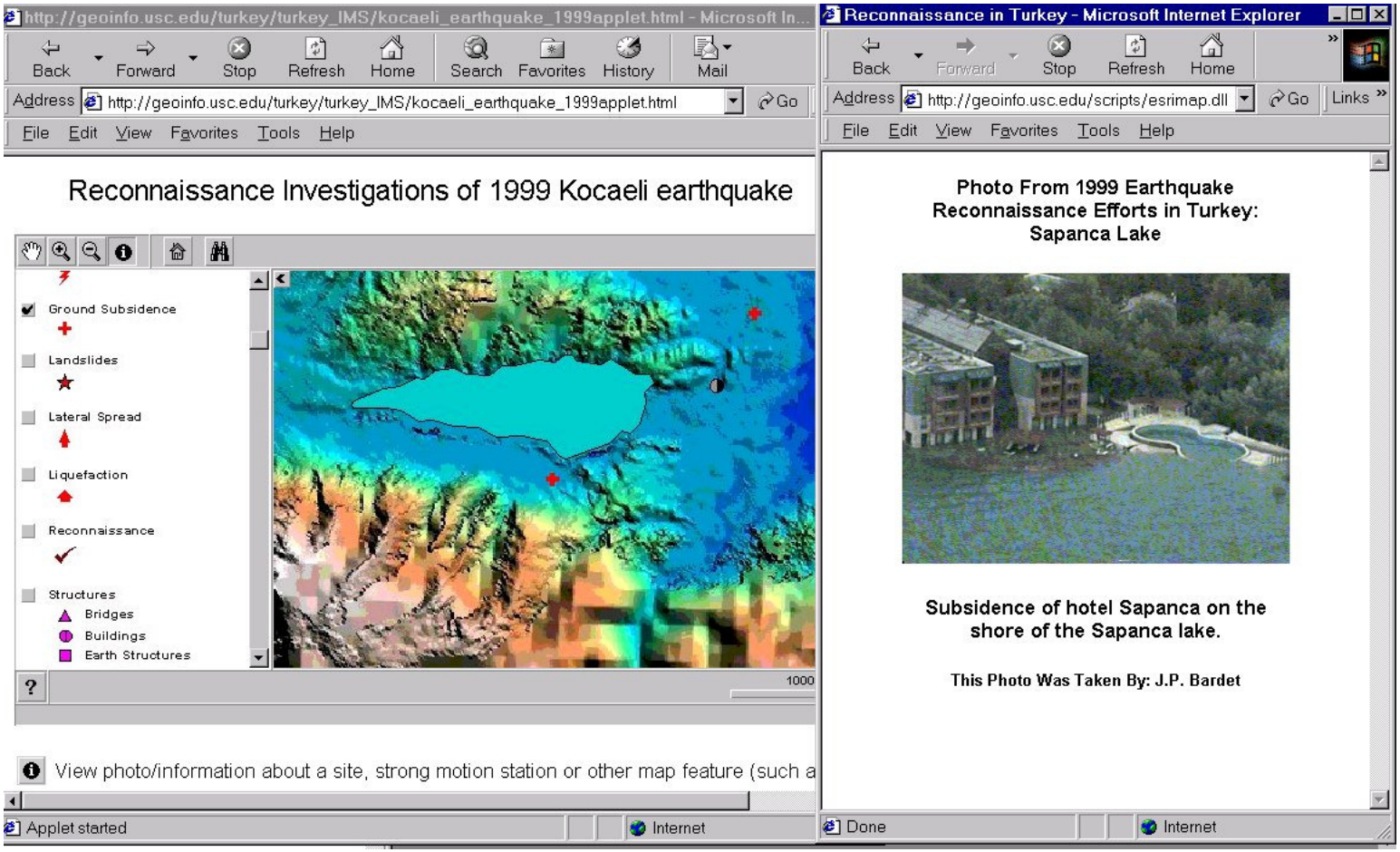
GIS-IMS Kocaeli, Turkey, Earthquake



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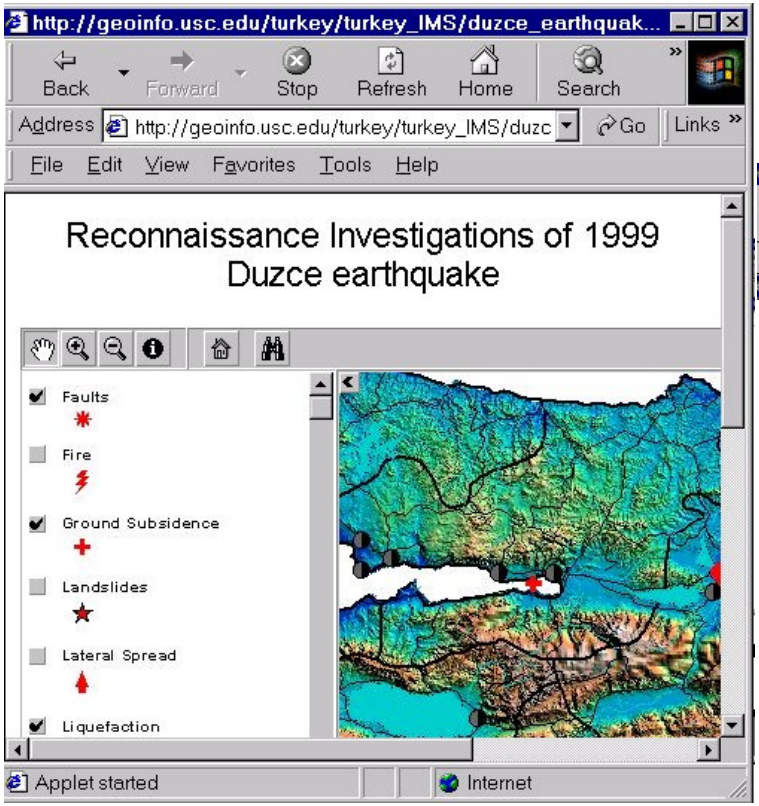
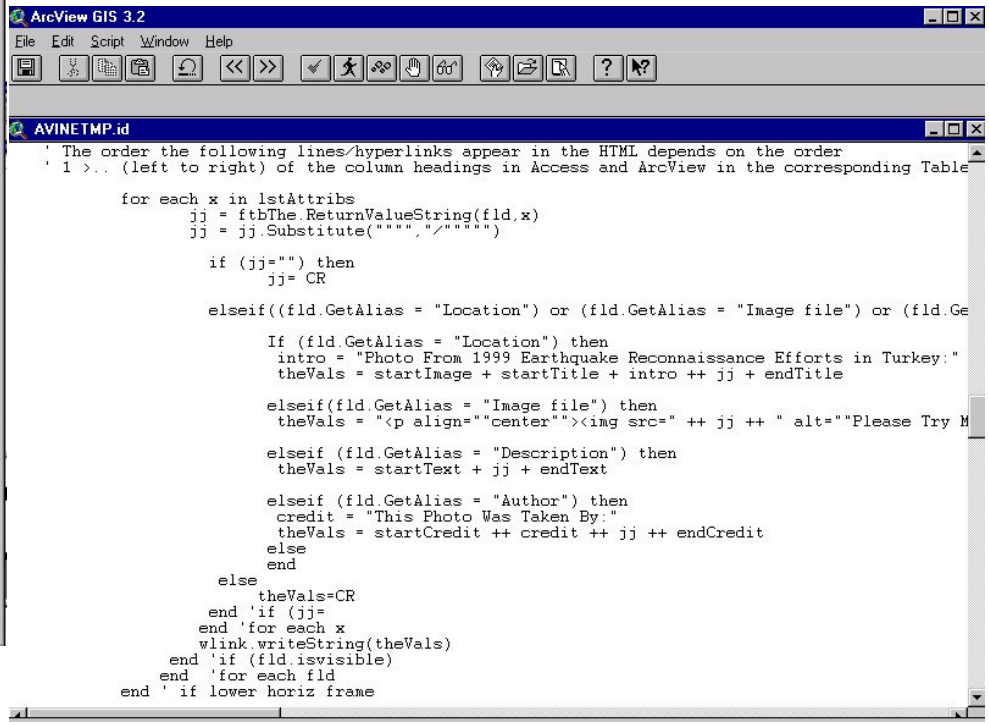
ArcView IMS Programming





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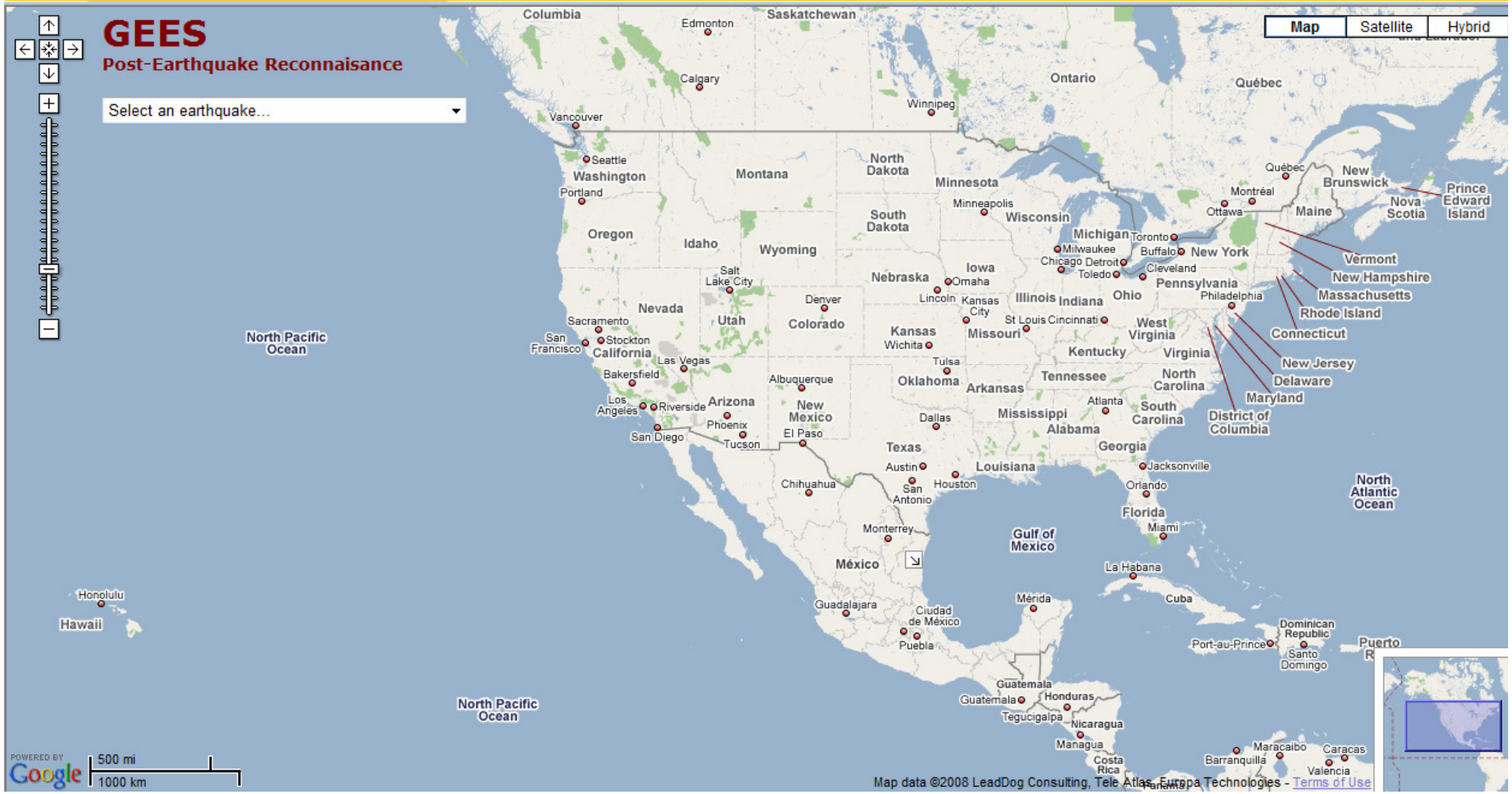
Renaissance: Google Maps



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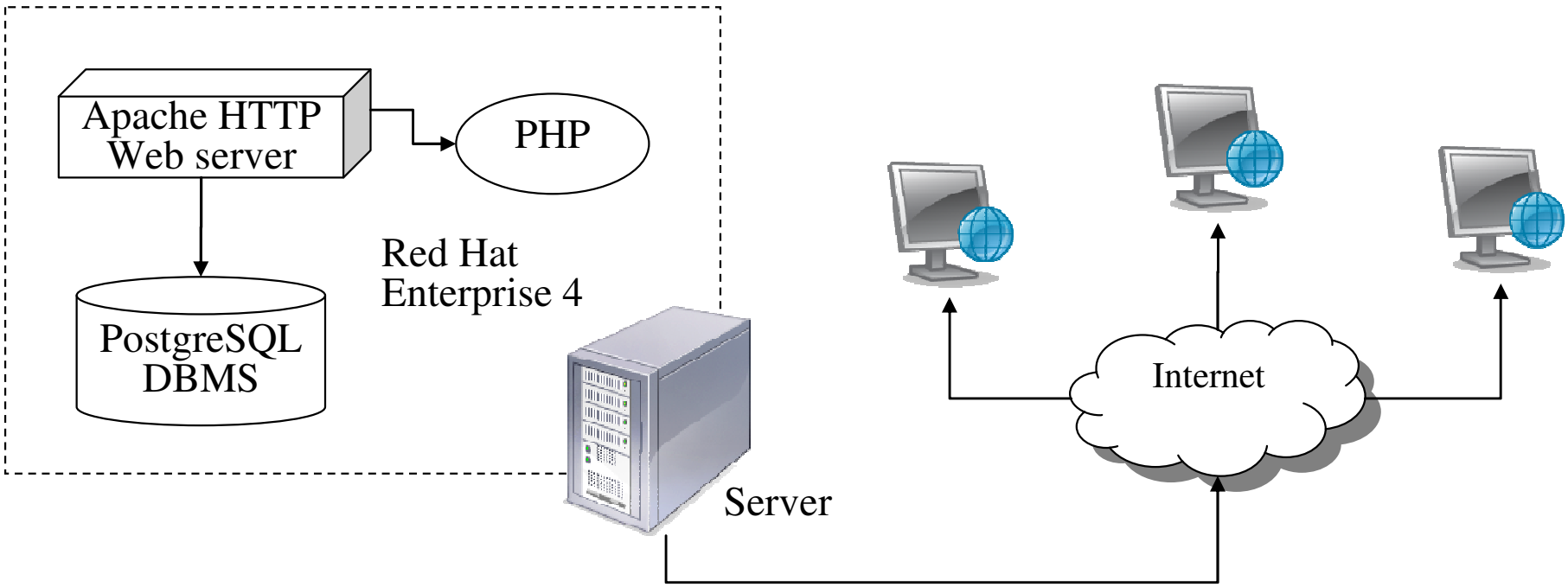
Serving Spatial Data with Google



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Google: 1999 Kocaeli, Turkey, Earthquake

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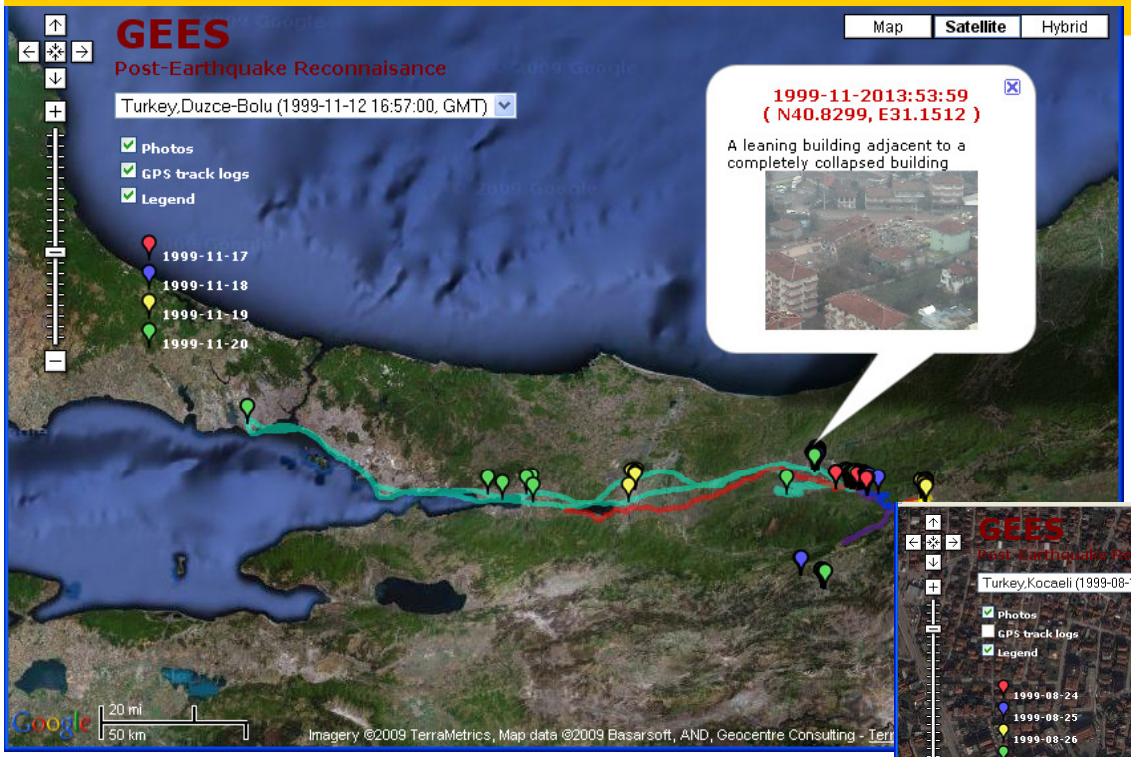

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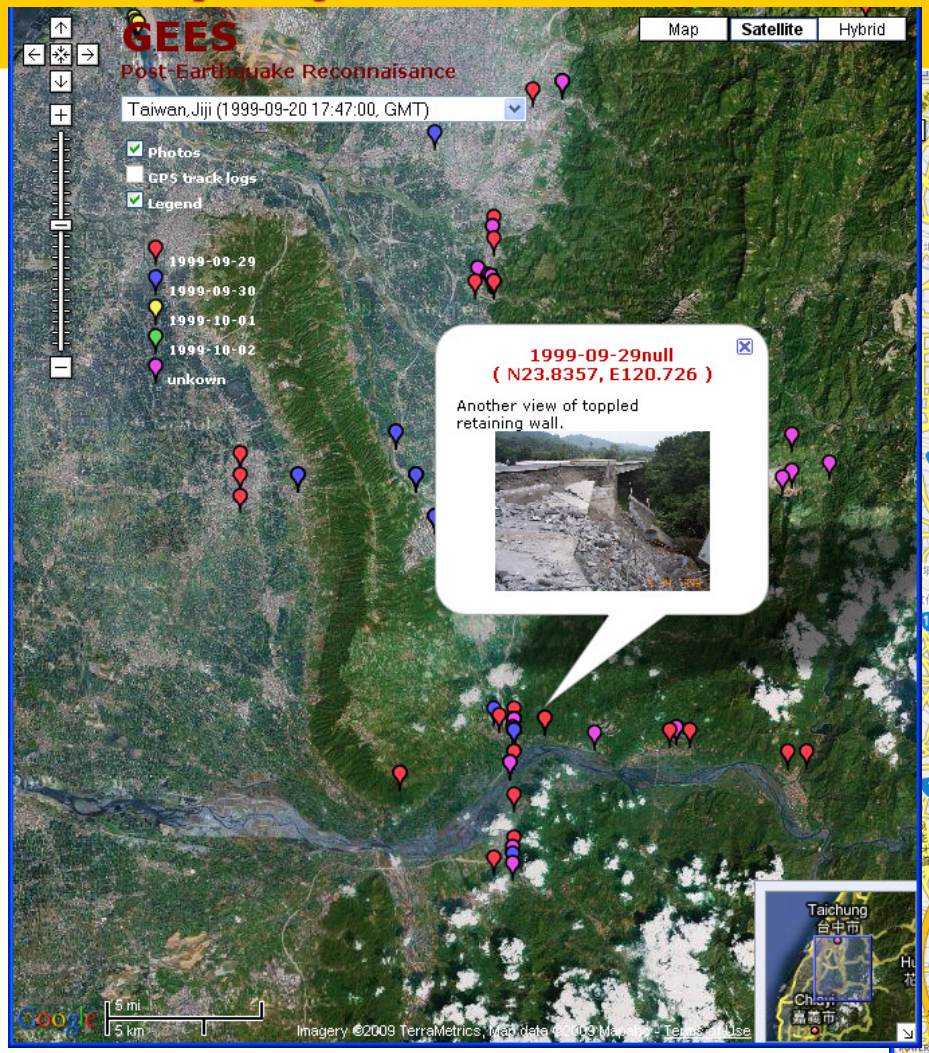

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11. Close-up view of headscarp above collapsed bridge (N24.2854 E120.7969).

12. Collapsed bridge spans near Highway 129/136 intersection near Taiping (N 24.1335 E120.7352). The longitudinal direction for the bridge has an azimuth of approximately 300 degrees. The fault is known to pass beneath the bridge based on exposures west and east of the spans, but its precise location is unknown due to grading near the bridge. View in photo is to the NE. Note the spans have been pushed to the SE (to the right in the photograph) off their supports, possibly from compression associated with the faulting.

Bridges across Tachia River and to the South along Highway 3

1. Waterfall created by reverse fault movement just north of the south abutment of heavily damaged multi-span bridge north of City of Fengyuan and to the west of the Shihkang Dam (N 24.2786 E 120.7592; 9/30/99)

2. View to south showing right lateral offset of about 3 to 4 m and uplift or about 4 to 5 m in this bridge (N 24.28 E 120.76; 9/30/99)

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2001 Bhuj, India, Earthquake

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The Bhuj, India, Earthquake of January 26, 2001

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Preliminary Report of the India-US Geotechnical Earthquake Engineering Reconnaissance Team
Sponsored by the US National Science Foundation in collaboration with the Earthquake Engineering Research Institute (EERI) and the Mid America Earthquake (MAE) Center

- Introduction
- Reconnaissance flight
- Damage to towns and villages
  - Anjar
  - Bhachau
  - Bhuj
- Damage to dams
- Damage to ports
  - Kandla
  - Navlakhi
  - Adani
- Damage to bridges
  - Surajbari bridges
  - Highway 8A bridge
- Ground failure, liquefaction and cracking
  - South of Chang dam and North of epicenter (February 17, 2001)
  - East of Lodai
  - Rann of Kachchh (February 16, 2001)
  - Rann of Kachchh (February 18, 2001)
- GIS database server of photos from post-earthquake reconnaisance
- Videos from earthquake reconnaisance
- PowerPoint presentations
  - Bardet's presentation
  - Bardet's presentation at EERI briefing on April 4, 2001
  - Singh's presentation in San Diego

Additional Information

Figure 1. In Ahmedabad, the aircraft used for flight over, and the aerial survey reconnaissance team. From left to right, Colonel H. Singh, J. P. Bardet, Capt. Rajiv Nanavaty, and J. P. Singh (2/12/01 6:18:56 PM, N23.06806 E72.61980).

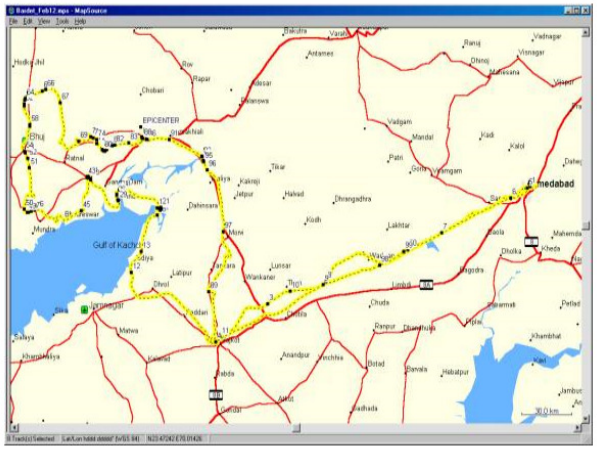

Figure 2. Flight path of February 12, 2001: Ahmedabad, Rajkot, Bhuj (Southern route), Rajkot (Northern Route), and back to Ahmedabad (straight route).

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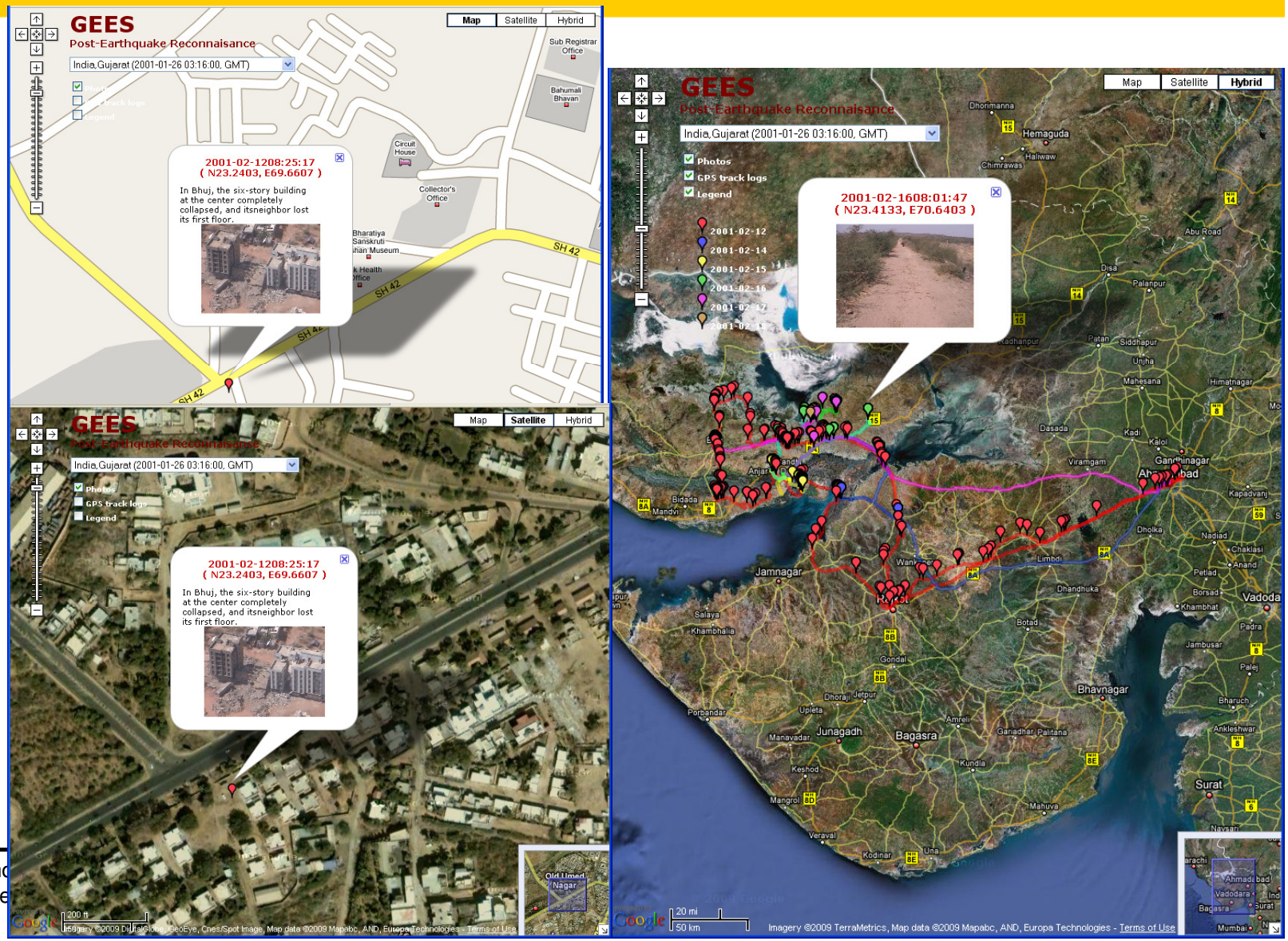
2001 Bhuj, India, Earthquake



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October 23, 2004 Niigata-ken Chuetsu Earthquake, Japan

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Report of the first reconnaissance team (October 30-November 2, 2004)

- Introduction
- EERI-GEER reconnaissance flight of October 30, 2004
- Hasshu reconnaissance flight of October 25, 2004
- Field reconnaissance of October 31, 2004 (White Rock slide, Shinkansen derailment, and damage to Shinkansen bridge)
- Field reconnaissance of November 1, 2004 (Landslides to the North of earthquake area, East of Nagaoka)
- Field reconnaissance of November 2, 2004 (Landslides to the South of earthquake area, North of Kawaguchi)

- GIS database of photos from post-earthquake reconnaissance
- Videos from earthquake reconnaissance
- PowerPoint presentations

Report of the second reconnaissance team (November 16-20, 2004)

- Field Reconnaissance of November 16, 2004 (Damage Observations throughout Affected Area)
- Field Reconnaissance of November 17, 2004 (Landslides east of Yamakoshi Village)
- Field Reconnaissance of November 18, 2004 (LIDAR System of Debris Flow)
- Field Reconnaissance of November 18, 2004 (Embankment Fill Failures in Takamachi Residential Area)
- Field Reconnaissance of November 19, 2004 (Landslides: South Yamakoshi and East Ojiya)
- Field Reconnaissance of November 20, 2004 (Reconnaissance of Possible Fault-related Surface Deformation)
- Field Reconnaissance of November 20, 2004 (Reconnaissance of Komatsugura Landslide Dam)

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Figure 14. One of the possible explanations proposed for the Shinkansen derailment was the large amplitude of the transient viaduct displacement induced by the softening of the liquefied ground (10/31/2004 10:04:42 AM, N37.39094 E138.84270).

Figure 15. The last car of the Shinkansen was leaning on its side (10/31/2004 10:21:12 AM, N37.39063 E138.84570).

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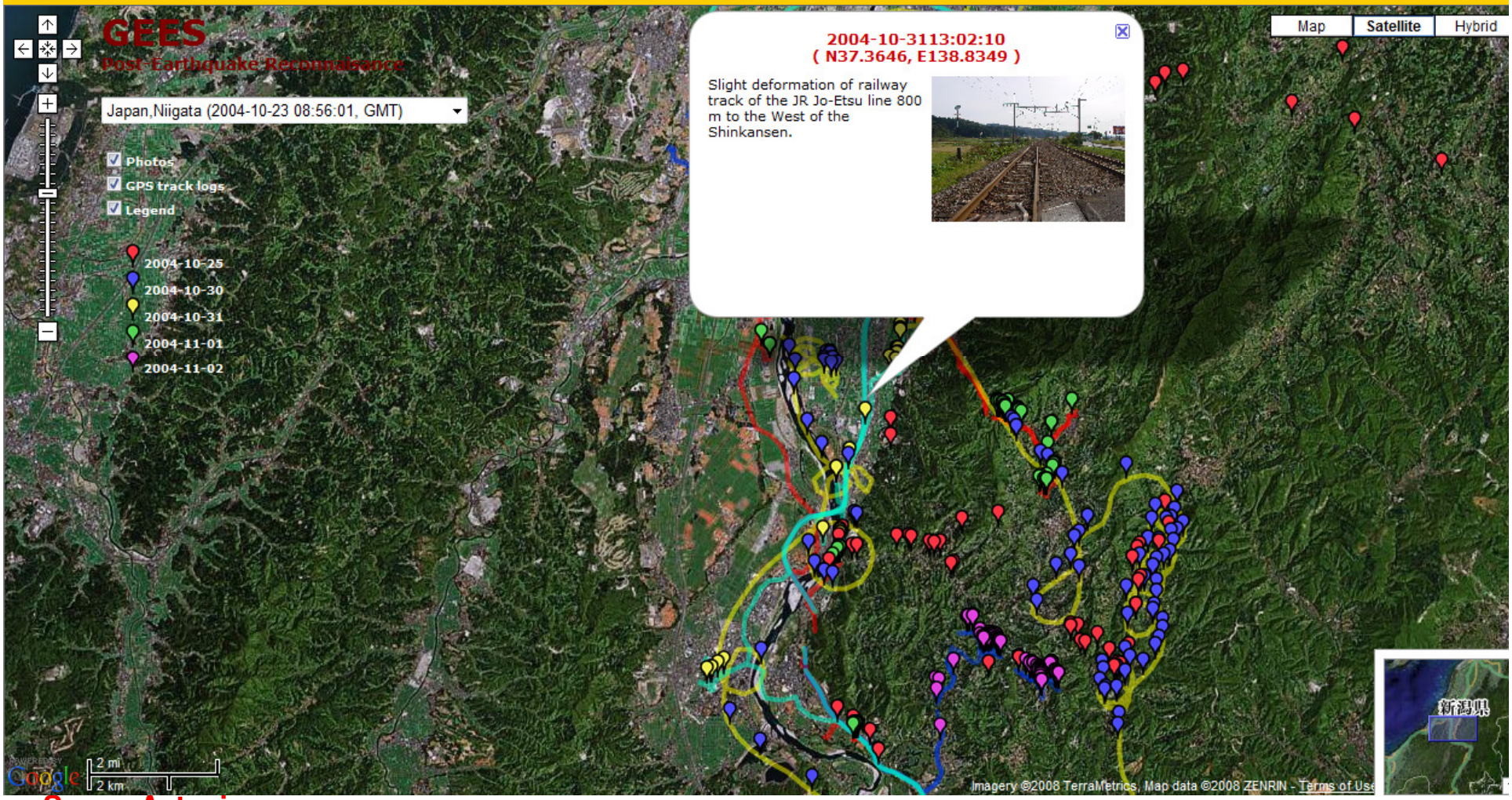
2003 Niigata-Chetsu Earthquake



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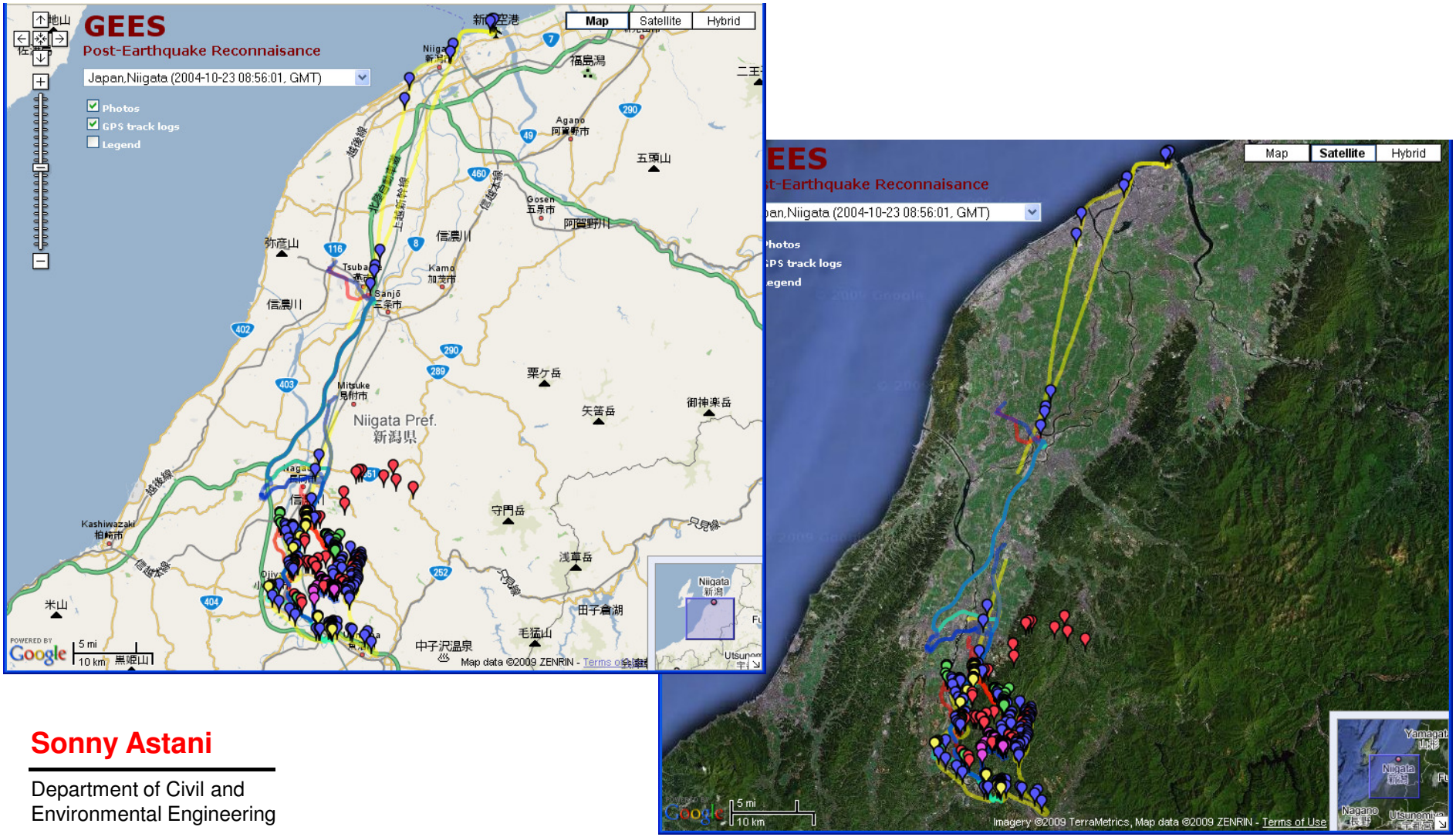

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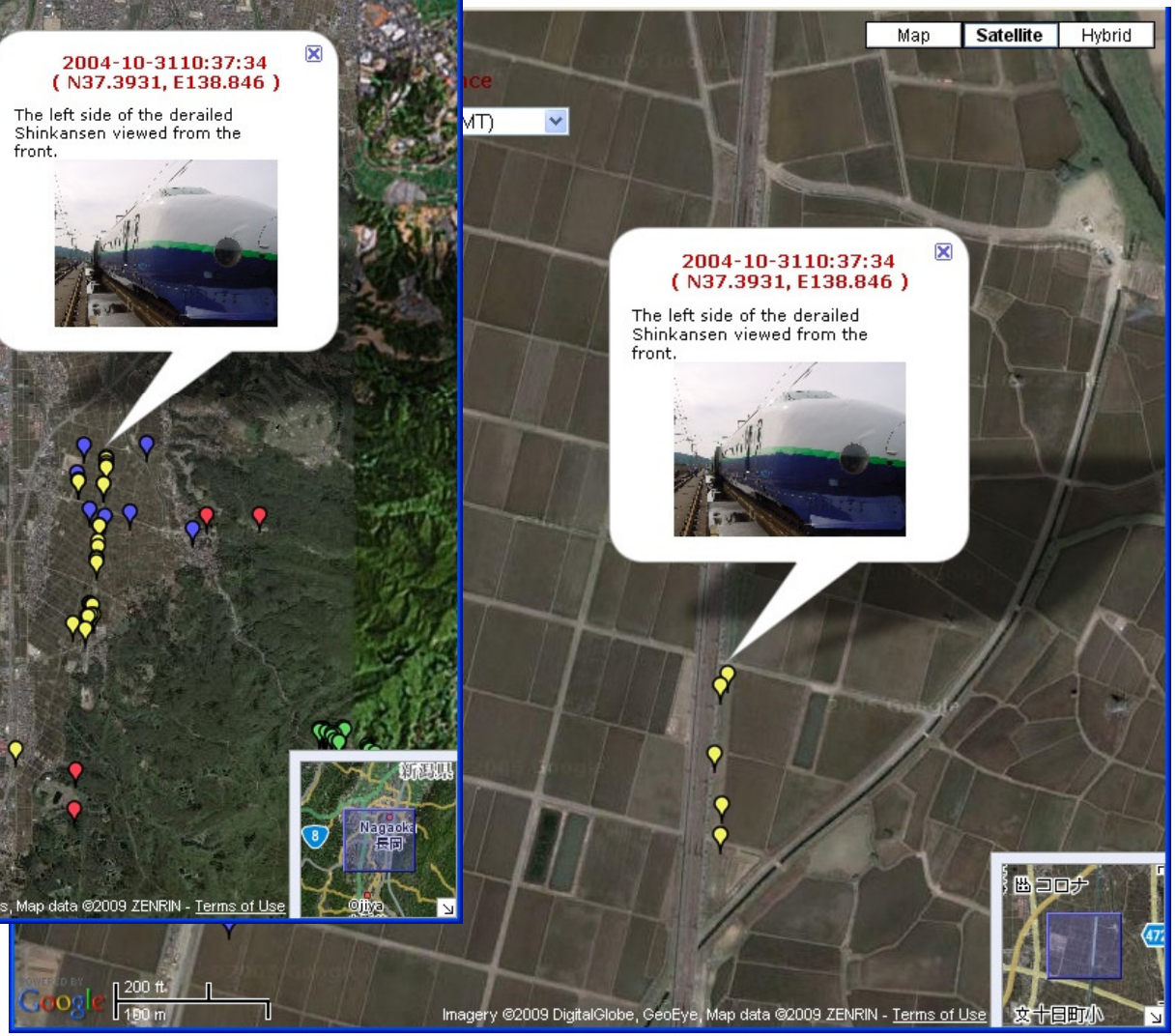

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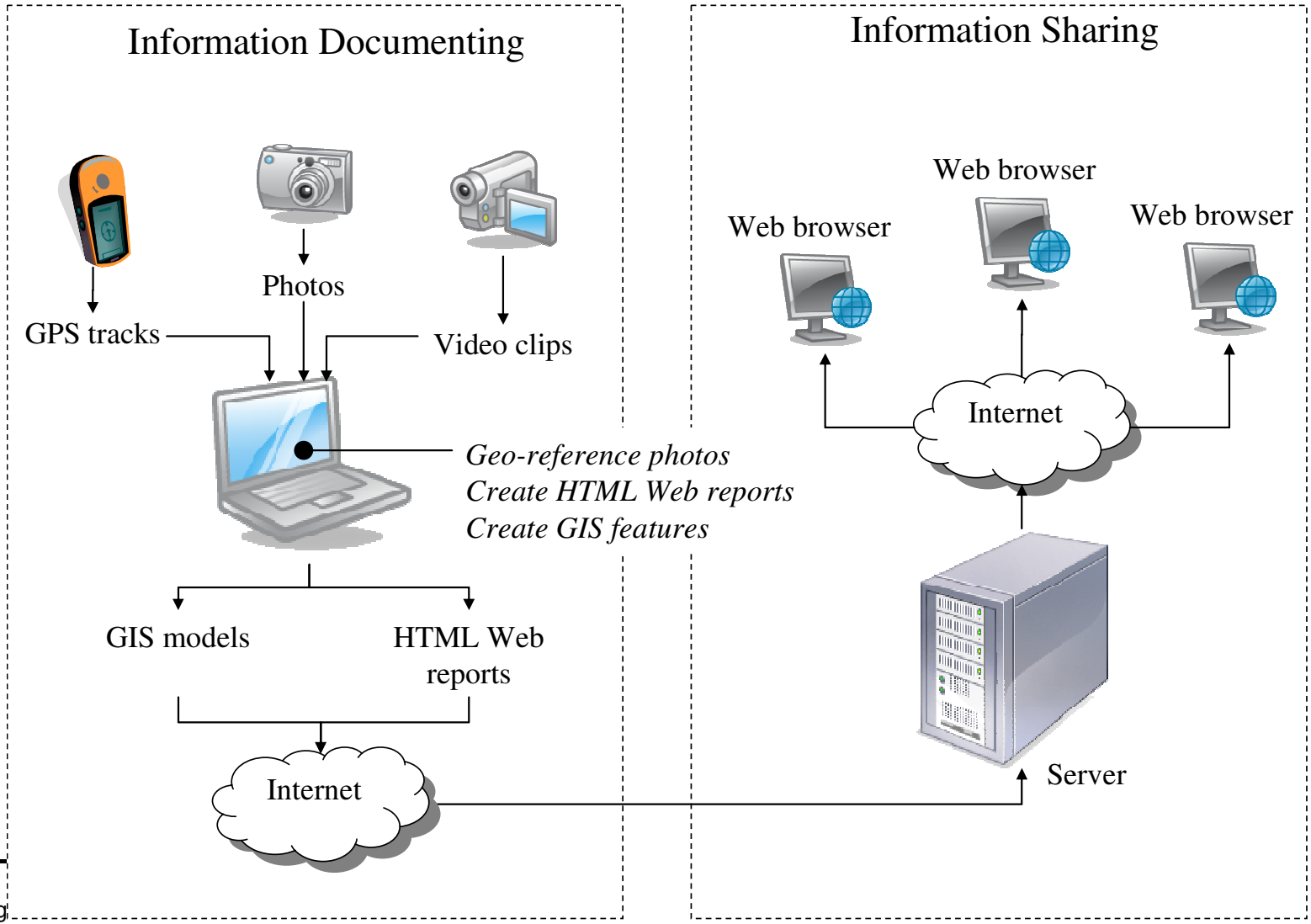

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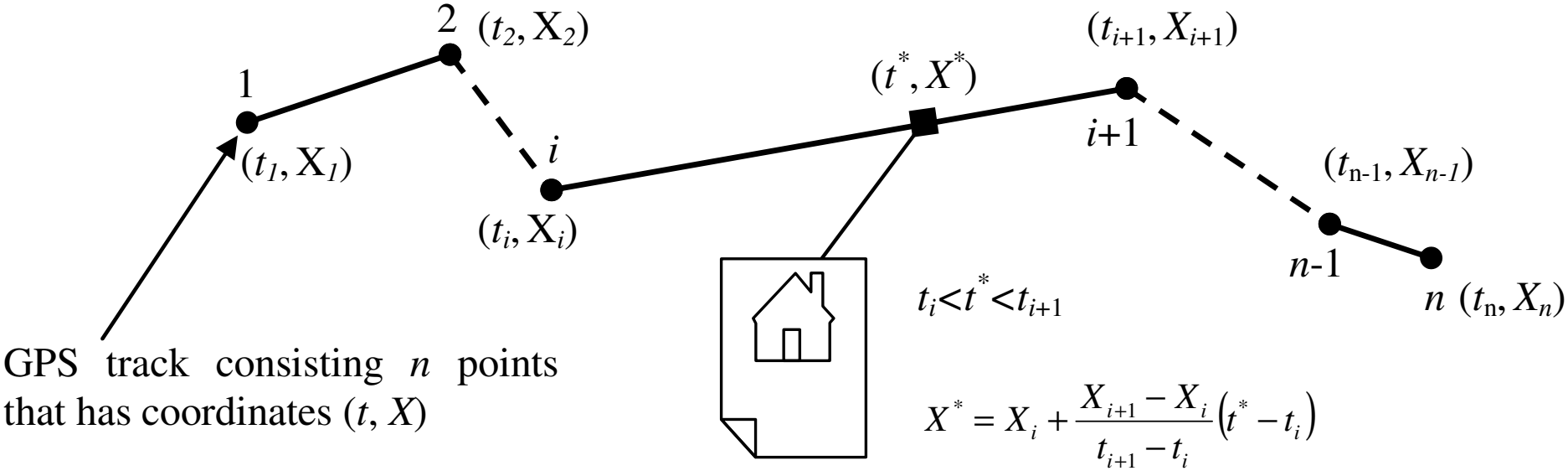
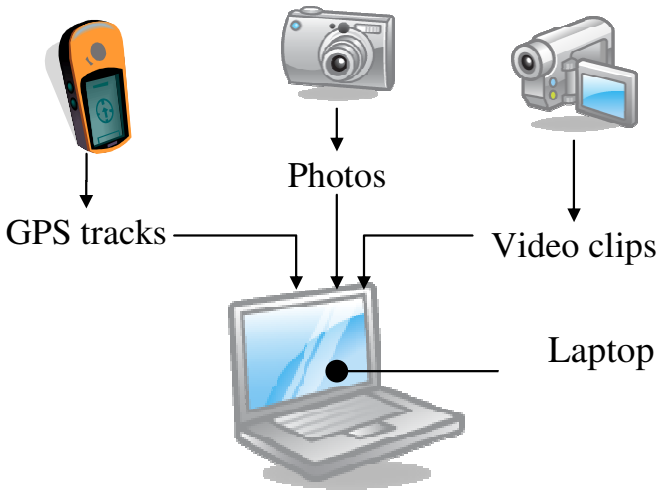
Geo-referencing photos using time stamp and GPS track





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Embedded Metadata

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FlashPix Version	1.00
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Focal Plane X Resolution	877/3888000 inches
Focal Plane Y Resolution	291/1296000 inches
ISO Speed Ratings	400
Make	Canon
Metering Mode	Multi-segment
Model	Canon EOS DIGITAL REBEL XTi
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Resolution Unit	Inch
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Y Resolution	72 dots per inch
YCbCr Positioning	Datum point

- Embedded metadata
  - embed data about an image into the image file itself.
- Embedded metadata can be written using
  - EXIF (Exchangeable Image File Format)
  - IPTC (International Press Telecommunications Council)
  - XMP (Extensible Metadata Platform)
- Embedded metadata
  - can be extracted and gathered into databases.
  - are recognized by many applications, e.g., viewers, editors, and image archiving applications.

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Outline

1. Reports on Earthquakes
2. Virtual Earthquakes
3. Conclusion

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Virtual Reality

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Virtual Earthquakes

- Earthquakes are not virtual; they actually occur.

- "Virtual earthquakes" are models that comprehensively integrate a large volume of heterogeneous time-stamped geospatial data on earthquake effects to describe, preserve and display time-sensitive information of importance to science, engineering, and our society, so that everyone can navigate and observe the earthquake damage as if they had participated in the post-earthquake field surveys.

- Virtual earthquakes are to
  - Visualize earthquake damages in 3D, possibly 4D
  - Immerse into a virtual reality to explore observations on earthquake effects on population and built environment.
  - Educate students and instruct our society about the potential risks of damaging earthquakes.
  - Train rescue teams for emergency operations.

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Pilot Virtual Wenchuan Earthquake

- Sponsored by GEER and the US National Science Foundation
- Collaboration with the Chinese Earthquake Authority, Zifa Wa
- Tong Qiu, Clarkson University
- David Frost, Georgia Institute of Technology
- Team member of Geo-Engineering Earthquake Reconnaissance (GEER)
- Earthquake Engineering Research Institute (EERI).

- Photos are embedded with metadata
- Photos are displayed on GEES in two different ways:
  1. HTML Web photo albums
  2. KMZ files viewable using Google Maps and Google Earth.

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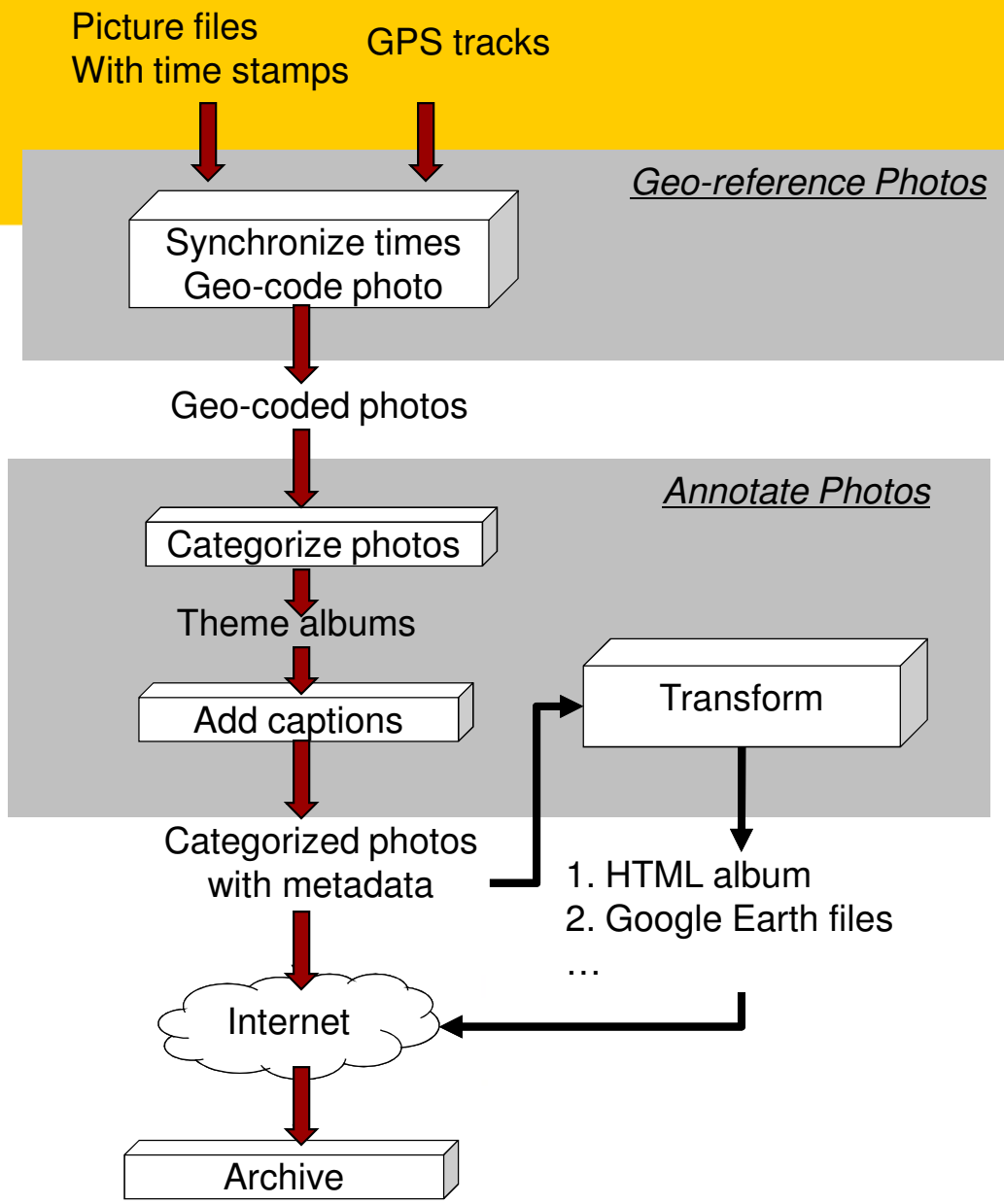
Workflow for sharing photos with embedded metadata



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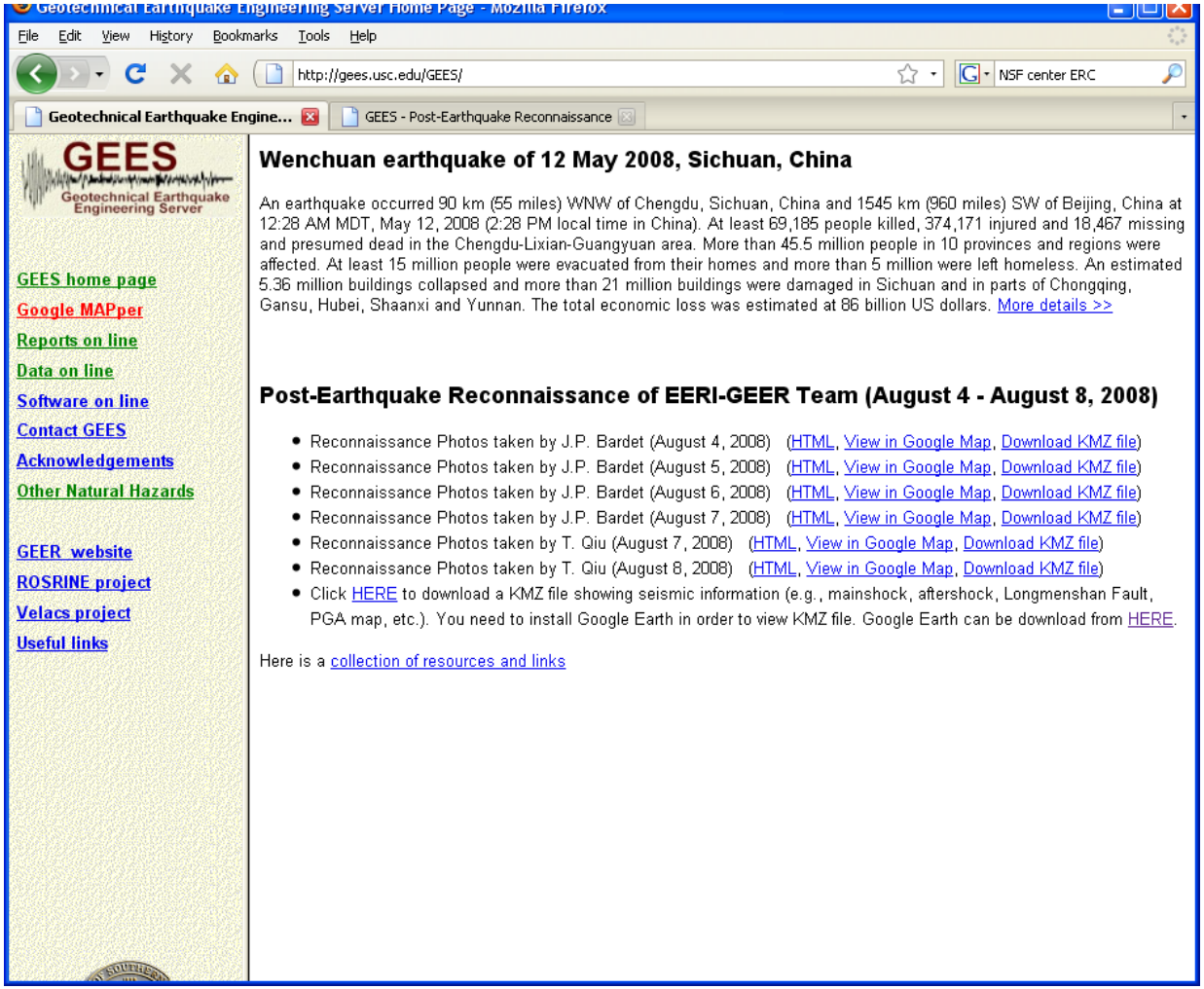
2008 Wenchuan Earthquake



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2008 Wenchuan Earthquake

Picasa™

August 4, 2008 Post-Earthquake Reconnaissance of Wenchuan Earthquake, May 12, 2008 (154 images)

Photos taken by J. P. Bardet, University of Southern California on August 4, 2008. The photos were taken during the post-earthquake reconnaissance that took place August 4- 8, 2008. and was sponsored by Geo-Engineering Earthquake Reconnaissance (GEER) through a funding of the National Science Foundation. The GEER team, which was lead by David Frost, Georgia Institute of Technolgy, collaborated with the Earthquake Engineering Research Institute (EERI). Both GEER and EERI teams were hosted by the Chinese Earthquake Authority lead by Zifa Wang.

Click a picture to see a larger view.

Picasa™

August 4, 2008 Post-Earthquake Reconnaissance of Wenchuan Earthquake, May 12, 2008 -- Landslide on rock ridge with debris flow

First | Previous Picture | Next Picture | Last | Thumbnails

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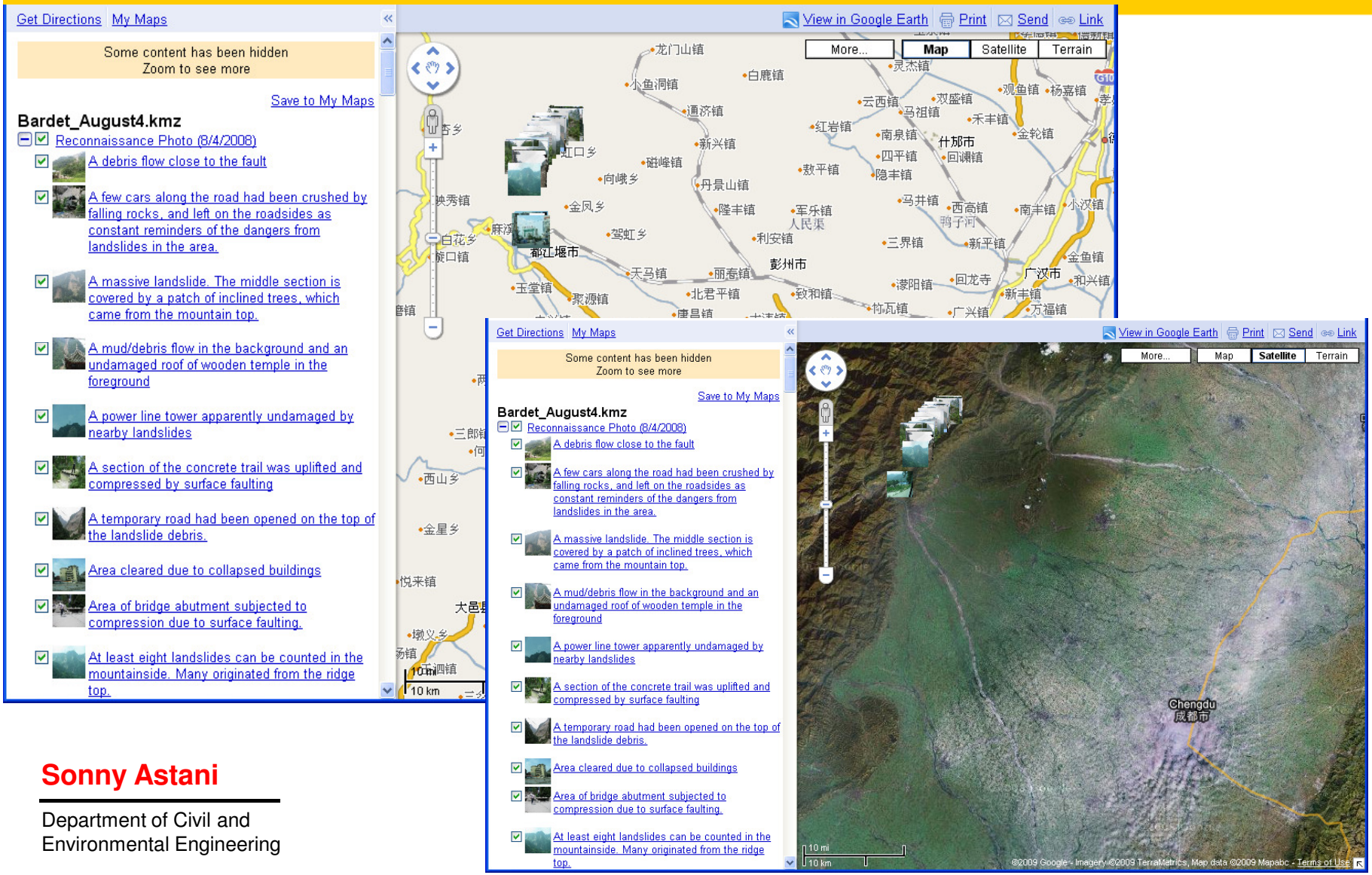
2008 Wenchuan Earthquake



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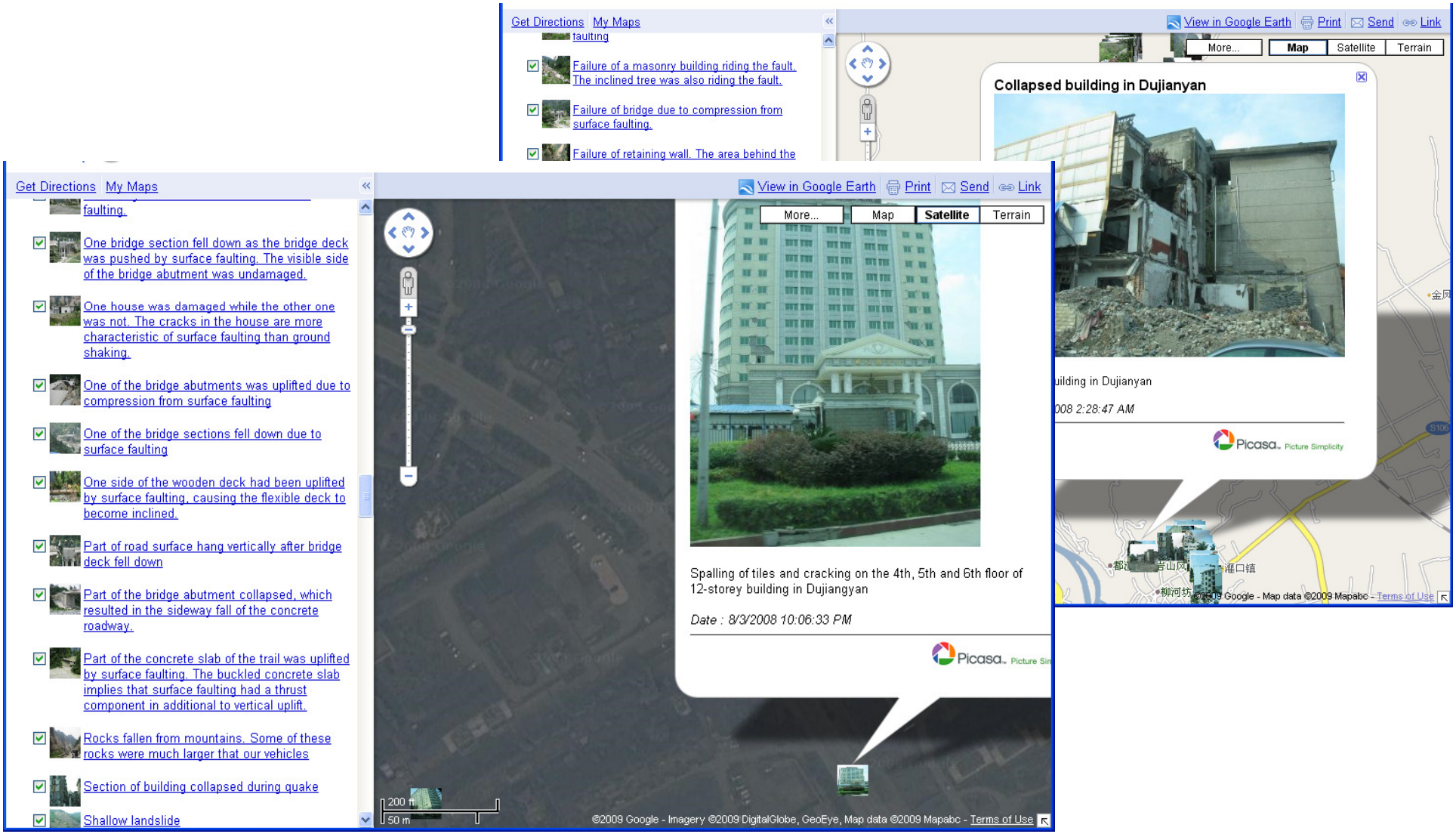
2008 Wenchuan Earthquake



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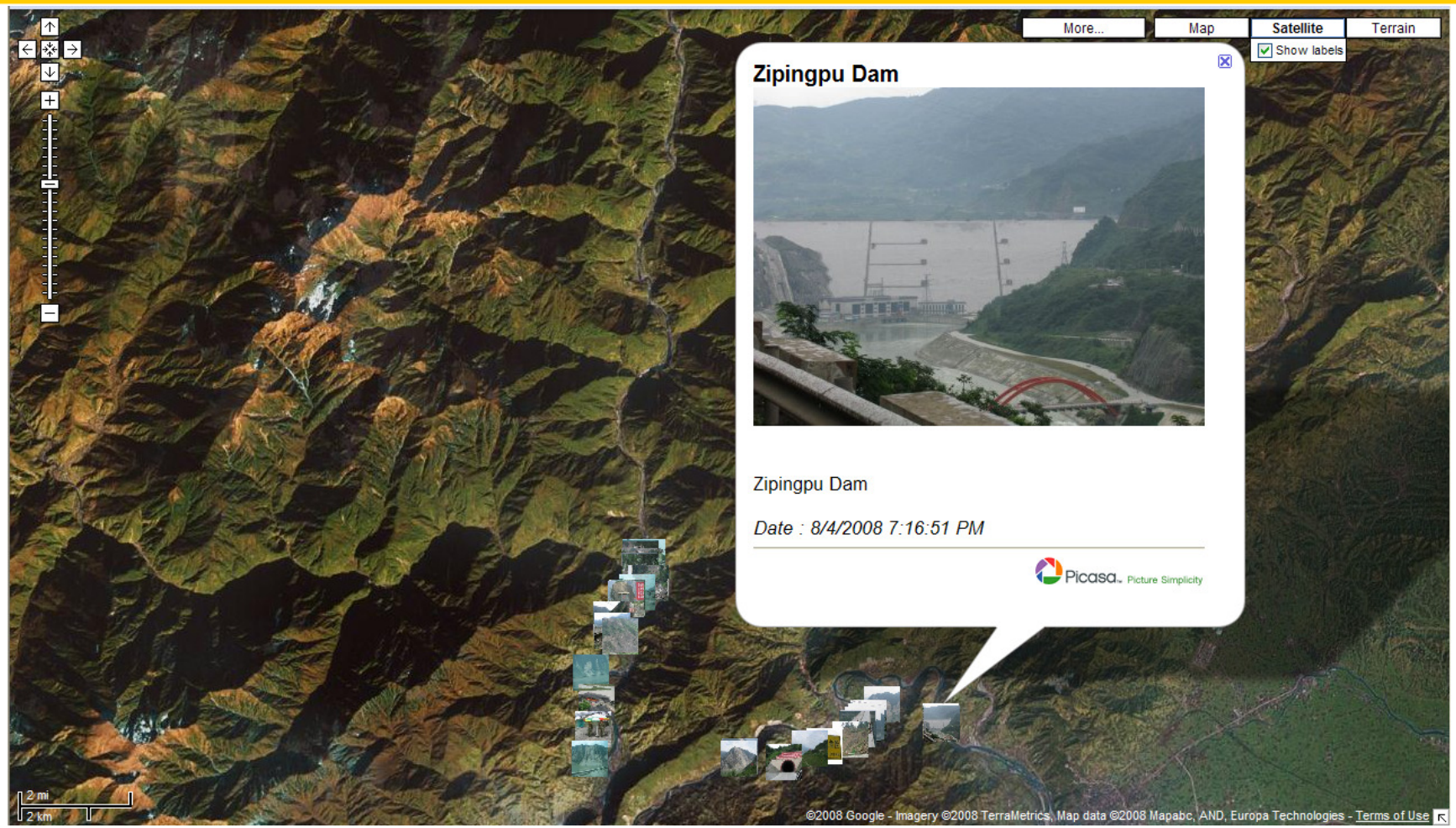
2008 Wenchuan Earthquake



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Building Virtual Earthquakes

- Building a virtual earthquake requires a large volume of time-stamped and geo-referenced data and metadata
  - before and
  - after the earthquake.

- Post-earthquake data could be generated using a team approach, in which many investigators share the geo-referenced photos with embedded metadata they collected during field surveys.

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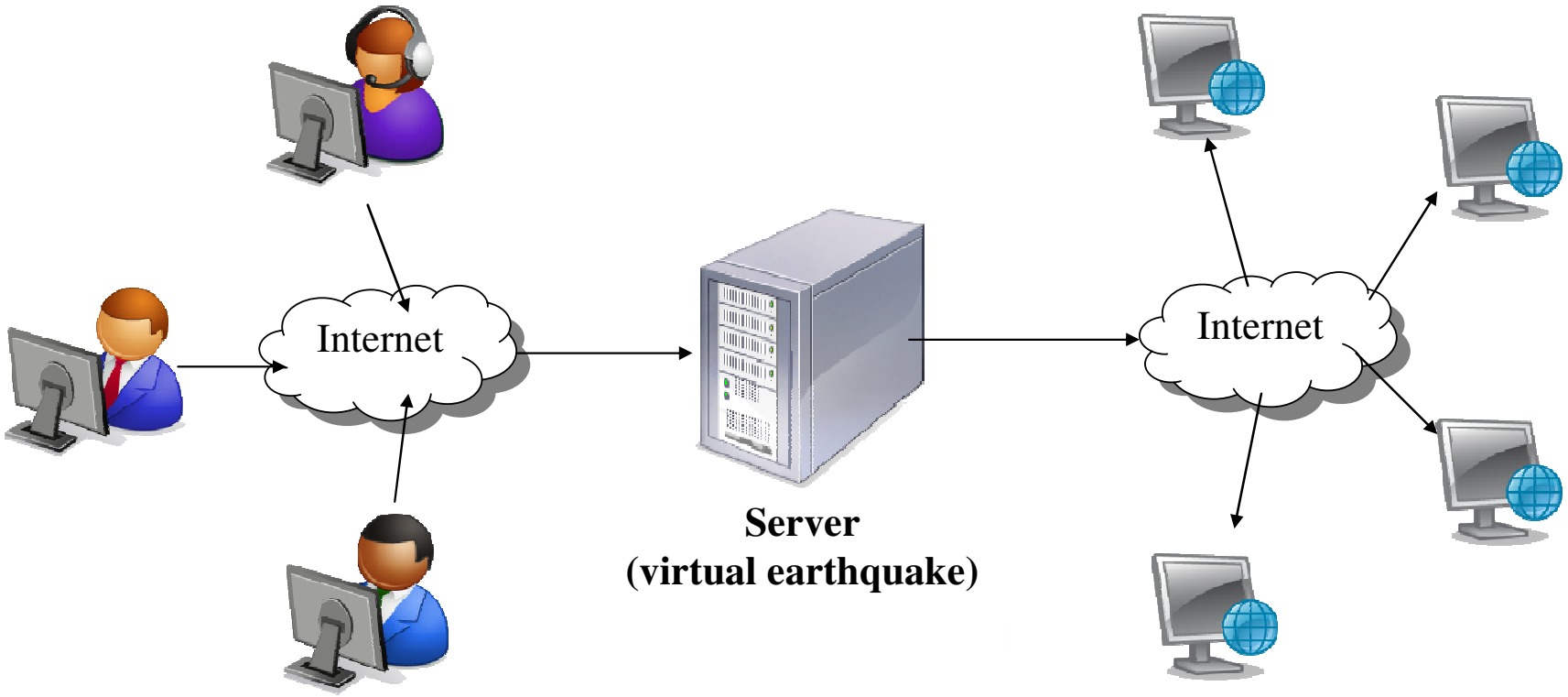
Building Virtual Earthquakes Together



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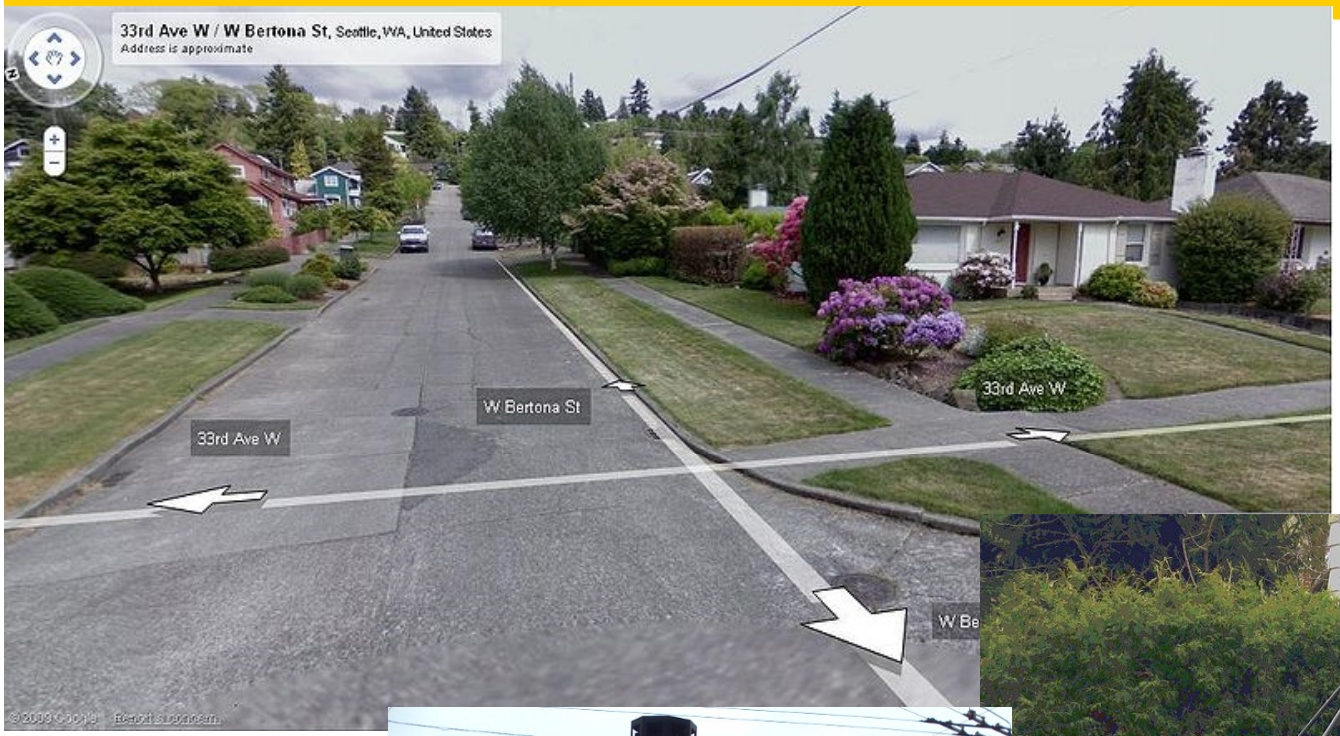
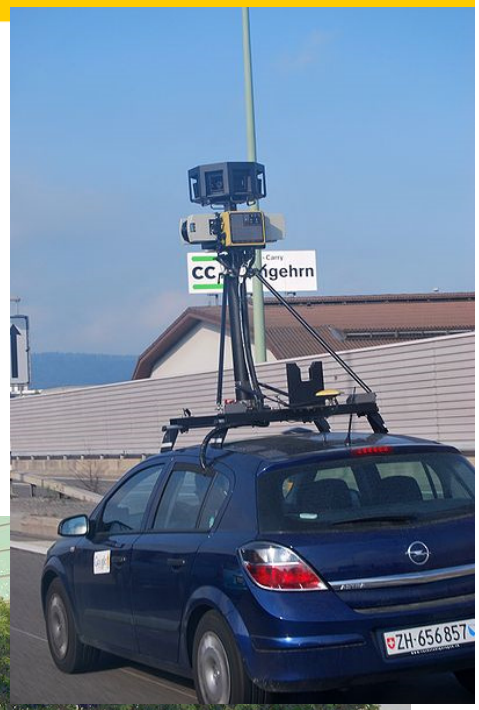
Google Street View





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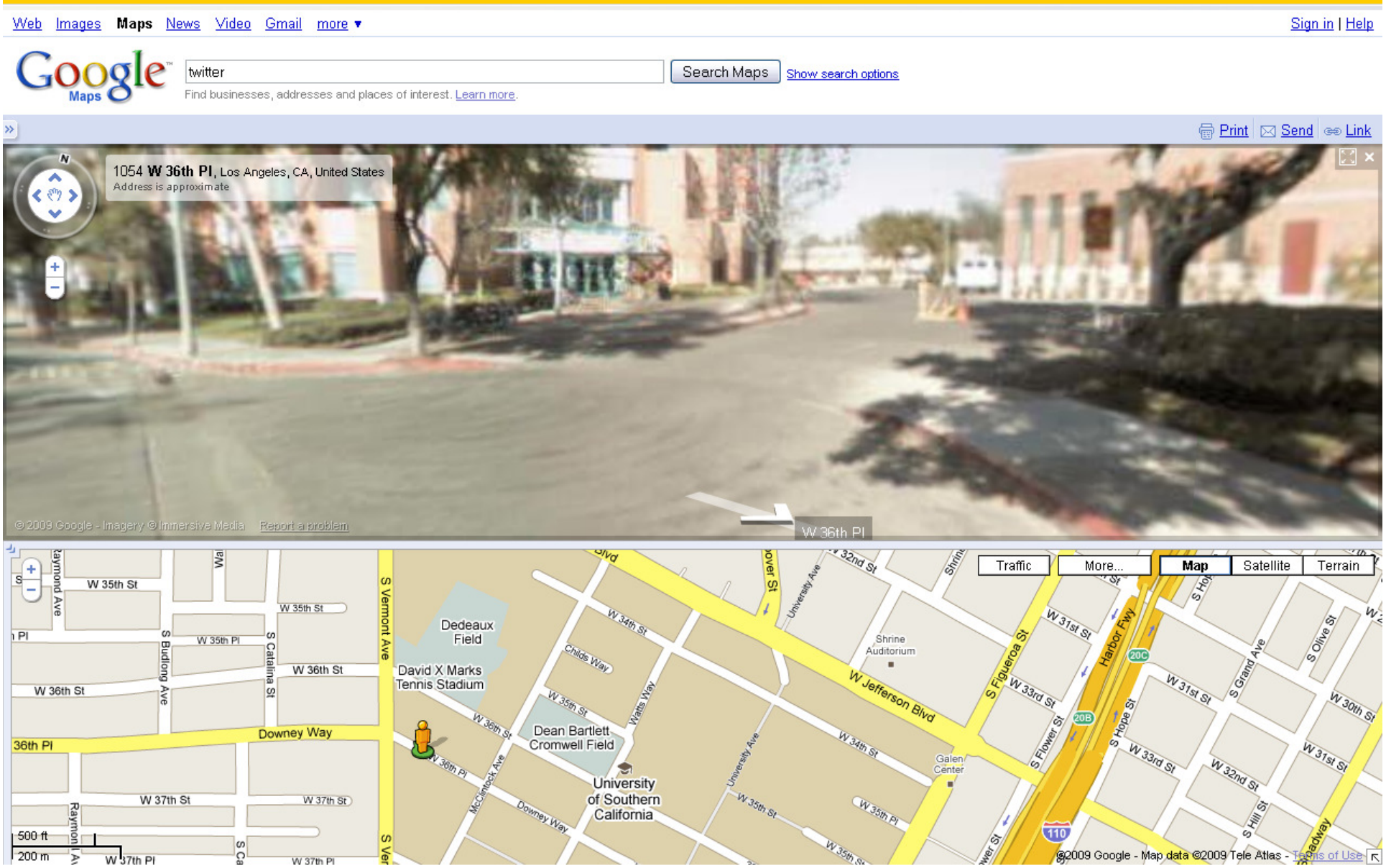
Google Street View



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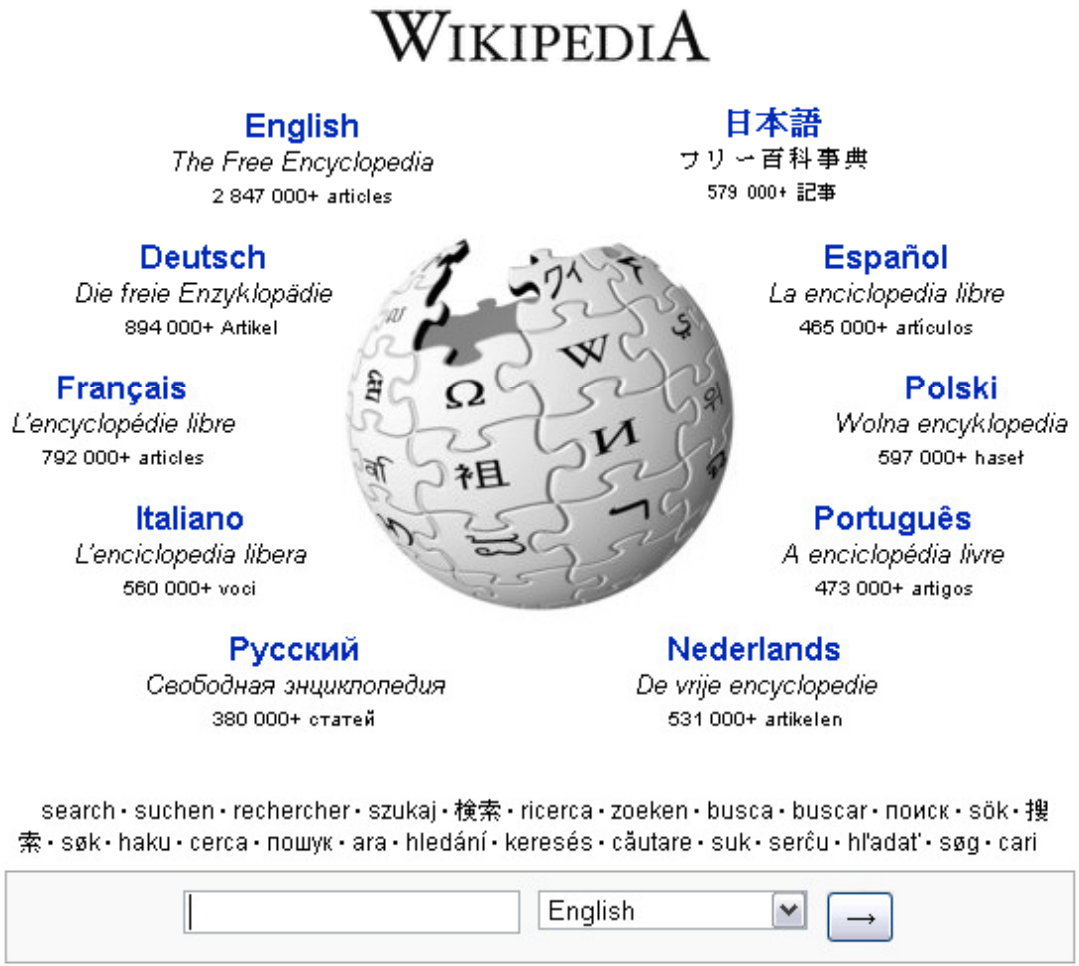
Wikipedia



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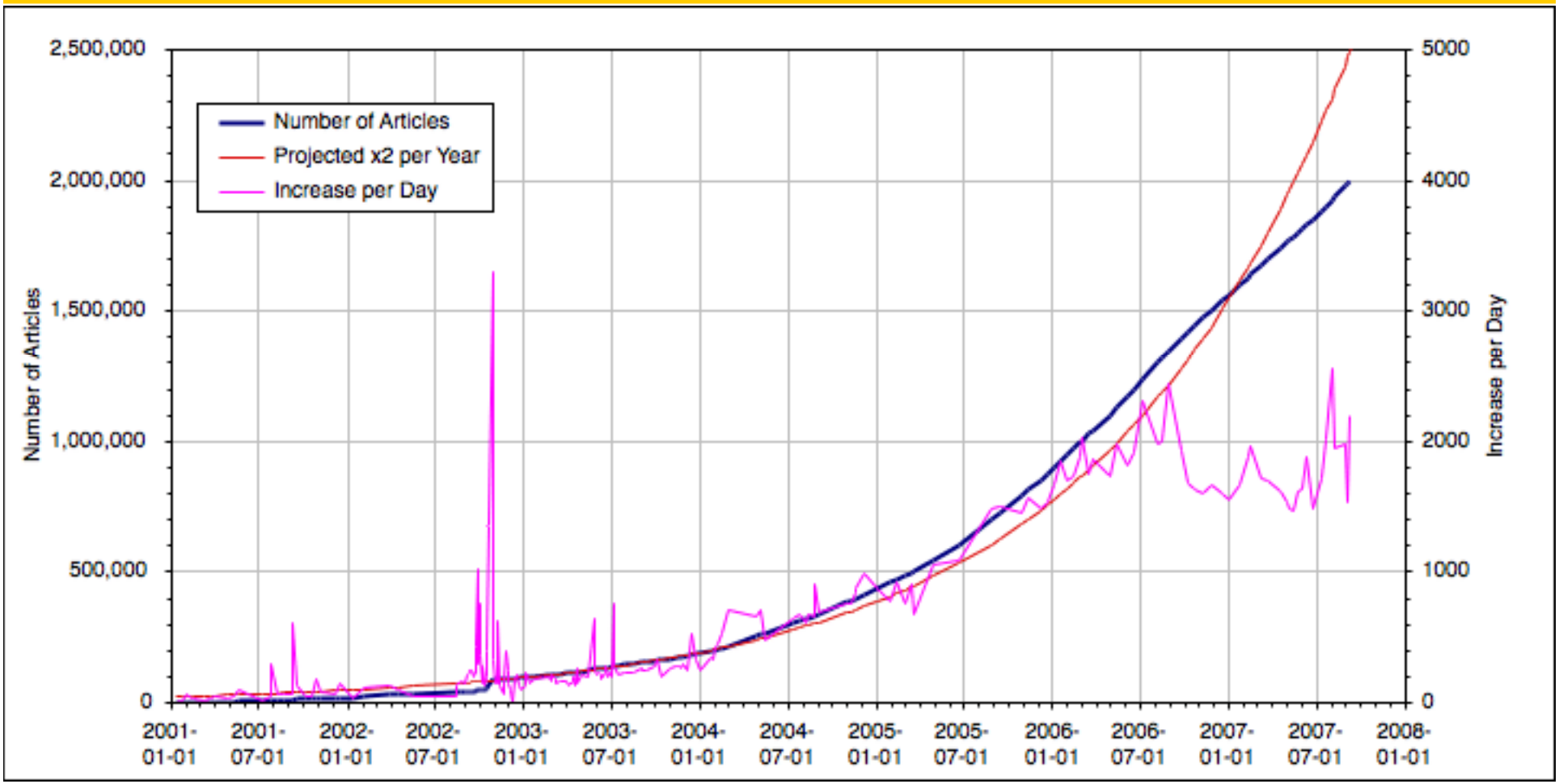
Wikipedia Growth



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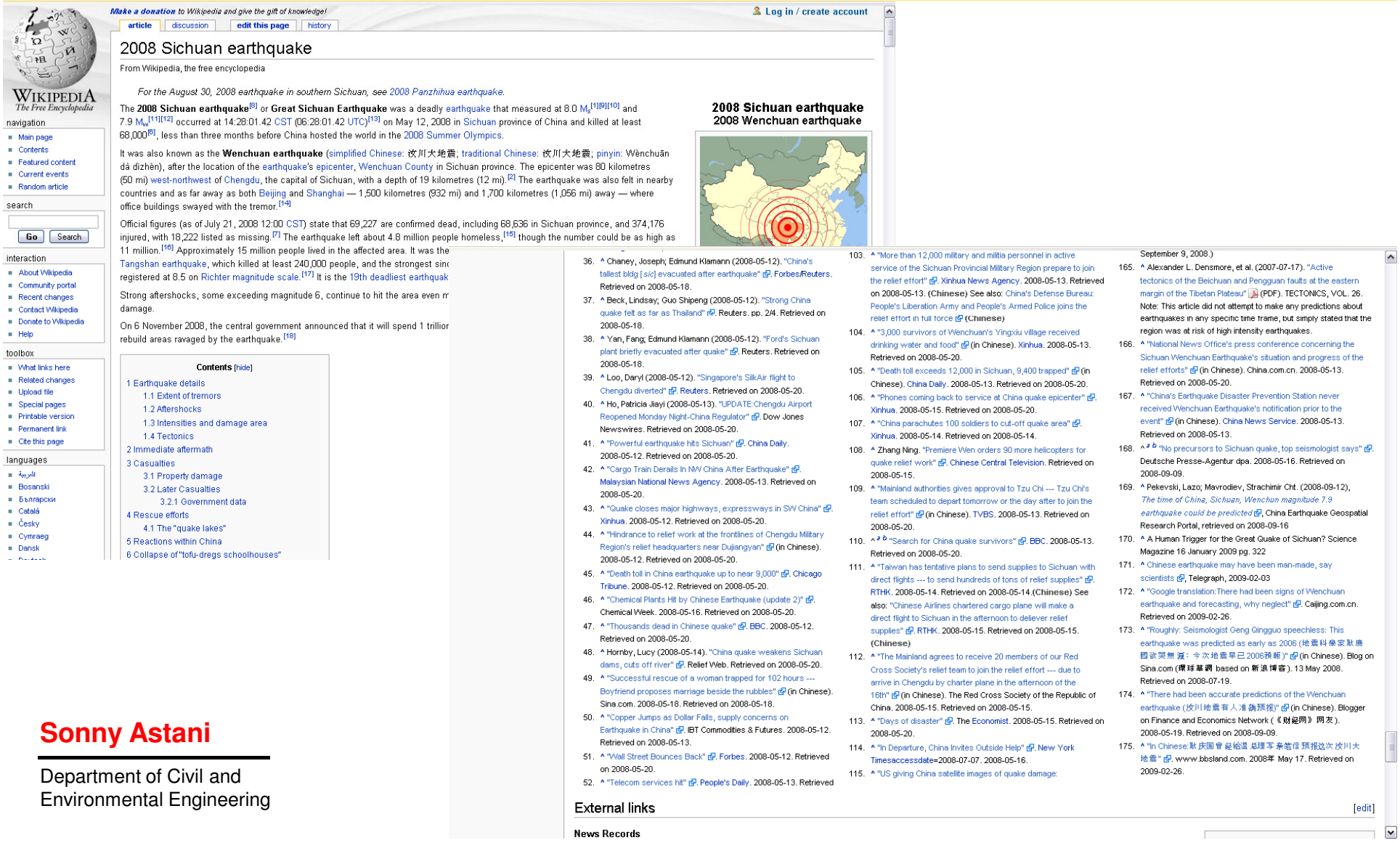
Wikipedia and 2008 Wenchuan Earthquake



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2008 Sichuan earthquake

From Wikipedia, the free encyclopedia

For the August 30, 2008 earthquake in southern Sichuan, see 2008 Panzhihua earthquake.

The **2008 Sichuan earthquake**[8] or **Great Sichuan Earthquake** was a deadly earthquake that measured at 8.0 M_s[1][9][10] and 7.9 M_w[11][12] occurred at 14:28:01.42 CST (06:28:01.42 UTC)[13] on May 12, 2008 in Sichuan province of China and killed at least 68,000[5], less than three months before China hosted the world in the 2008 Summer Olympics.

It was also known as the **Wenchuan earthquake** (simplified Chinese: 汶川大地震; traditional Chinese: 汶川大地震; pinyin: Wènchuān dà dìzhèn), after the location of the earthquake's epicenter, Wenchuan County in Sichuan province. The epicenter was 80 kilometres (50 mi) west-northwest of Chengdu, the capital of Sichuan, with a depth of 19 kilometres (12 mi).[2] The earthquake was also felt in nearby countries and as far away as both Beijing and Shanghai — 1,500 kilometres (932 mi) and 1,700 kilometres (1,056 mi) away — where office buildings swayed with the tremor.[14]

Official figures (as of July 21, 2008 12:00 CST) state that 69,227 are confirmed dead, including 68,636 in Sichuan province, and 374,176 injured, with 18,222 listed as missing.[7] The earthquake left about 4.8 million people homeless,[15] though the number could be as high as 11 million.[16] Approximately 15 million people lived in the affected area. It was the Tangshan earthquake, which killed at least 240,000 people, and the strongest sinc registered at 8.5 on Richter magnitude scale.[17] It is the 19th deadliest earthquak

Strong aftershocks, some exceeding magnitude 6, continue to hit the area even m damage.

On 6 November 2008, the central government announced that it will spend 1 trillior rebuild areas ravaged by the earthquake.[18]

2008 Sichuan earthquake
2008 Wenchuan earthquake

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- 1.2 Aftershocks
- 1.3 Intensities and damage area
- 1.4 Tectonics

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- 3.1 Property damage
- 3.2 Later Casualties
  - 3.2.1 Government data

4 Rescue efforts
- 4.1 The "quake lakes"

5 Reactions within China
6 Collapse of "tofu-dregs schoolhouses"

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External links [edit]

News Records

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Conclusion

- Web reports about earthquakes have evolved since 1995 due to GPS, digital cameras, and web technologies.
  - Contain quantitative information on positions, times and characteristics of observations.
- Virtual earthquakes
  - Harvest data from photo repositories and other sources.
  - Metamorphose web/map reports using geo-coding and photo metadata.
  - Reproduce and share field experiences
  - Involve the public
- Virtual earthquakes may have profound impacts for
  - Research and education
  - Teaching everyone about earthquakes
  - Training rescue teams
  - Making a safer world.

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Thank You

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