Final Technical Report:
Mid-America Integrated Seismic Network—CERI

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Abstract

This is final report for operation of the CERI seismic network partially funded by USGS Award 04HQAG0009: "*Mid-America Integrated Seismic Network—CERI*" (MAISN). The report includes the period from December 1, 2003 through December 1, 2006. The cooperative agreement covers the CERI component of the MAISN to perform network operations, routine data processing, archiving, and dissemination for the purpose of rapid earthquake notification, seismic hazards evaluation, and scientific studies in the Mid-America region of the Advanced National Seismic System (ANSS-MA). Collaborating MAISN institutions include the University of Memphis, St Louis University, Virginia Tech, the University of Kentucky, the University of South Carolina, and the U.S. Geological Survey.

The CERI seismic network consists of 139 permanent seismic stations (1 shortperiod vertical, 96 shortperiod 3-component, 13 broadband, and 28 ANSS urban strongmotion). Telemetry concerns require operation of twelve data concentrators (or nodes) linked to a central processing facility at CERI. Each node contains about 11 days of continuous revolving buffer and local creation and storage of triggered datasets. All nodes are linked to CERI in continuous near-real-time. The remote nodes are able to operate autonomously in the event of communication failure and thus, in addition to helping to solve the "last mile" communication problem, provide a backup for the regional processing in Memphis.

Background

This is final report for operation of the CERI seismic network partially funded by USGS Award 04HQAG0009: "*Mid-America Integrated Seismic Network—CERI*" (MAISN). The report includes the period from December 1, 2003 through December 1, 2006. The cooperative agreement covers the CERI component of the MAISN to perform network operations, routine data processing, archiving, and dissemination for the purpose of rapid earthquake notification, seismic hazards evaluation, and scientific studies in the Mid-America region of the Advanced National Seismic System (ANSS-MA). Collaborating MAISN institutions include the University of Memphis, St Louis University, Virginia Tech, the University of Kentucky, the University of South Carolina, and the U.S. Geological Survey.

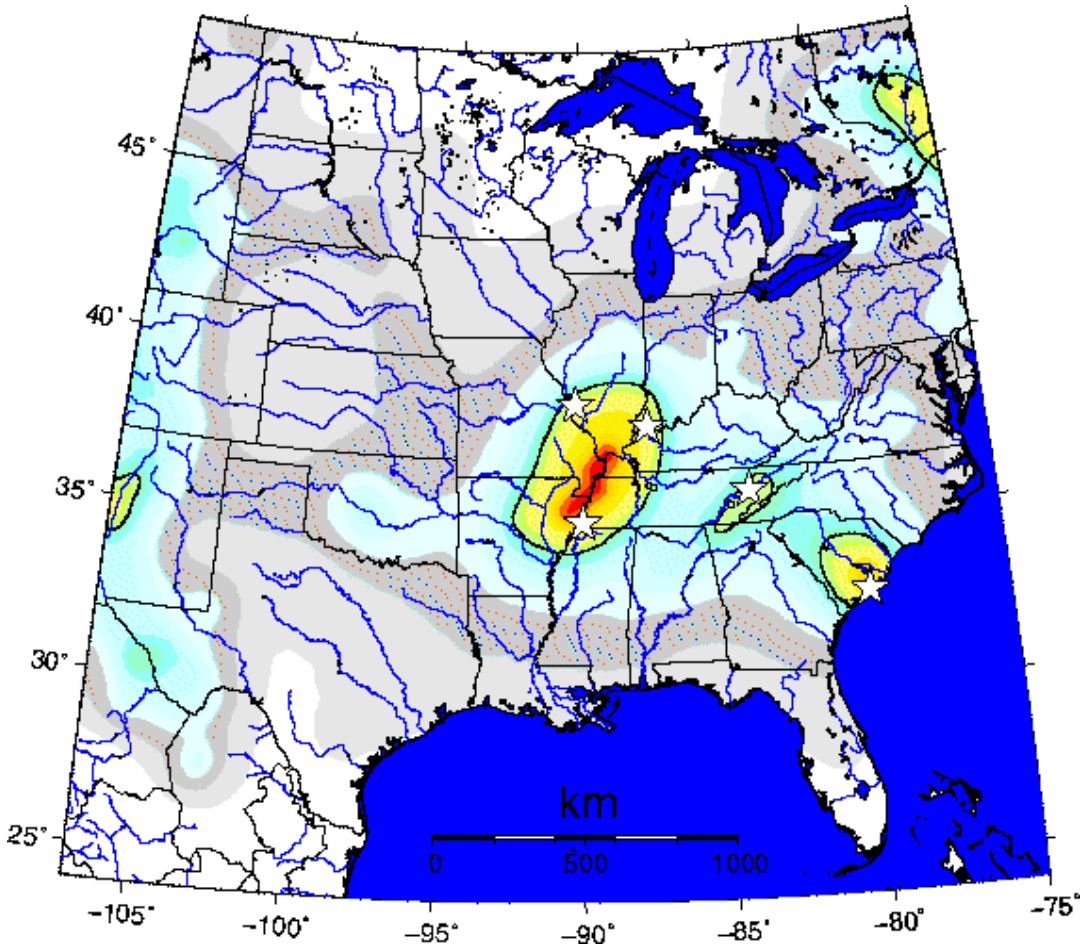

Figure 1. 2002 National Hazard Map 10% probability of exceedance in 50 years for the ANSS Mid-America region. Stars are urban monitoring targets from USGS Circular 1188. The 8%g exceedance level is the line contour.

The regional seismic networks in the MAISN provide raw and derived earthquake products to the ANSS system and provide local expertise on earthquake information, models, and methods. Each institution provides core operations and maintenance as well as locally specific tasks and expertise where appropriate. The purpose of the MAISN is twofold:

1. to provide scientists, engineers, public and private entities, emergency responders, and the media with rapid and reliable information about felt and damaging earthquakes within a timeframe that maximizes the utility of the information,
2. and to provide high quality data on a timely basis to the scientific and engineering communities for the purpose of improving:
   - seismic hazard estimation for urban population centers and the lifelines and critical facilities upon which they depend
   - estimation and measurement of strong ground motions, our understanding of the basic earthquake process, and seismotectonics of earthquake zones, particularly in

intraplate regions.

Network Description

The CERI seismic network consists of 139 permanent seismic stations (1 shortperiod vertical, 96 shortperiod 3-component, 13 broadband, and 28 ANSS urban strongmotion). Telemetry concerns require operation of twelve data concentrators (or nodes) linked to a central processing facility at CERI (Figures 2 and 3). Each node contains about 11 days of continuous revolving buffer and local creation and storage of triggered datasets. All nodes are linked to CERI in continuous near-real-time. The remote nodes are able to operate autonomously in the event of communication failure and thus, in addition to helping to solve the “last mile” communication problem, provide a backup for the regional processing in Memphis.

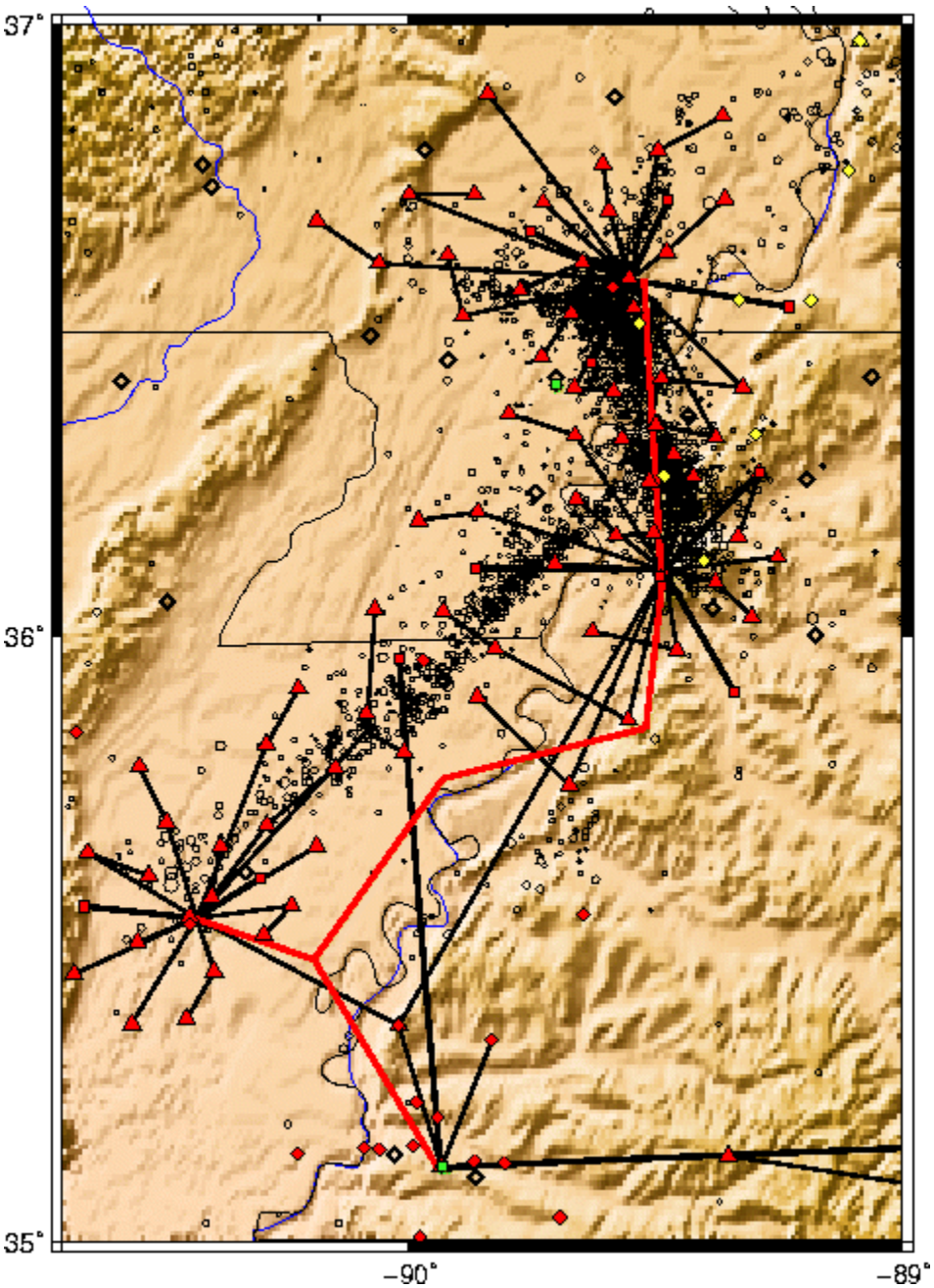

Figure 2. NMSZ stations operated by CERI (red) with telemetry paths. Triangles are shortperiod stations, squares are broadband, and diamonds are strongmotion. Black lines are digital or analog radio. Red lines are the 2.4 GHz spread spectrum digital backbone that provides tcp/ip connectivity with the nodes.

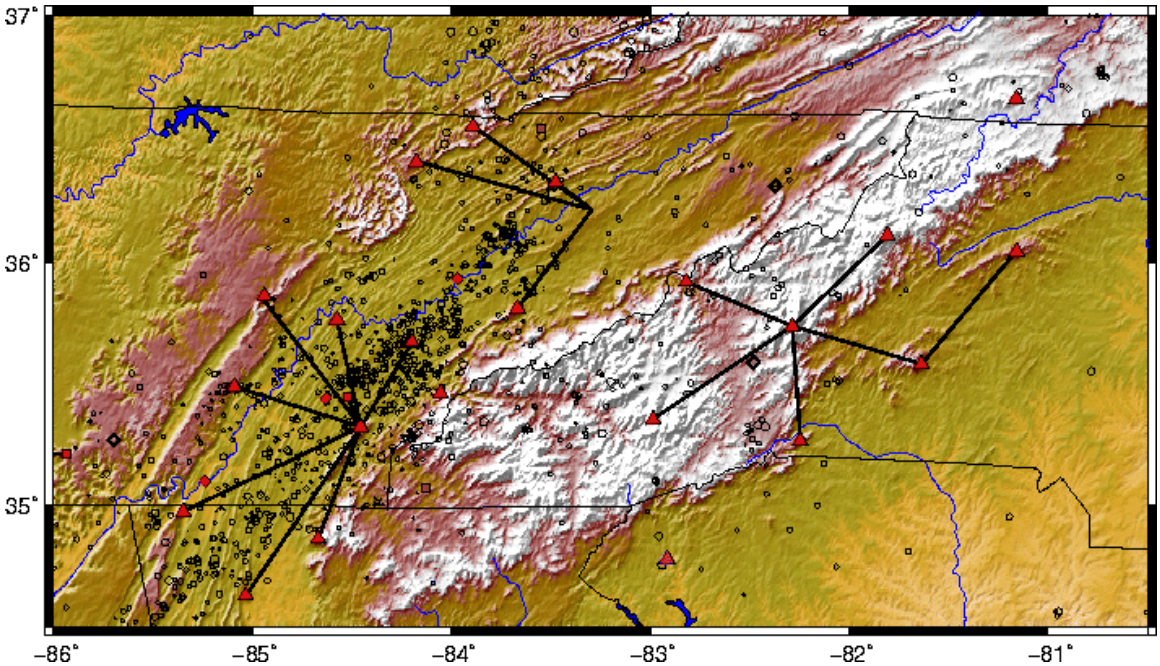

Figure 3. ETSZ stations operated by CERI (red) with telemetry topology. Triangles are shortperiod stations, squares are broadband, and diamonds are strongmotion. Black lines are digital or analog radio. Node connectivity is accomplished via public internet or DSL.

Subnetwork triggers are analyzed daily at CERI for both the New Madrid and East Tennessee Seismic Zones (NMSZ and ETSZ respectively). Both paper and digital *helicorder* records are monitored for state of health purposes and missed events. From one to several hours of data are archived for teleseismic events of interest. Routine and automated event locations are shared with other networks via *QDDS*. Reviewed parameters are similarly shared and are emailed to the ENS listserve (about 6566 recipients were migrated from the ma_quake listserve to ENS in 2006). By far the most popular tool has been the *recenteqs* webpage accounting for more than half of the 15 million hits over the past twelve months. Hypocenters are submitted weekly to the ANSS composite catalog. Reviewed and automated earthquake summaries are available for events within the past six months. Various catalog searches are also supported. Pseudo-helicorder images provide a quick review of station operation and events for the previous week.

Data Acquisition and Processing

Twelve remote acquisition systems and one local system in Memphis are maintained and provide several levels of redundancy (Figure 4). The remote systems are PC-based *earthworm* using National Instruments 12 bit digitizers. Standard short-to-long-term average ratios are employed to store triggered data streams. Additionally, a revolving continuous buffer of about 12 days provides opportunities for post-event archiving. All remote nodes include about 3 days of battery backup. The node at CERI consists of 12 computers (Figure 5) housed in earthquake resistant racks within a physically secure, environmentally controlled room with battery and diesel generator backup and 100baseT

infrastructure. Each remote node is identically configured and provides traditional triggered data as well as real-time export of select channels and station triggers. Station triggers are subnetted at the Regional Processing Center (RPC) to form subnet triggers and subsequent data files.

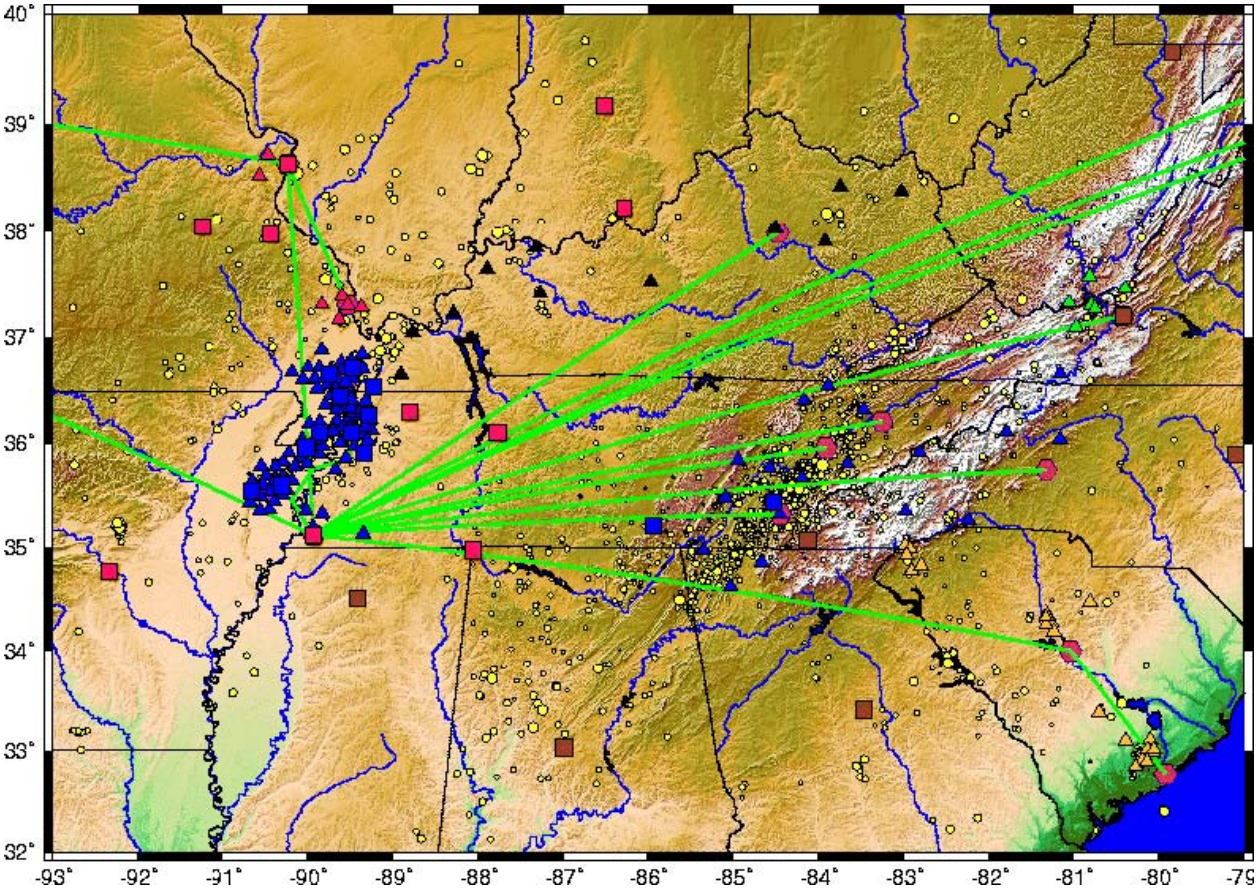

Figure 4. Communications between regional data nodes are accomplished primarily through public internet, though dedicated lines are employed in some cases. Cooperating partners include Univ. of Memphis, USGS/USNSN, St Louis Univ., Univ. of South Carolina, Univ. of Kentucky, Virginia Tech, Maryland Geological Survey.

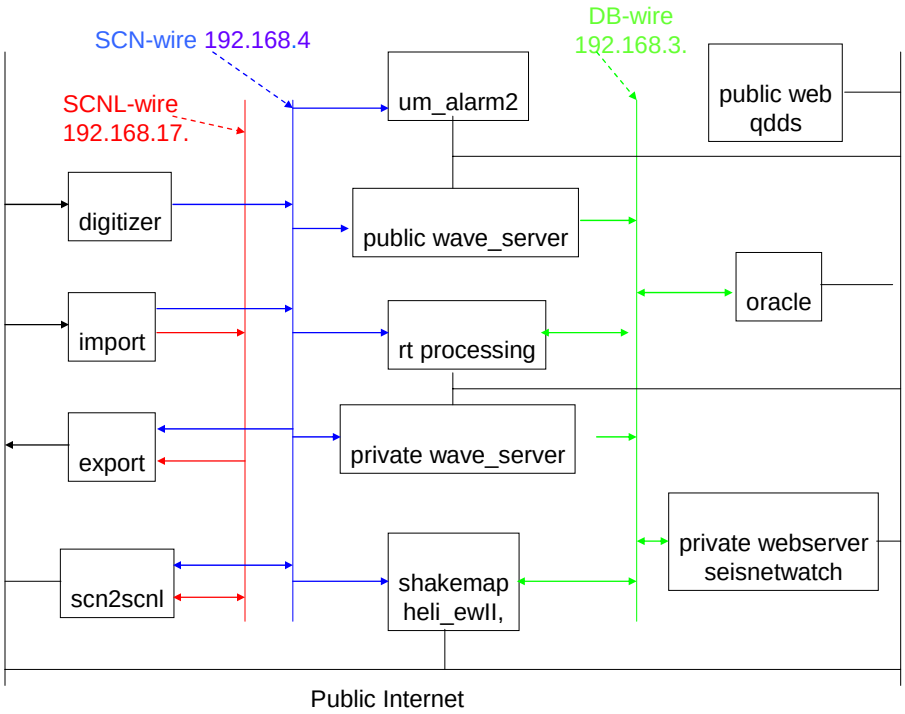

Figure 5. Block Diagram of ANSS-MA Regional Processing Center. Data and products approximately flow from top to bottom and to the left. Communications over private wires is udp/ip and over public wires is tcp/ip.

Components of the above RPC block diagram include:

- Data Acquisition (Dell GX-1):
  - digitize analog shortperiod
- Import (Sun Netra X1):
  - Extract waveforms from ANSS urban strong motion stations
  - Import waveforms from standalone broadbands (e.g. SWET and GNAR)
  - Import waveforms from St Louis Univ.
  - Import waveforms from Univ. of Kentucky
  - Import waveforms from Virginia Tech
  - Import waveforms from Univ. of South Carolina
  - Import waveforms from NEIC
  - Import waveforms from Maryland Geological Survey
  - Import waveforms from New Madrid, MO node
  - Import waveforms from Lennox, TN node
  - Import waveforms from Marked Tree, AR node
  - Import waveforms from Mount Gibbs (aka Blue Ridge), NC node
  - Import waveforms from Morristown, TN node
  - Import waveforms from Athens, TN node
- Export (Sun Ultra 10):
  - export waveforms to St Louis Univ.
  - export waveforms to NEIC
  - export waveforms to Virginia Tech
  - export waveforms to Maryland Geological Survey

- Data Processing (Sun Sunfire 280R):
    - perform station and subnet triggers
    - archive triggered waveforms to disk
    - perform automatic earthquake locations
    - populate dbms
    - perform strongmotion functions
- ShakeMap Server (Sun Sunfire 280R):
    - Produce ShakeMap
- Private Waveserver (Sun Netra T1 and 3 StorEdge S1):
    - approximate seven day revolving disk buffer of all available waveforms with access restricted to RPC
- Public Waveserver (Sun Netra T1 and 3 StorEdge S1):
    - approximate seven day revolving disk buffer of all available waveforms with unrestricted access
- Private Webserver (Sun Netra T120):
    - Serve ShakeMap web pages
    - Operate and serve heli (aka webicorder) pages
    - SeisNetWatch
- Rapid Notification (Sun Ultra5):
    - cell
    - email
    - QDDS
- Public Webserver (Sun Ultra5):
    - searchable catalog
    - digital helicorder
    - recent earthquakes
    - QDDS interface
- DBMS (Dell PowerEdge 2600):
    - earthworm real-time database
    - scn/scnl conversion
- Analysis (Sun Ultra5):
- Development (Sun Sunblade 1000)

Products and Dissemination

Data and Information are distributed by several mechanisms. Event information for events within the past 6 months is provided by *recenteqs* which averages about 80,000 visits per month (1,000,000+ hits per month). Events from 1974 to present are available through the ANSS composite catalog and through the CERI online catalog (available at http://folkworm.ceri.memphis.edu). Submissions are made to the ANSS composite catalog weekly with a one week delay (to assure inclusion of partial weeks at month boundaries). An event Data Handling Interface (DHI) also connects the CERI catalog to the IRIS DMC. IRIS extracts waveform data from CERI waveservers which IRIS will make publicly available when INV at CERI is populated (initial prototype implementation complete) and we are able to provide dataless SEED to the DMC. Event waveforms are also made available via anonymous ftp on request. The 6,000+ ma_quake

earthquake email notification list was migrated to ENS in May 2006 with assistance from Stan Schwarz at USGS Pasadena. CISN Display is operated in select emergency operations centers. ShakeMap is initiated following automatically located earthquakes. Due to the relative immaturity of our ShakeMap effort, the maps are currently only available on a password protected website.