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RAPID POST-EARTHQUAKE STRONG-MOTION DATA FROM THE CISN ENGINEERING STRONG MOTION DATA CENTER

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SUMMARY

Performance based engineering and effective response by engineers to earthquake shaking requires communication of strong-motion data to the engineering community rapidly after significant earthquakes. The California Integrated Seismic Network (CISN) is a newly formed consortium of institutions (USGS, CGS, Caltech and UC Berkeley) engaged in statewide earthquake monitoring. The Engineering Strong Motion Data Center (EDC) of the CISN will provide products focused on engineering applications.

Internet Quick Reports (IQR) produced by the EDC are evolved from the traditional hard-copy Quick Reports on strong-motion records distributed after earthquakes in the past. The IQR uses Internet technology as a means to provide engineers access to processed strong-motion data and spectral information, as well as information about the structures and sites, very rapidly after an earthquake. In its simplest use the IQR is an up-to-date table listing of recorded peak ground and structural accelerations in either distance or alphabetical order. Users of the EDC can download processed strong-motion data from previous earthquakes and access information on instrumented structures. The EDC also allows users to search for data from specific types of structures. The CISN EDC, at **http://www.cisn-edc.org**, increases the ability of earthquake engineering users to respond knowledgeably and rapidly after earthquakes in California.

INTRODUCTION

The California Integrated Seismic Network (CISN) is a consortium of institutions engaged in statewide earthquake monitoring. The five core members are the California Geological Survey, the California Institute of Technology, the U.S. Geological Survey Offices at Pasadena and Menlo Park, and UC Berkeley. The California Office of Emergency Services (OES) participates as an ex-officio participant. The TriNet project initiated in southern California with Federal Emergency Management Agency (FEMA) support was a prototype for the statewide CISN project.

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The CISN has a statewide Engineering Data Center, a southern California Seismic Data Center at Pasadena, and a northern California Seismic Data Center in the Bay area. The CISN Engineering Data Center is operated by the CGS Strong Motion Instrumentation Program (CSMIP) in cooperation with the USGS National Strong Motion Program (NSMP).

A primary goal of the Engineering Data Center as well as the other two Data Centers is to provide robust and rapid information products after an earthquake, with products ranging from the ShakeMap to strong-motion data and calculated parameters. A high-speed T-1 computer communication network, or Intranet, which connects all CISN partner agencies, has been recently established. The Internet is also used in communication between the centers, but the T-1 ring provides the secure, reliable backup to the Internet that is needed. Details on the CISN and its status are presented in the paper by Shakal et al. [1].

THE ENGINEERING DATA CENTER

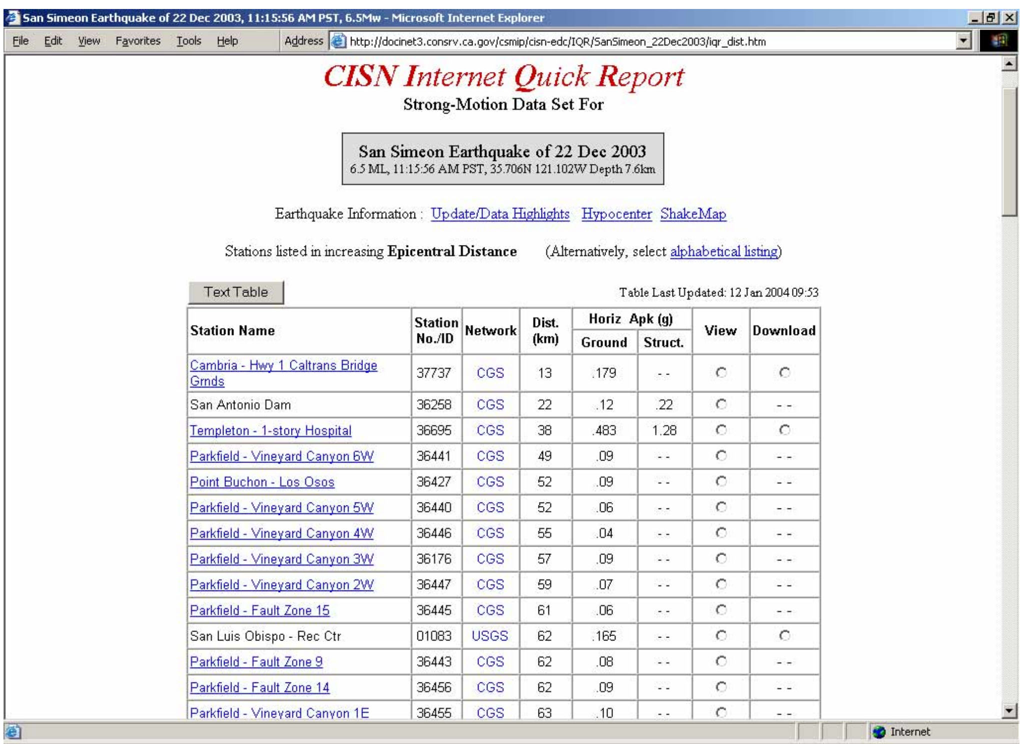
The Engineering Data Center is at URL http://www.cisn-edc.org and additional mirror sites are planned at CGS and USGS in the future. These will provide the critically needed robustness and redundancy, in the case of a major earthquake or other disabling event at either Sacramento or Menlo Park, a central goal of the CISN and of OES. The EDC home page is shown in Figure 1. The three products provided by the EDC are accessible on the center of the page. The COSMOS Strong Motion Virtual Data Center, the Northern and Southern California Earthquake Data Centers are linked at the right side of the page, while ShakeMaps are linked on the left side of the page.

Figure 1. CISN Engineering Strong Motion Data Center, with links to Internet Quick Reports, Internet Data Reports, and data searches by station or structure type, as well as links to the other two CISN Data Centers, the COSMOS data center, and ShakeMaps for northern and southern California.

THE INTERNET QUICK REPORT

The EDC uses the Internet Quick Report (IQR) to rapidly disseminate strong-motion data for engineering applications immediately after major earthquakes. The IQR is based on the concept of the traditional Quick Report, streamlined for automated generation. A total of 19 IQRs have been released after earthquakes of magnitude 4 and larger since August 2001. In addition, a search function has been developed to provide users a simple but versatile tool to locate strong-motion data of specific interest. The design of the search function allows access to the strong-motion data at the EDC according to the parameters of the instrumented station or structure. The search provides two essentially orthogonal paths to access data, one by earthquake for all stations, and the other by station/structure types independent of earthquakes. This approach allows users to quickly locate the specific data of interest for their engineering applications.

An Internet Quick Report is generally prepared for earthquakes over magnitude 4.0, for which a ShakeMap is also released by CISN. The content of the IQR is dynamic and cumulative after an earthquake, expanding as new data continues to be recovered. Initial work on the IQR is described in Shakal and Scrivner [2], Lin et al. [3, 4], and Shakal et al. [5]. An example of a recent IQR, for the San Simeon earthquake in California on December 22, 2003, is shown in Figure 2. It lists data recovered from the CGS and USGS strong-motion stations, in order of increasing epicentral distance. At the top of the IQR web page is given the name and date of the earthquake, links to related information about the event at other CISN sites (location, magnitude and ShakeMap), and the time of last modification of the table.



San Simeon Earthquake of 22 Dec 2003, 11:15:56 AM PST, 6.5Mw - Microsoft Internet Explorer

File Edit View Favorites Tools Help Address http://docinet3.consrv.ca.gov/csmip/cisn-edc/IQR/SanSimeon_22Dec2003/iqr_dist.htm

CISN Internet Quick Report

Strong-Motion Data Set For

San Simeon Earthquake of 22 Dec 2003

6.5 ML, 11:15:56 AM PST, 35.706N 121.102W Depth 7.6km

Earthquake Information : Update/Data Highlights Hypocenter ShakeMap

Stations listed in increasing **Epicentral Distance** (Alternatively, select alphabetical listing)

Text Table

Table Last Updated: 12 Jan 2004 09:53

Station Name	Station No./ID	Network	Dist. (km)	Horiz Apk (g) Ground	Struct.	View	Download
Cambria - Hwy 1 Caltrans Bridge Grnds	37737	CGS	13	.179	- -	○	○
San Antonio Dam	36258	CGS	22	.12	.22	○	- -
Templeton - 1-story Hospital	36695	CGS	38	.483	1.28	○	○
Parkfield - Vineyard Canyon 6W	36441	CGS	49	.09	- -	○	- -
Point Buchon - Los Osos	36427	CGS	52	.09	- -	○	- -
Parkfield - Vineyard Canyon 5W	36440	CGS	52	.06	- -	○	- -
Parkfield - Vineyard Canyon 4W	36446	CGS	55	.04	- -	○	- -
Parkfield - Vineyard Canyon 3W	36176	CGS	57	.09	- -	○	- -
Parkfield - Vineyard Canyon 2W	36447	CGS	59	.07	- -	○	- -
Parkfield - Fault Zone 15	36445	CGS	61	.06	- -	○	- -
San Luis Obispo - Rec Ctr	01083	USGS	62	.165	- -	○	○
Parkfield - Fault Zone 9	36443	CGS	62	.08	- -	○	- -
Parkfield - Fault Zone 14	36456	CGS	62	.09	- -	○	- -
Parkfield - Vineyard Canyon 1E	36455	CGS	63	.10	- -	○	- -

Internet

Figure 2. Internet Quick Report (partial) for the M6.5 earthquake near San Simeon, California on December 22, 2003. The table is sorted in epicentral distance order; alphabetical order can be selected at the top. A text table of the data can be downloaded for analysis via the 'Text Table' link. Stations with strong-motion data available for viewing and/or downloading are indicated by the presence of buttons in the right columns. For underlined stations, a linked page contains station photographs and station information. The network column indicates that the IQR includes data from both the CGS and the USGS.

The ShakeMap for the San Simeon earthquake shown in Figure 3 can be linked from the top of the IQR page. In addition, highlights and updates on the data are provided in Figure 4, which is accessible from the top of the IQR page.

The table lists peak acceleration values and station distances for the strong-motion records recovered. Each row of the table includes, for one record, the station name and number, network, epicentral distance, and peak horizontal acceleration on the ground and the structure (if applicable). The table shown, designed for viewing using Internet browsers, is complemented by a more comprehensive table available as an ASCII text file using a link at the top of the page. A user can easily import this table into a spreadsheet program for analysis. Both the web table and the text table have a date-time stamp to indicate when they were last modified by the update or addition of data.

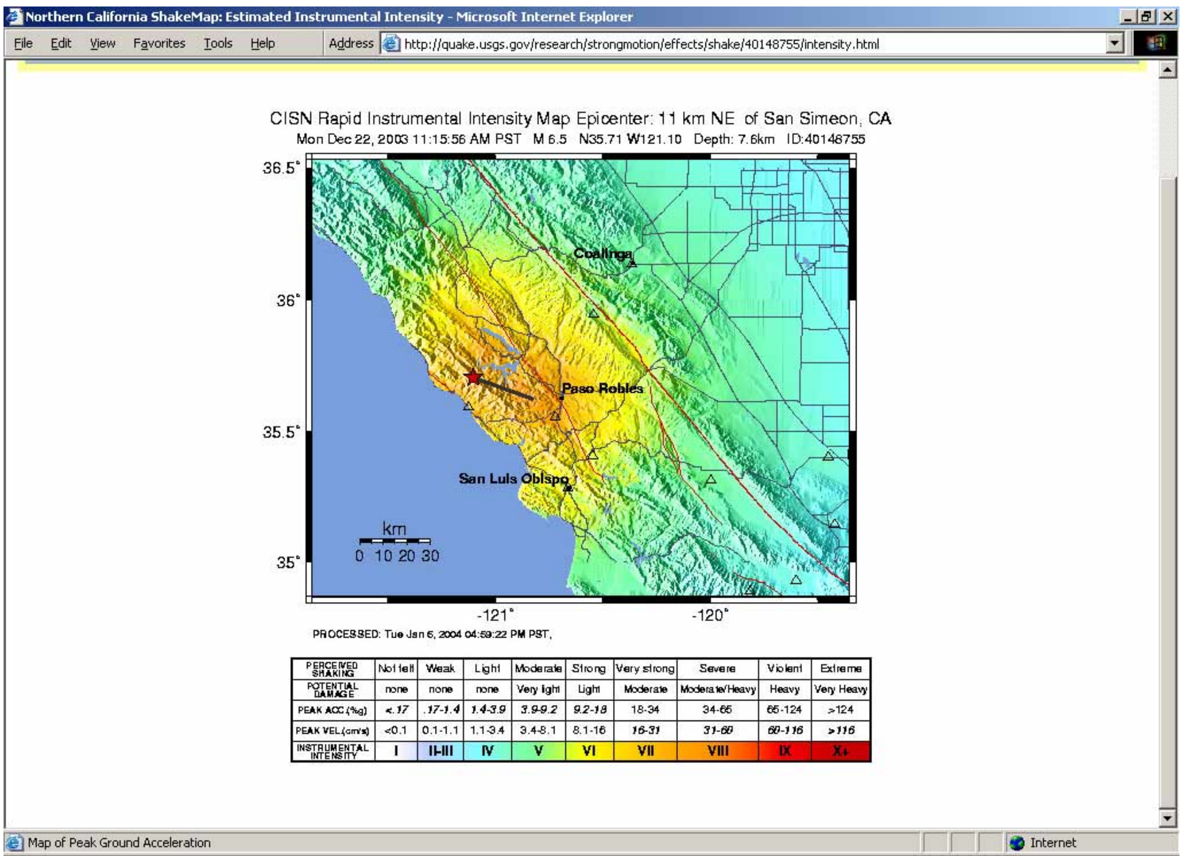
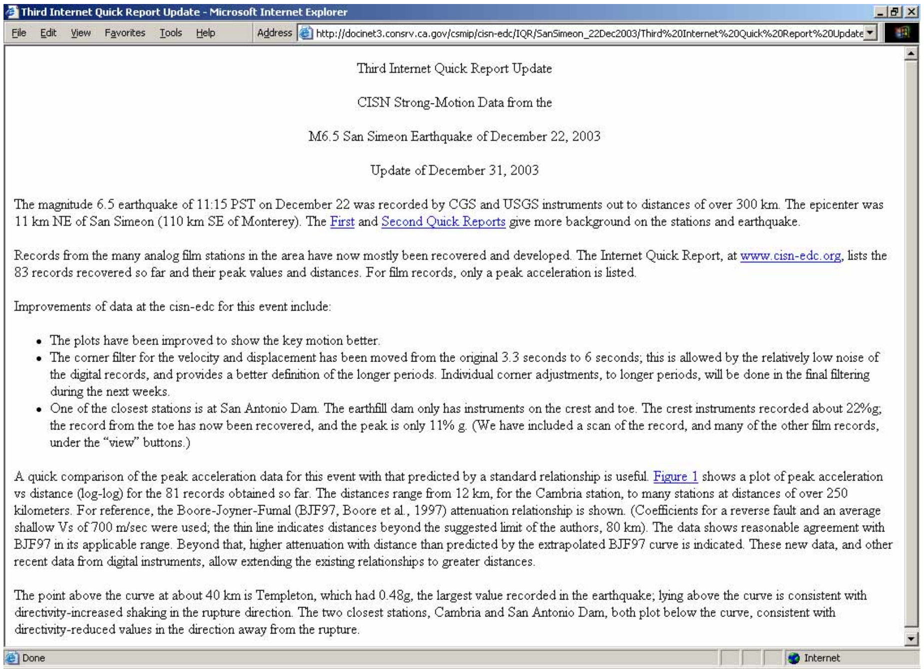


Figure 3. The ShakeMap (Instrumental Intensity Map) for the San Simeon, California earthquake of December 22, 2003 at the CISN Engineering Data Center. The ShakeMap is linked with the Internet Quick Report (IQR). ShakeMaps also include maps for peak ground acceleration, peak ground velocity, and acceleration response spectra at 0.3, 1.0 and 3 seconds.


Third Internet Quick Report Update - Microsoft Internet Explorer

Address http://docinet3.consrv.ca.gov/csmip/cisn-edc/IQR/SanSimeon_22Dec2003/Third%20Internet%20Quick%20Report%20Update

Third Internet Quick Report Update

CISN Strong-Motion Data from the

M6.5 San Simeon Earthquake of December 22, 2003

Update of December 31, 2003

The magnitude 6.5 earthquake of 11:15 PST on December 22 was recorded by CGS and USGS instruments out to distances of over 300 km. The epicenter was 11 km NE of San Simeon (110 km SE of Monterey). The First and Second Quick Reports give more background on the stations and earthquake.

Records from the many analog film stations in the area have now mostly been recovered and developed. The Internet Quick Report, at www.cisn-edc.org, lists the 83 records recovered so far and their peak values and distances. For film records, only a peak acceleration is listed.

Improvements of data at the cisn-edc for this event include:

- The plots have been improved to show the key motion better.
- The corner filter for the velocity and displacement has been moved from the original 3.3 seconds to 6 seconds; this is allowed by the relatively low noise of the digital records, and provides a better definition of the longer periods. Individual corner adjustments, to longer periods, will be done in the final filtering during the next weeks.
- One of the closest stations is at San Antonio Dam. The earthfill dam only has instruments on the crest and toe. The crest instruments recorded about 22%g; the record from the toe has now been recovered, and the peak is only 11% g. (We have included a scan of the record, and many of the other film records, under the "view" buttons.)

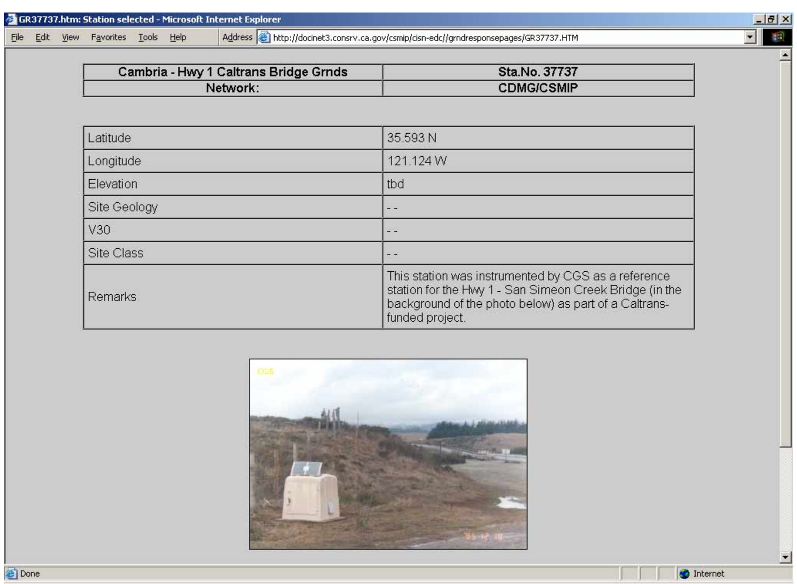
A quick comparison of the peak acceleration data for this event with that predicted by a standard relationship is useful. Figure 1 shows a plot of peak acceleration vs distance (log-log) for the 81 records obtained so far. The distances range from 12 km, for the Cambria station, to many stations at distances of over 250 kilometers. For reference, the Boore-Joyner-Fumal (BJF97, Boore et al., 1997) attenuation relationship is shown. (Coefficients for a reverse fault and an average shallow Vs of 700 m/sec were used; the thin line indicates distances beyond the suggested limit of the authors, 80 km). The data shows reasonable agreement with BJF97 in its applicable range. Beyond that, higher attenuation with distance than predicted by the extrapolated BJF97 curve is indicated. These new data, and other recent data from digital instruments, allow extending the existing relationships to greater distances.

The point above the curve at about 40 km is Templeton, which had 0.48g, the largest value recorded in the earthquake; lying above the curve is consistent with directivity-increased shaking in the rupture direction. The two closest stations, Cambria and San Antonio Dam, both plot below the curve, consistent with directivity-reduced values in the direction away from the rupture.

Figure 4. Third update and highlight of the strong-motion data from for the San Simeon, California earthquake of December 22, 2003 at the CISN Engineering Data Center.

Internet Quick Report – Ground Response Records

Information regarding the ground response station is accessible directly using the Internet link under the station name. The row also includes buttons for viewing and/or downloading the data once the data are available at the EDC. For example, Figure 5 shows the photo, coordinates and other information for the Cambria – Hwy 1 Caltrans Bridge Grounds station, the closest station to the epicenter of the San Simeon earthquake. The plots for the processed record, including acceleration, velocity and displacement, from the station (shown in Figure 6) can be viewed from the IQR.


GR37737.htm: Station selected - Microsoft Internet Explorer

Address http://docinet3.consrv.ca.gov/csmip/cisn-edc//grndresponsepages/GR37737.HTM

Cambria - Hwy 1 Caltrans Bridge Grnds	Sta.No. 37737
Network:	CDMG/CSMIP

Latitude	35.593 N
Longitude	121.124 W
Elevation	tbd
Site Geology	- -
V30	- -
Site Class	- -
Remarks	This station was instrumented by CGS as a reference station for the Hwy 1 - San Simeon Creek Bridge (in the background of the photo below) as part of a Caltrans-funded project.

Figure 5. An example Internet page (partial) for a ground response station at the CISN Engineering Data Center. The photo, coordinates and other information for the Cambria – Hwy1 Caltrans Bridge Grounds station are included.

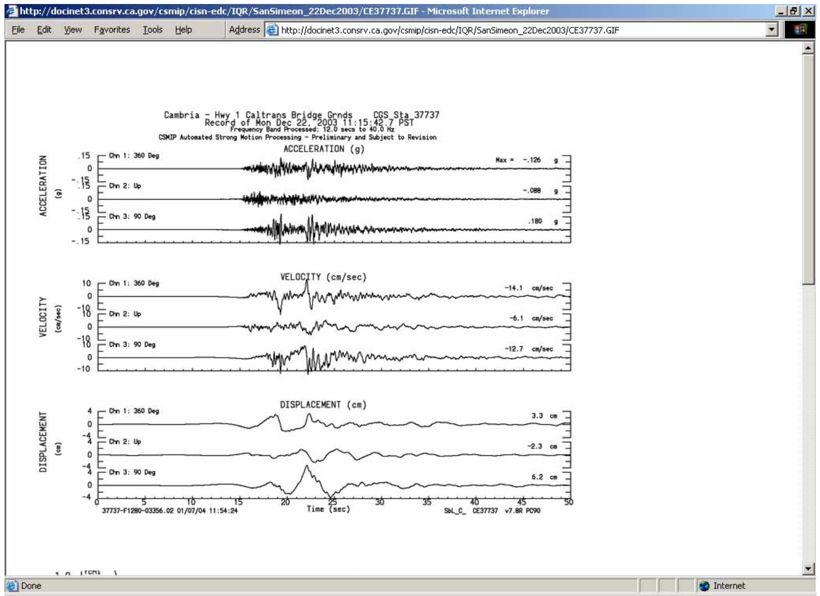


Figure 6. Acceleration, velocity and displacement records obtained from the ground response station shown in Figure 5 during the San Simeon earthquake can be viewed and downloaded from the Internet Quick Report at the CISN Engineering Data Center.

Internet Quick Report – Structure Records

Information regarding the instrumented structure is accessible directly using the Internet link under the station name. The table row for the structure also includes buttons for viewing and/or downloading the data once the data are available at the EDC. For example, Figure 7 shows the photo, structural system and other information for a 1-story hospital at Templeton, California and Figure 8 gives the sensor locations in the building. The plots for the acceleration records from the building, shown in Figure 9, can be viewed from the IQR.

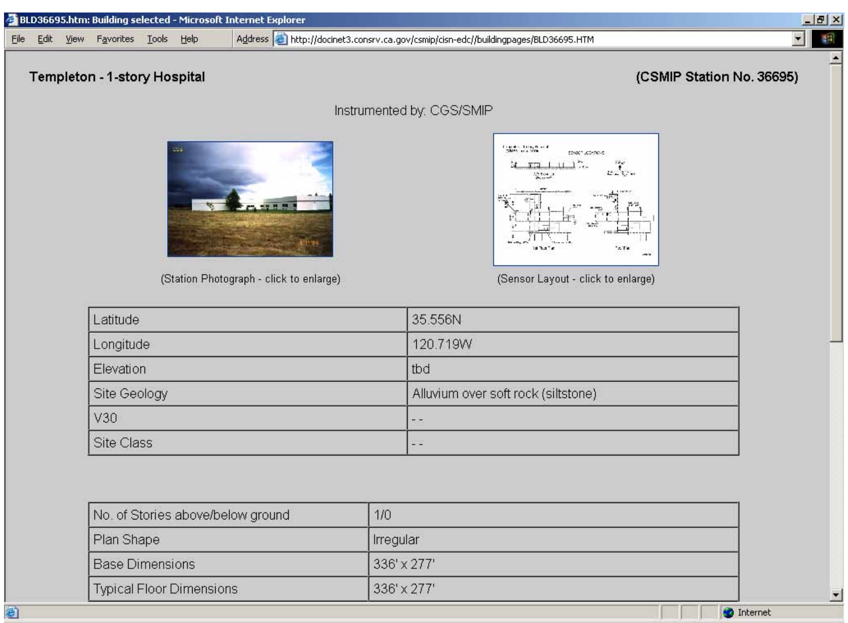


Figure 7. An example Internet page (partial) for a building station at the CISN Engineering Data Center. In addition to the basic station data, a photo of the building, the sensor layout, and a detailed description on the structural system are included.

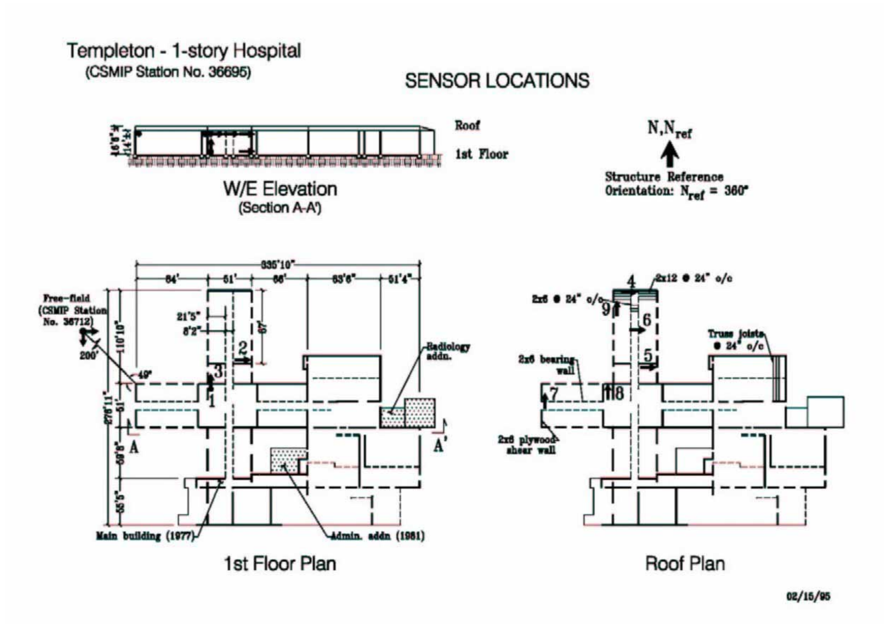


Figure 8. Sensor layout for the building shown in Figure 7. The full-scale image is displayed when users click on the link to the sensor layout in the building page in Figure 7.

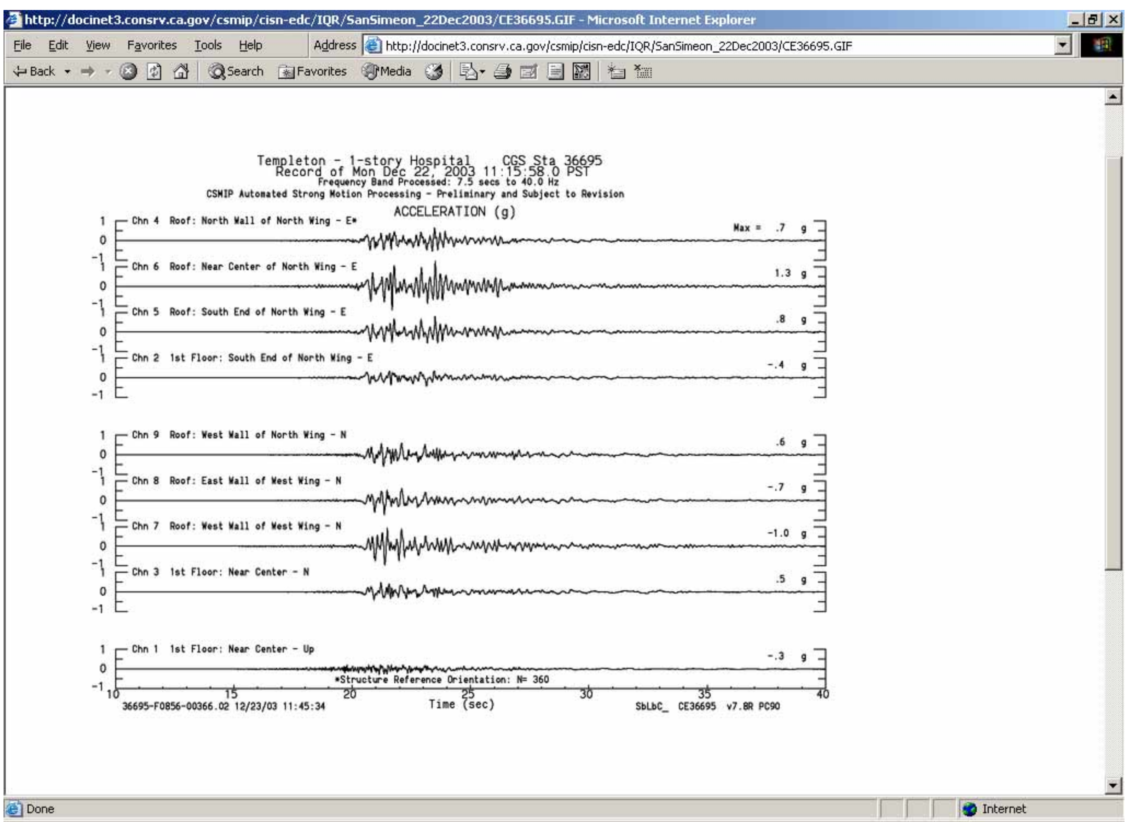
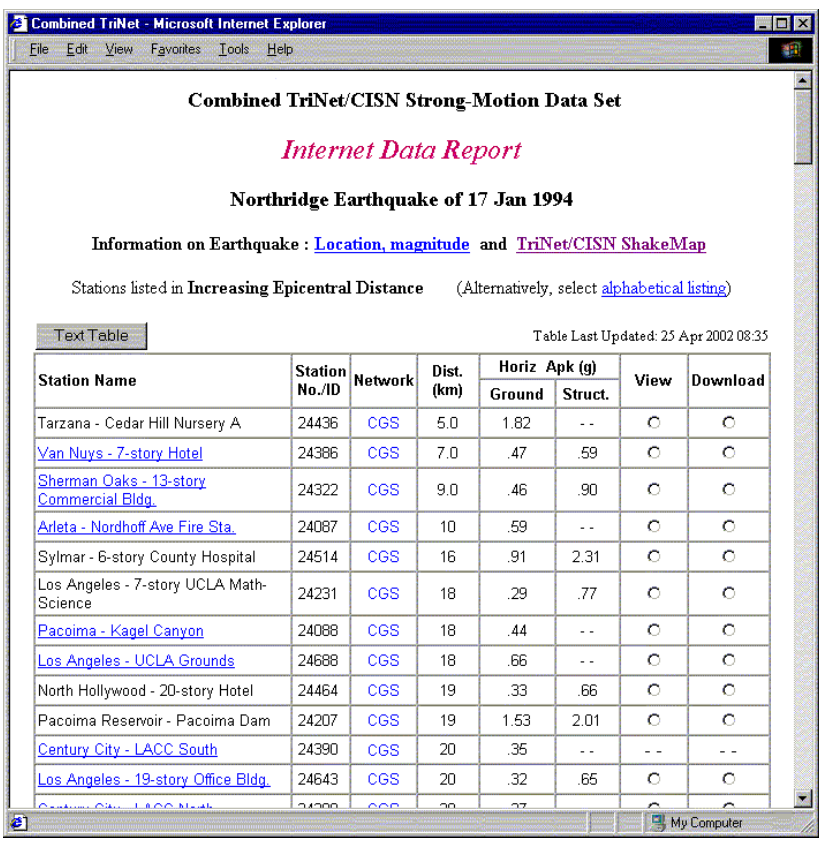


Figure 9. Acceleration records obtained from the building shown in Figure 7 during the 2003 San Simeon earthquake can be viewed from the Internet Quick Report at the CISN Engineering Data Center. The processed data, including acceleration, velocity, displacement time histories and response spectra can be downloaded.

DATA FROM PREVIOUS EARTHQUAKES – INTERNET DATA REPORTS

The discussion above is focused on data in the immediate post-earthquake period. Earthquake data are also important for longer-term analysis, beyond the immediate earthquake response time frame. In the past, paper-copy Quick Reports (e.g., CSMIP [6]) were the pre-Internet analog to the Internet Quick Reports, and those Quick Reports were followed by a final hard-copy report on the event's strong-motion data, which was usually released one month after the event (e.g., Shakal et al. [7]; Porcella et al. [8]). In many ways, the IQR is as comprehensive as that report. Using new technology, the IQR is produced in 30 minutes and is very comparable to what was available only after 30 days. For a given event, the Internet Quick Report will transition to the Internet Data Report, to reflect its more final nature, after enough time has gone by for all data (including those from any analog instruments) to be included and quality controlled.

The EDC has created Internet Data Reports for four major historical earthquakes, to provide users the same access to the earlier strong-motion data as for new data. More historical earthquakes are being added. An example showing part of the Internet Data Report for the 1994 Northridge earthquake is shown in Figure 10. The Internet Data Reports have the same format as the IQR and are placed in the archive section of the EDC, paralleling the way the CISN ShakeMaps are archived. Internet Data Reports are being created for additional historical earthquakes as current data work allows.



Combined TriNet - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Combined TriNet/CISN Strong-Motion Data Set

Internet Data Report

Northridge Earthquake of 17 Jan 1994

Information on Earthquake : Location, magnitude **and** TriNet/CISN ShakeMap

Stations listed in **Increasing Epicentral Distance** (Alternatively, select alphabetical listing)

Text Table

Table Last Updated: 25 Apr 2002 08:35

Station Name	Station No./ID	Network	Dist. (km)	Horiz Apk (g) Ground	Horiz Apk (g) Struct.	View	Download
Tarzana - Cedar Hill Nursery A	24436	CGS	5.0	1.82	- -	○	○
Van Nuys - 7-story Hotel	24386	CGS	7.0	.47	.59	○	○
Sherman Oaks - 13-story Commercial Bldg.	24322	CGS	9.0	.46	.90	○	○
Arleta - Nordhoff Ave Fire Sta.	24087	CGS	10	.59	- -	○	○
Sylmar - 6-story County Hospital	24514	CGS	16	.91	2.31	○	○
Los Angeles - 7-story UCLA Math-Science	24231	CGS	18	.29	.77	○	○
Pacoima - Kagel Canyon	24088	CGS	18	.44	- -	○	○
Los Angeles - UCLA Grounds	24688	CGS	18	.66	- -	○	○
North Hollywood - 20-story Hotel	24464	CGS	19	.33	.66	○	○
Pacoima Reservoir - Pacoima Dam	24207	CGS	19	1.53	2.01	○	○
Century City - LACC South	24390	CGS	20	.35	- -	- -	- -
Los Angeles - 19-story Office Bldg.	24643	CGS	20	.32	.65	○	○

My Computer

Figure 10. An example of the Internet Data Report table, sorted in epicentral distance order, for the Northridge earthquake of January 17, 1994. The table parallels the functionality of the Internet Quick Report, but is permanently available, beyond the time of post-earthquake response, and includes records from analog film stations and other records recovered manually (this is an example and only includes CGS data).

SEARCHING FOR STRONG-MOTION DATA AT THE CISN ENGINEERING DATA CENTER

The above sections considered access to data on a single-earthquake basis. A second path for access to strong-motion data is to use the search function of the EDC. The data contents for the search function are updated immediately following an IQR update operation as part of the EDC process. Contrary to the IQR and IDR, in which data for a single earthquake are listed for all stations, the search function lists data for a single station (or class of stations) for various earthquakes. The user can access the strong-motion data for a structure of interest (a certain building, bridge, or dam) or for a class of structures (e.g., all mid-height steel buildings) by specifying the categorization or type of the structure.

The design goal of the EDC search function is to distribute strong-motion data from stations of the CISN network and to provide station information and associated structural information, as applicable. It complements the worldwide ground-response database available through the COSMOS virtual data center (e.g., Archuleta [9]) and the newly completed Internet Site for European Strong Motion Data (Ambraseys [10]).

The layout of the EDC search function is a typical top-down tier approach that guides the user through a series of choices. The user can further confine the search criteria by entering keywords in appropriate fields anytime during the search process. Results of a given search are presented in a table listing all stations that matched the search criteria. Each station has a direct link in the result table that leads the user to a list of readily accessed strong-motion data for the station.

The initial search page, which includes six predefined station categories (ground response, buildings, bridges, dams, geotechnical arrays, and other structures) is shown in Figure 11. At the first level of the search process, the user starts a search request by selecting a station category. The system responds by displaying second level options for the selected category. For ground response stations, the user can search for strong-motion data based on station name, station number, and site geology.

Figure 11. The initial page of the EDC search function. The station data are categorized in six major station types including ground response, buildings, bridges, dams, geotechnical arrays, and other structures.

More earthquakes and station data have been added to the EDC. The functionality of the search feature was improved to incorporate the newly added data. Currently, data for all 13 Internet Quick Reports and four Internet Data Reports of historic earthquakes have been entered into the database. In addition, station information on all ground response stations, and most of the building and bridge stations, has been loaded into the EDC search feature. The EDC is continuing to work with the CISN partners to increase the inventory of information for the CISN stations.

With the inventory of the ground response stations nearly complete, it is now possible to search for station information for most ground response stations and for the earthquake data associated with the stations. Users can take advantage of the search feature to obtain information on a single station or group of stations based on the geographical location, such as city name. Figure 12 shows the result of a sample search that lists the ground response stations in the city of Los Angeles.

Figure 12. An example of a search for ground response stations in Los Angeles (first screen). This allows searching for ground motion data by stations or within certain areas, regardless of what earthquakes were recorded at the stations.

For structural stations, the second level allows search options that are unique to the structure category as well as the same search criteria as for ground response stations. An example of search options for a building station is shown in Figure 13. Similar structure-type specific options are included for bridges and for dam stations. There is also a third level search option for building stations that considers the lateral force resisting system used in the structural design.

A data search request results in a table listing all stations that match the search criteria. Figure 14 shows an example of a search result for high-rise (8-stories and over) steel frame buildings (the building classifications adopted are those of FEMA 310). Within the table, there is a link for each building, which will take the user to a web page with a list of records just for that building (e.g., Figure 15). The station-data page is again a peak acceleration table. Each row of the table represents one record, and includes the name of the earthquake (which incorporates a link to the Internet Data Report for that event), the epicentral distance, and the peak acceleration on the ground and on the structure. The strong-motion records for the earthquake can be directly viewed or downloaded via the web link buttons.

Figure 13. An example of the second level search options for building stations. Shown in the figure are the pull-down menu choices for building construction material. A following selection menu can be used to establish the desired building height category, and, if desired, the local site geology at a structure.

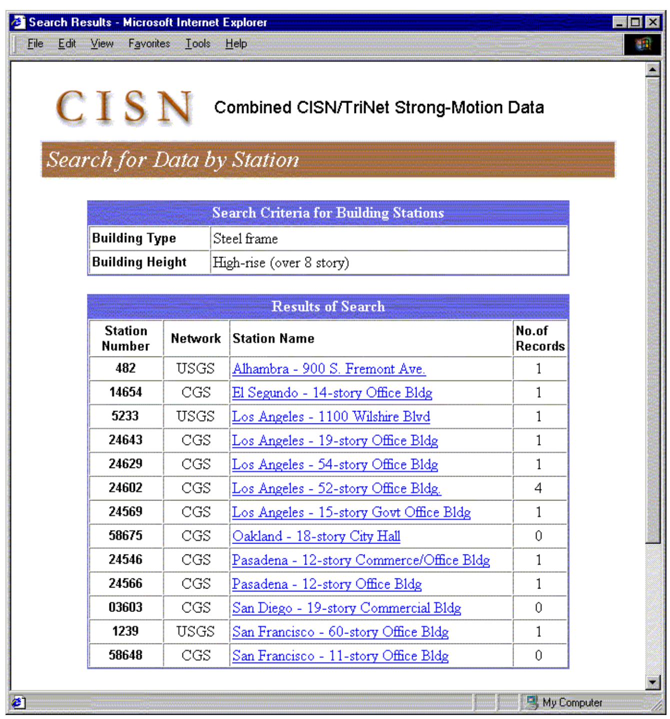
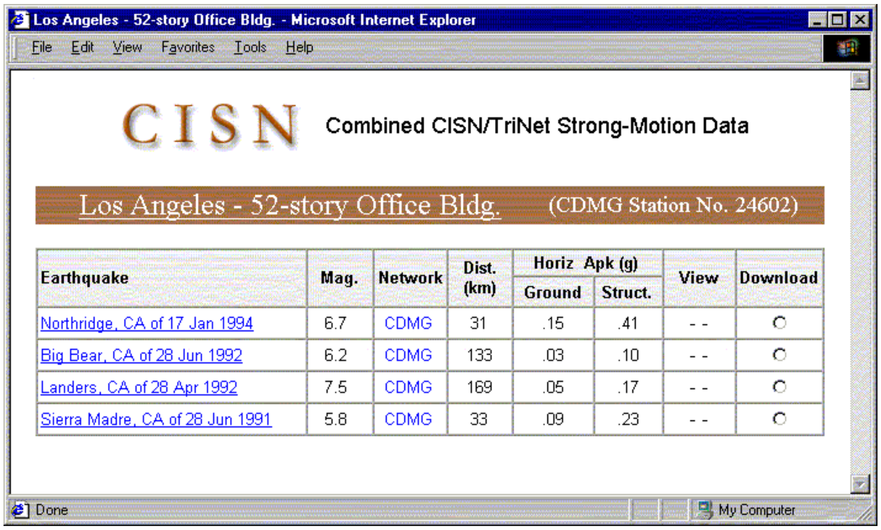


Figure 14. An example of the result of a search request for data from high-rise (8-stories and over) steel frame buildings. The table indicates the network that responsible for the instrumented building and the number of records available (more records will be added as the existing structural records and information is added to the archive). A user can click on any of listed stations to link to a station-data web page.



Los Angeles - 52-story Office Bldg. - Microsoft Internet Explorer

CISN Combined CISN/TriNet Strong-Motion Data

Los Angeles - 52-story Office Bldg. (CDMG Station No. 24602)

Earthquake	Mag.	Network	Dist. (km)	Horiz Apk (g)		View	Download
				Ground	Struct.		
Northridge, CA of 17 Jan 1994	6.7	CDMG	31	.15	.41	- -	○
Big Bear, CA of 28 Jun 1992	6.2	CDMG	133	.03	.10	- -	○
Landers, CA of 28 Apr 1992	7.5	CDMG	169	.05	.17	- -	○
Sierra Madre, CA of 28 Jun 1991	5.8	CDMG	33	.09	.23	- -	○

Figure 15. An example of the station-data web page for a specific building selected in Figure 14. The table shows the collection of strong-motion records for different earthquakes that have been obtained from this specific building. A user can click on any of these links to access the IQR or the Internet Data Reports for the earthquakes.

SHAKEMAP UTILIZATION

The ShakeMap product, developed under TriNet, provides a graphical portrayal of the regional shaking (Wald et al. [11]) for use in rapid post event response. Another level of utilization of the ShakeMap by engineers is in guiding the assessment of structural performance and structural safety after an event. The strong-motion record itself, in addition to the information captured in ShakeMaps, is also important. The ATC-54 report prepared by the Applied Technology Council (Rojahn et al. [12]) provides guidelines on these engineering applications. This is an important progression in increasing the usefulness of ShakeMap.

Another important application of ShakeMap is in earthquake loss estimation. HAZUS, a project of FEMA and the National Institute of Building Sciences (NIBS) is an advanced computational methodology to estimate loss after a significant earthquake. With the introduction of ShakeMap, it becomes possible to do loss estimation based on recorded ground motion in near real time. HAZUS was conceived in a time when rapid data was not available, so ShakeMap expands its value, as well as increases the importance of calibration of methodology and inventory in order for the results, produced rapidly and possibly without human intervention, to be credible. Kircher [13] discusses aspects of calibration of HAZUS to the 1994 Northridge data, a key step toward its general application.

CONTINUING DEVELOPMENT OF THE EDC

The CISN Engineering Strong Motion Data Center greatly accelerates access to strong-motion data after earthquakes and allows users to conveniently obtain data for specific stations and structure types. The development of the EDC is continuing and will focus on the following areas:

- Fully automating the Internet Quick Report, to be available routinely within 15 minutes or less after M>4 earthquakes by later in 2004; until then it is partly manual and will be available within minutes to hours after a significant earthquake.

- The data archives are being populated to include strong-motion data from previous earthquakes and station/structure information, from the CGS/CSMIP and USGS/NSMP networks and the other partners.

- Continuing to add new installed stations and expand the search capability, to allow users to conveniently access strong-motion earthquake data and detailed information on instrumented structures and other stations, including location, site geology, structural system, sensor layouts, and other information.

- Expanding the linking between the Internet Quick Report and the ShakeMap for an earthquake, allowing users to see the regional and the very local shaking associated with an earthquake, in forms customarily used in earthquake engineering.

- A software system to perform 3-dimensional visualization of the recorded motion from instrumented buildings is being developed to facilitate engineers in evaluating the performance of instrumented buildings immediately after a significant earthquake. Video clips generated by the software system will be available at the CISN Engineering Data Center. The users can view the building motion by playing the video clip on a media player (e.g., Figure 16).

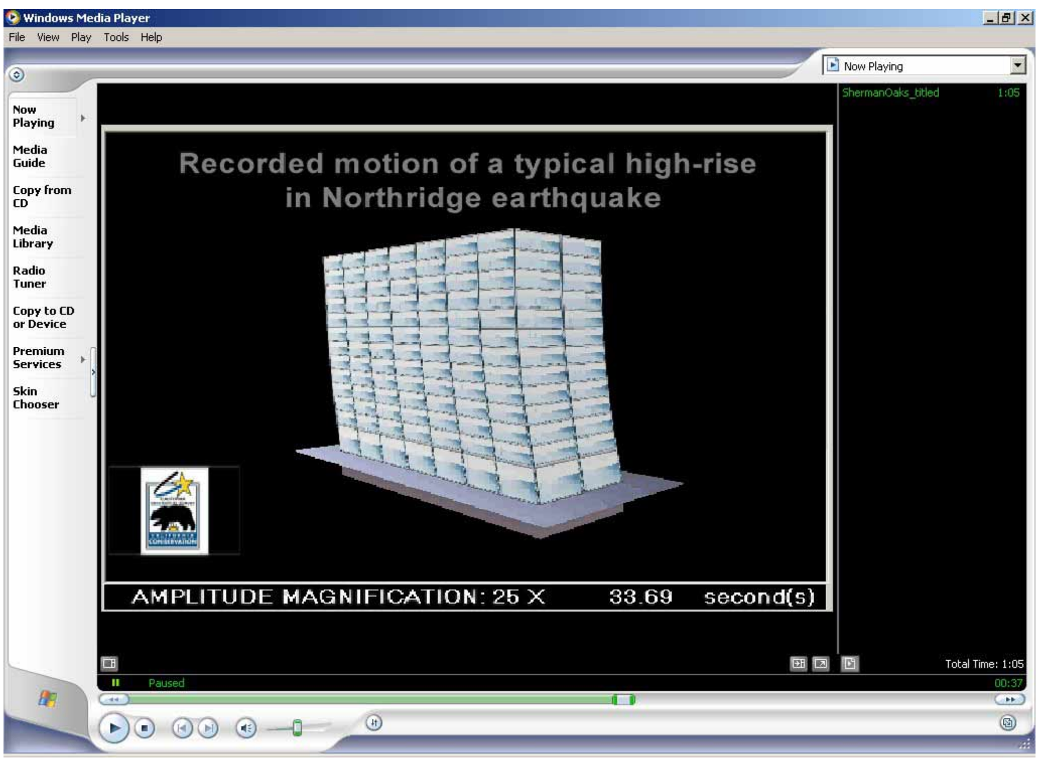


Figure 16. An example of a video clip generated for the motion recorded at a 13-story building during the 1994 Northridge earthquake by the 3-dimensional visualization software system will be added to the CISN Engineering Data Center.

REFERENCES

1. Shakal, A.F., L. Gee, D. Given, D. Oppenheimer and E. Hauksson. "The California Integrated Seismic Network: Status and Application in Earthquake Engineering," in Proceedings of the 13th World Conference on Earthquake Engineering, 2004.

2. Shakal, A.F. and C.F. Scrivner. "TriNet Engineering Strong-Motion Data Center," in Proceedings of SMIP2000 Seminar on Utilization of Strong-Motion Data, 2000, p. 115-124.

3. Lin, Kuo-Wan, A.F. Shakal and C. Stephens. "TriNet/CISN Engineering Strong Motion Data Center and the Internet Quick Report," in Proceedings of SMIP01 Seminar on Utilization of Strong-Motion Data, 2001, p. 53-64.

4. Lin, Kuo-Wan, A.F. Shakal, M. Huang, C. Stephens and W. Savage. "Dissemination of Strong Motion via the Internet Quick Report and the Internet Data Report at the CISN Engineering Data Center," in Proceedings of SMIP02 Seminar on Utilization of Strong-Motion Data, 2002, p. 115-126.

5. Shakal, A.F., K-W Lin, M. Huang, C. Stephens and W. Savage. "Utilizing Strong-Motion Data after Earthquakes: Update on the CISN Engineering Data Center, Internet Quick Reports, ShakeMap and CISN Display," in Proceedings of SMIP03 Seminar on Utilization of Strong-Motion Data, 2003, p. 35-46.

6. CSMIP. "First Quick Report on CSMIP Strong-motion Data from the San Fernando Valley Earthquake of January 17, 1994," OSMS Report 94-01, 10 pp., 17 January 1994.

7. Shakal, A., M. Huang, R. Darragh, T. Cao, R. Sherburne, P. Malhotra, C. Cramer, R. Sydnor, V. Graizer, G. Maldonado, C. Petersen and J. Wampole. "CSMIP strong motion records from the Northridge, California earthquake of 17 January 1994," Report OSMS 94-07, 1994, 308 pp.

8. Porcella, R.L., E.C. Etheredge, R.P. Maley and A.V. Acosta. "Accelerograms recorded at USGS National Strong-Motion Network stations during the Ms 6.6 Northridge, California earthquake of January 17, 1994," USGS OFR 94-141, 1994, 100 pp.

9. Archuleta, R.. "COSMOS Virtual Data Center," in Proceedings of SMIP2000 Seminar on Utilization of Strong-Motion Data, 2000, p. 97-114.

10. Ambraseys, N., P. Smit, R. Sigbjörnsson, P. Suhadolc, and B. Margaris. Internet Site for European Strong-Motion Data, EVR1-CT-1999-40008, European Commission, Directorate-General XII, Environmental and Climate Programme, Bruxelles, Belgium; Internet address: http://www.isesd.cv.ic.ac.uk 2002.

11. Wald, D.J., V. Quitoriano, T. Heaton, C.F. Scrivner and C. Worden. "TriNet ShakeMaps: Rapid Generation of Instrumental Ground Motion and Intensity Maps for Earthquakes in Southern California," *Earthquake Spectra*, 15, 1999, p.537-556.

12. Rojahn, C., C.D. Comartin and S.A. King. "Guidelines for Utilizing Strong-Motion and ShakeMap Data in Post-Earthquake Response (ATC-54)," in Proceedings of SMIP03 Seminar on Utilization of Strong-Motion Data, 2003, p. 47-58.

13. Kircher, C.A. "Near-Real-Time Loss Estimation Using HAZUS and ShakeMap Data," in Proceedings of SMIP03 Seminar on Utilization of Strong-Motion Data, 2003, p. 59-65.