Contents

Chapter 1

Introduction

1. Director's report

1.1 Background

The Berkeley Seismological Laboratory (BSL) is an Organized Research Unit (ORU) of the University of California at Berkeley, whose mission, since the 1930's, has been to conduct research and train students in seismology, as well as provide timely information and education on earthquakes in central and northern California to the University, local and state government and the public. This latter specific mission sets our ORU apart, in that a major component of our activities is focused on developing and maintaining several regional observational networks, and participating, along with other agencies at the State, National and International level, in various aspects of the collection, analysis, archival and distribution of data pertaining to earthquakes, while maintaining a vigorous research program on earthquake processes as well as earth's structure and tectonics.

Notably, following 15 years of parallel operations, the BSL and the US Geological Survey at Menlo Park have, since 1996, combined efforts in a joint Earthquake Notification Program for northern California, which capitalizes on the complementary capabilities of the networks operated by each institution to provide rapid and reliable information on the location, size and other relevant source parameters of regional earthquakes. In recent years, a major emphasis in instrumentation at the BSL has been in densifying the state of the art seismic and geodetic networks that we operate, while a major on-going emphasis in research has been the development of robust methods for quasi-real time automatic determination of earthquake source parameters and predicted strong ground motion, using a sparse network combining broadband and strong motion seismic sensors, as well as permanent geodetic GPS receivers.

The backbone of the BSL operations is a regional network of about 20 digital broadband and strong motion seismic stations, the Berkeley Digital Seismic Network (BDSN), with continuous frame-relay phone telemetry to UC Berkeley. This network provides the basic regional data for the real-time estimation of location, size and rupture parameters for earthquakes of M 3 and larger in central and northern California, within our Rapid Earthquake Data Integration (REDI) program. It also provides a fundamental database for the investigation of three dimensional crustal structure and its effects on regional seismic wave propagation, ultimately crucial for estimating ground shaking for future earthquakes. Most stations also record auxiliary temperature/pressure channels, valuable in particular for background noise quality control. Complementing this network is a 10 station "high-resolution" network of borehole seismic sensors along the Hayward Fault (HFN), operated jointly with the USGS/MP and linked to the Bridge Safety Project of the California Transportation department, which has made possible the installation of sensor packages at 15 bedrock boreholes at 5 east-bay bridges in collaboration with LLNL. A major basic science goal of this network is to collect high signal-to-noise data for microearthquakes along the Hayward Fault in order to gain insight into the physics that govern fault rupture and its nucleation. The BSL is also involved in the operation and maintenance of the Parkfield borehole seismic array, which, after 15 years of intense data collection and processing, is now yielding enlightening results on quasi-periodic behavior of microearthquake clusters and important new constraints on earthquake scaling laws.

In addition to the seismic networks, BSL is heavily involved in data archival and distribution for the permanent geodetic BARD network (Bay Area Regional Deformation Array) as well as the operation and maintenance, and data processing of 18 out of its 40-or-so sites. Whenever possible, BARD sites are collocated with BDSN sites in order to minimize telemetry costs. In particular, the development of analysis methods combining the seismic and geodetic data for the rapid estimation of source parameters of significant earthquakes has been one focus of BSL research.

Finally, two of the BDSN stations also share data acquisition and telemetry with 5 component electromagnetic sensors installed with the goal of investigating the possibility of detection of tectonic signals.

Archival and distribution of data from these and other regional networks is performed through the Northern California Earthquake Data Center (NCEDC), operated at the BSL in collaboration with USGS/MP. The data reside on a mass-storage device, recently upgraded to 2.5 Terrabyte capacity, and are accessible "on-line" over the Internet. Among others, data from the USGS Northern California Seismic Network (NCSN), since its deployment in 1984, are archived and distributed through the NCEDC.

Core University funding to our ORU provides salary support for 3 field engineers, one computer expert, 2 data analysts, 1 staff scientist and 2 administrative staff. This covers the basic needs of the operations of the BDSN and seed funding for our other activities. All other programs are supported through a combination of extra-mural grants primarily from the USGS and NSF. We acknowledge valuable recent contributions from other sources such as the OES, Caltrans, the CLC program, as well as our Earthquake Research Affiliates Program.

1.2 Recent Highlights

First and foremost, I would like to stress the difficult conditions under which our staff has worked in the past year, due to the on-going renovation of McCone Hall, including a major move, in January 1999, of our offices and operations from the 4th and 5th floor on the one hand, and temporary quarters in Wellman Trailers on the other, requiring much time and effort to ensure the proper and continuous functioning of our computer systems, data center hardware and telemetry. The smooth operation of the BSL has continued to be disrupted, after the move, and up to this date, by miscellaneous problems related, in particular to the ventilation and electrical systems in the building. In spite of that, much has been accomplished in the past year. I would like to give special thanks to Doug Neuhauser, Charley Paffenbarger and Lind Gee for devoting much of their time to help us live smoothly through this troubled period, of which the end is hopefully in sight.

In 1998-1999, we have continued to consolidate and expand our regional instrumentation programs, adding two SF Bay Area stations to the BDSN, 3 new BARD stations, and upgrading telemetry capabilities at various sites. Notably, with the help of funding from OES, we have put in place a redundant data acquisition and processing system at the OES headquarters in Sacramento. This system is designed to provide bare-bones back-up capabilities for our REDI program (in addition to the two twin data processing computers, Athos and Porthos, at the BSL) in the event that communications are lost to our central processing site during a major earthquake. The Sacramento computer receives data from 6 of our BDSN stations over frame-relay and has worked well on the occasion of several recent M4-5 events. As described further in this report, we are in the process of developing enhanced processing methodologies that utilize the broadband waveform information from a small number of stations in order to provide reliable estimates of source location and size using this back-up facility.

In the past year, with the help of funding from the USGS, we have been upgrading the NCEDC mass-store from an initial capacity of 600 Gbytes (optical discs, capacity reached at the end of 1998) to 2.5 Terrabytes (magneto optical discs). This process has been much slower than anticipated, due to unexpected hardware and software problems with the new mass-storage system, but should provide us room for the ever increasing quantity of data collected over our networks, for the immediate future. Notably, the NCEDC has played an active role in the development of a program lead by IRIS to link different seismological Data Centers worldwide over the internet (NetDC) in order to rationalize researchers' access to complementary datasets. The prototype software is in place and operational and the capability will be released publicly during the Fall'99 AGU meeting in San Francisco.

So far, progress in densifying instrumentation in the San Francisco Bay Area and northern California with state of the art systems to provide timely information on ground shaking and earthquake processes has been progressing steadily, but slowly, due to limited funding. Compared to southern California, where over 150 broadband/strong motion seismic stations are being installed in the framework of the TriNet program, and an equivalent number of permanent GPS stations in the framework of the SCIGN program, our capabilities are still modest. However, much progress has been achieved in the past year in northern California in designing the plans for a northern California component of the TriNet program. The three institutions involved, UC Berkeley, CDMG and USGS/MP have drafted a proposal, with input from the OES, for the enhancement of infrastructure in northern California, with particular emphasis on developing capabilities for rapid estimation of strong ground shaking (i.e. ShakeMaps) (See MOA attached as Appendix). While no specific funding for this ~$20 M initiative has yet been secured, the BSL staff and faculty have been actively involved in all aspects of the design of this plan.

In January 1998, we submitted a collaborative proposal to the MRI program of NSF, to enhance the infrastructure for the monitoring of tectonic deformation in central California. Funding from the resulting grant and matching funds from the participating institutions (UC Berkeley, Carnegie Inst. of Washington, UC San Diego, USGS/MP) will serve to install on the order of 10 multiparameter stations in the San Francisco Bay Area, involving borehole strainmeters and seismometers as well as permanent GPS receivers, and another 9 GPS stations covering the gap between the SCIGN and BARD networks in central California. This will serve as a pilot project for a much broader initiative, the "Plate Boundary Observatory", currently being prepared in the framework of an MRE/NSF program ("Earthscope") by the US geophysical community.

The BSL faculty and research staff are also actively involved in the preparation of several other major US instrumentation initiatives, namely the ANSS (Advanced National Seismic System) of the USGS, and the USArray and SAFOD programs, which are part of Earthscope.

Finally, in collaboration with MBARI (Monterey Bay Aquarium Research Institute), we are beginning to plan the installation of a permanent seismic observatory on the ocean floor in Monterey Bay. Telemetry of data to shore will be developed either over a cable or using an MBARI mooring. This is a follow-up of the 1997 MOISE experiment and we hope it will be the first station of a network of ocean bottom broadband observatories offshore California, to complement the land-based network across the North-America/Pacific plate boundary.

Sections 9 and 10 of this report describe the research accomplishments at the BSL during the past year. You will note that our research encompasses many regional, earthquake and tectonics related problems on the one hand, and fundamental problems in global geophysics, through our work in global tomography and more generally, through modelling of teleseismic travel times and waveforms. A recent focus has been the re-evaluation of simple models of inner core anisotropy, in the light of recent results on the strong heterogeneity at the base of the mantle.

Finally, the BSL contributions to general education have been enhanced in the last year, as described in the Outreach section, and in particular through our continued participation in the Interactive University Project. Scientists at the BSL are also frequently solicited by the media and public for information about current regional and worldwide earthquakes. We respond through individual interviews and have put much effort in the last year in further developing our web interface.

I wish to thank our technical and administrative staff, scientists and students for their contributions to this annual report and wish good luck with their careers for the 3 graduate students have completed their PhD's in 1999: Ludovic Bréger, Charles Mégnin, and Paul Parker. I also wish to thank our undergraduate assistants/interns Derek Lerch, Sheer El Showk, Jacob Fink, Sean Ford, Christine Ng, Shawn Lawrence, Valier Pacheu, Enrou Yang, and visiting from France Sébastien Rousset for their contributions to our research.

Barbara Romanowicz
Sept 23, 1999

AGU	American Geophysical Union
ANSS	Advanced National Seismic System
BARD	Bay Area Regional Deformation
BDSN	Berkeley Digital Seismic Network
BSL	Berkeley Seismological Laboratory
CalREN	California Research and Educational Network
CDMG	California Division of Mines and Geology
CLC	Campus Laboratory Collaboration
EM	Electromagnetic
EPRI	Electric Power Research Institute
FBA	Force Balance Accelerometer
FRAD	Frame Relay Access Device
GPS	Global Positioning System
HFN	Hayward Fault Network
HRSN	High Resolution Seismic Network (Parkfield)
IGS	International Geodetic Service
InSAR	Interferometric Synthetic Aperture Radar
IRIS	Incorporated Research Institutions for Seismology
ISC	International Seismological Center
ISTAT	Integrating Science, Teaching, and Technology
IUP	Interactive University Project
JPL	Jet Propulsion Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
MRI	Major Research Initiative
MRE	Major Research Equipment
MT	Magnetotelluric
NCSN	Northern California Seismic Network
NCEDC	Northern California Earthquake Data Center
NEHRP	National Earthquake Hazards Reduction Program
NGS	National Geodetic Survey
NSF	National Science Foundation
OES	Office of Emergency Services
PVC	Permanent Virtual Circuits
REDI	Rapid Earthquake Data Integration
SAPSE	South Island Passive Seismic Experiment
SAR	Synthetic Aperture Radar
SEED	Standard for the Exchange of Earthquake Data
SIO	Scripps Institutions of Oceanography
SSA	Seismological Society of America
UCB	University of California at Berkeley
ULF	Ultra Low Frequency
UNAVCO	University NAVSTAR Consortium
USGS	United States Geological Survey

Table 1.1: Table of standard acronyms and abbreviations used in this report.

Chapter 2

Berkeley Digital Seismic Network

Bill Karavas, John Friday, Dave Rapkin, Bob Uhrhammer, and Doug Neuhauser

1. Introduction

The Berkeley Digital Seismic Network (BDSN) is a regional network of very broadband and strong motion seismic stations spanning northern California and linked to UC Berkeley through continuous telemetry (Figure 2.1). This network is designed to monitor regional seismic activity at the magnitude M 3 level as well as to provide high quality data for various research projects in regional and global broadband seismology.

The network upgrade and expansion initiated in 1991 has continued, and it has grown from the original 3 broadband stations installed in 1986-87 (BKS,SAO,MHC) to 21 stations in 1999. Two stations were added in the past year (BDM and POTR).

We take particular pride in high quality installations, which involves often lengthy searches for appropriate sites away from sources of low frequency noise, as well as continuous improvements in installation procedures and careful monitoring of noise conditions at existing stations.

Future expansion of our network is contingent on the availability of funding and coordination with other institutions for the development of a denser state-of-the-art strong motion/broadband seismic network and joint earthquake notification system in this seismically hazardous region.

2. Sensors, Recording and Telemetry systems

Each of the BDSN sites is equipped with a broadband seismometer, a strong-motion accelerometer, and a 24-bit digital datalogger and is recorded at UC Berkeley using continuous telemetry (Figures 2.2–2.3). In order to insure against data loss during utility disruptions, each site has a 3-day supply of battery power and is accessible via a dialup phone line. The combination of high-dynamic range sensors and digital dataloggers ensures that the BDSN has the capability to record the full range of earthquake motion for source and structure studies. Figure 2.4 shows a synopsis of low frequency background nosie over the last year at BDSN stations. The high level of noise at station FARB reflects a combination of limited bandwidth sensor (CMG 40) and the island environment. Figure 2.5 shows an example of recording of the P wavetrain from a large deep teleseismic across the BDSN network.

As noted above, all BDSN sites are equipped with three-component broadband sensors and three-component strong motion accelerometers. A Guralp CMG-3T downhole broadband sensor contributed by LLNL is deployed at BRIB and a Guralp CMG-40T is installed at FARB. All other BDSN stations use Streckeisen sensors (*Wielandt and Streckeisen*, 1982; *Wielandt and Steim*, 1986). The strong-motion instruments are Kinemetrics FBA-23 or FBA-ES-T with 2 g dynamic range. The recording systems at all sites are either Q935 or Q4120 Quanterra dataloggers, with 6, 8, or 9 channel systems. The Quanterras employ FIR filters to extract data streams at a variety of sampling rates (Figure 2.6). In general, the BDSN stations record continuous data at .01, 0.1, 1.0, and 20.0 samples per second and triggered data at either 80 or 100 samples per second (Table 2.1) using the Murdock, Hutt, and Halbert event detection algorithm (*Murdock and Hutt*, 1983). In addition to the 6-channels of seismic data, signals from thermometers and barometers are recorded at nearly every site.

In parallel with the growth of the broadband network, a grant from the CalREN (California Research and Education Network) Foundation enabled the BSL to convert data telemetry from analog leased lines to digital frame-relay connections. The frame-relay network uses digital phone circuits that can support 56 Kbit/s to 1.5 Mbit/s

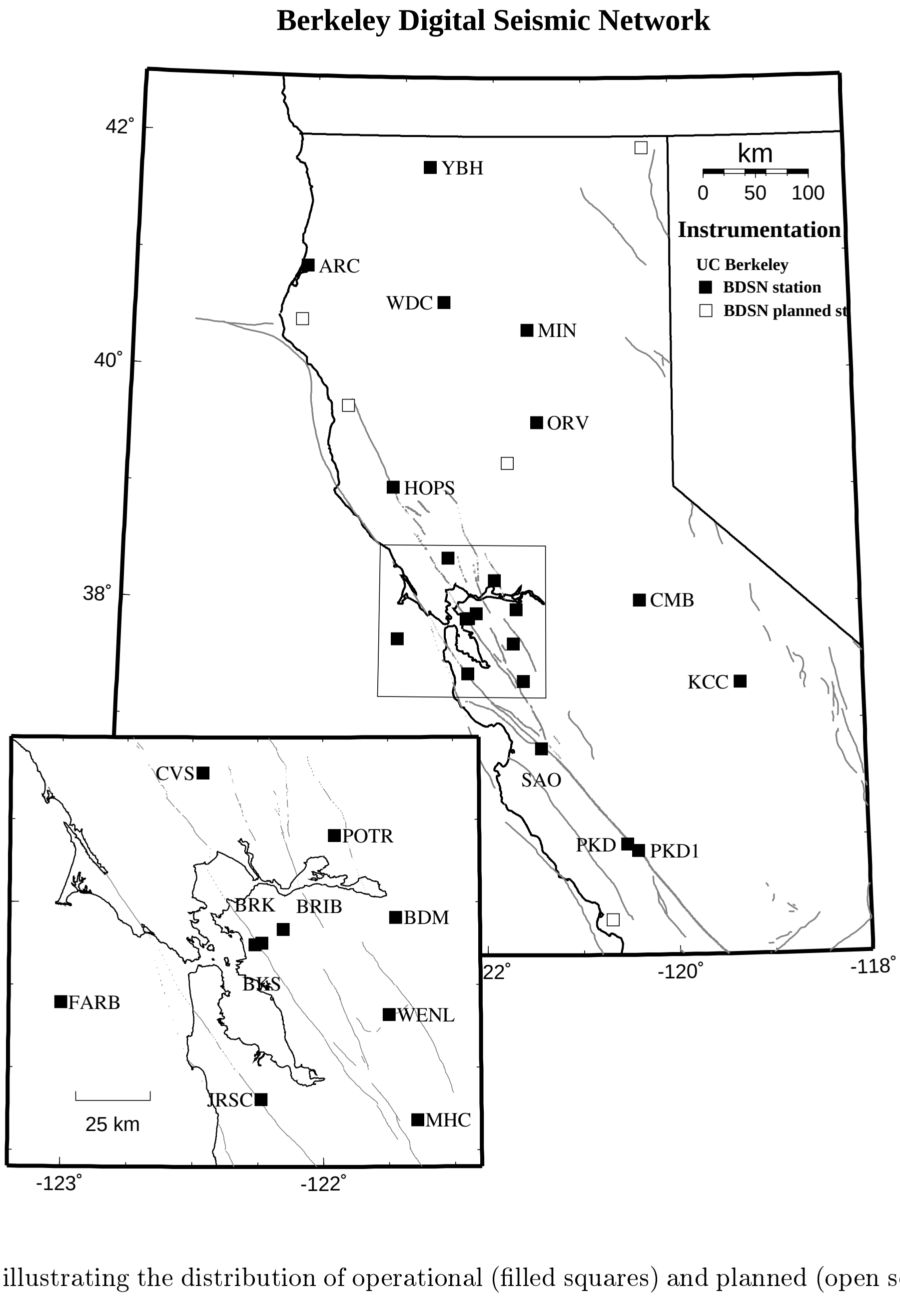

Figure 2.1: Map illustrating the distribution of operational (filled squares) and planned (open squares) BDSN stations. *Courtesy of L. Gee.*

throughput. Since frame-relay is a packet-switched network, a site may use a single physical circuit to communicate with multiple remote sites through the use of "permanent virtual circuits". Frame Relay Access Devices (FRADs), which replace modems in a frame-relay network, can simultaneously support multiple interfaces such as RS-232 async ports, synchronous V.35 ports, and ethernet connections. In practical terms, the upgrade to frame relay communication provides faster data telemetry between the remote sites and the BSL, remote console control of the dataloggers, additional services such as ftp and telnet to the dataloggers, data transmission to multiple sites, and the ability to communicate and transmit data from multiple instruments such as GPS receivers and/or multiple dataloggers at a single site. Today, 20 of the BDSN sites use frame-relay telemetry for part of their communications system.

In order to take advantage of the capabilities of the frame-relay telemetry, we have upgraded the Q935 dataloggers with the installation of an Ethernet board (the Q4120 systems were delivered with Ethernet boards). 19 of the 21 BDSN sites now have Ethernet capability and 2 upgrades remain to be completed.

Central site data acquisition is performed by two computer systems located at the BSL using the comserv software. A third system acquires data from the NSN VSAT (BDSN stations CMB, SAO, and WDC and TERRASCOPE station ISA) (Figure 2.7). Comserv clients feed data into shared memory regions for REDI processing, to the seismic alarm process, to the DAC480 system, and to the Momento Mori Web page.

BDSN data are routinely monitored for state-of-health. An automated power spectral density analysis is computed weekly to characterize the seismic noise level recorded by each broadband seismometer. The algorithm sends the results via email to the engineering and some research staff members and it also generates a bargraph output which compares all the BDSN broadband stations by components. A summary of the results for 1998-1999 is displayed in Figure 2.4. The occurrence of a significant teleseism also provides the opportunity to review station performance and calibration. Figure 2.5 displays the response of the BDSN to a deep teleseism.

BDSN data are archived at the Northern California Earthquake Data Center and this is described in detail in the chapter on Archive and Distribution.

3. Station Maintenance

BDSN sites have experienced the usual type of maintenance problems over the last year. Nearby lightning strikes affected telemetry at several stations. Mice, attracted by the warm electronics, destroyed telemetry equipment on the Farallon Islands (FARB) and at Carmenet Vineyards (CVS). Ethernet and disk upgrades were performed at ARC and MHC. Several sites were visited to replace the GOES clocks with GPS (BRK, CMB, ORV), and several GPS clocks were replaced in order to avoid Y2K problems. Overall, the weather was less severe during 1998-1999 and we did not experience major problems from flooding or heavy snowfall.

4. New Station Installations

4.1 Black Diamond Mines Regional Park - Antioch

During the summer of 1998, a new broadband station was added at the Black Diamond Mines, East Bay Regional Park, south of Antioch. The Park was the site of extensive underground lignite mining during the 1800's. The clean sand intra-burden was mined as late as post World War II for glass making. The East Bay Regional Park District conducts educational and historical tours in two areas of the underground sand mine workings. Under permit from the Park District, the addition of the seismographic equipment in an area of the mine not open to public tours, is in keeping with the educational and research goals of the Park.

The instruments are located approximately 150 meters from the daylight entrance to the mine. Approximately 100 meters of sandstone, shale, and coal overburden cover all the instruments. The overburden is sufficient to limit thermal variations. Additionally, the seismometers are covered with 7 centimeters of foil-faced, closed-cell foam. Differential GPS was used to precisely locate a reference outside the mine, and traditional surveying methods then located the instrument offset from the GPS determined coordinates.

Station BDM features a Q4120 data logger, STS-2 broadband seismometers, FBA-ES-T accelerometers and 56 Kbit/s continuous telemetry to Berkeley. A GPS clock provides reference timing. Low loss co-axial cable (< 2 dB per 100 feet) was used to minimize the attenuation of the signal, and corresponding loss of external clock source.

4.2 Potrero Hills - Fairfield

In the fall of 1998, a new broadband station was added in the Potrero Hills area of the Sacramento River Delta near Fairfield. The new site, POTR, is located with the facility of OEA Aerospace Inc. The facility is on and

Figure 2.2: Stations of the Berkeley Digital Seismic Network

	Station	Coordinates (degrees)	Instruments	Date of Upgrade or Installation	Data Telemetry	Notes
1	BKS	37.877 N 122.235 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	05/91	Continuous frame relay, etherrnet, 9.6 k baud terminal, redundant modem on dial-up as backup	upgrade telemetry warpless baseplate added 1998 therm/baro installed 1998
2	PKD1	35.889 N 120.425 W	Quanterra Q935 FBA-23 GPS Clock	10/91	Continuous frame relay, ethernet, 9.6 k baud terminal, redundant modem on dial-up as backup	
3	MHC	37.342 N 121.642 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	04/92	Continuous frame relay, ethernet 9.6 k baud terminal, redundant modem on dial-up as backup	therm/baro installed 1996
4	ARC	40.877 N 124.075 W	Quanterra Q935 STS-2, FBA-23 GPS Clock	05/92	Continuous frame relay, ethernet 9.6 k baud terminal, redundant modem on dial-up as backup	
5	CMB	38.035 N 120.385 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	06/92	Continuous frame relay, ethernet, redundant modem on dial-up as backup Redundant NSN Satellite link	Data provided to IRIS warpless baseplate added 1998 therm/baro installed 1998
6	SAO	36.765 N 121.445 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	06/92	Continuous frame relay, ethernet, redundant modem on dial-up as backup Redundant NSN Satellite link	thermo/baro intslled 1996 warpless baseplate added 1998
7	ORV	39.556 N 122.500 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	07/92	Continuous frame relay, ethernet, 9.6 k baud terminal, redundant modem on dial-up as backup	therm/baro installed 1996 warpless baseplate added 1998
8	WDC	40.580 N 122.540 W	Quanterra Q935 STS-2, FBA-23 GPS Clock	07/92	Continuous frame relay, ethernet, redundant modem on dial-up as backup Redundant NSN Satellite link	therm/baro installed 1996
9	MIN	40.345 N 121.605 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	03/93	Continuous 19.2 K baud, redundant second modem on dial-up as backup	
10	YBH	41.732 N 122.711 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	07/93	Continuous frame relay, ethernet, 9.6 k baud terminal, redundant modem on dial-up as backup	therm/baro installed 1996 warpless baseplate added 1998
11	BRK	37.873 N 122.260 W	Quanterra Q935 STS-2, FBA-23 GPS Clock	03/94	Continuous 9.6 K baud, ethernet	Historical Berkeley campus site.
12	JRSC	37.404 N 122.238 W	Quanterra Q935 STS-2, FBA-23 GPS Clock	07/94	Continuous frame relay, ethernet 9.6 k baud terminal, redundant modem on dial-up as backup	Collaborative with Stanford University.
13	HOPS	38.994 N 123.072 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	10/94	Continuous frame relay, ethernet, 9.6 k baud terminal, redundant modem on dial-up as backup	therm/baro installed 1997 warpless baseplate added 1998
14	BRIB	37.919 N 122.151 W	Quanterra Q935 CGM-3T FBA-23 GPS Clock	06/95	Continuous frame relay, ethernet, 9.6 k baud terminal, redundant modem on dial-up as backup	Via frame relay, shared with Hayward Fault Net. Seismometer currently installed at surface. Collaborative with LLNL.
15	KCC	37.324 N 119.318 W	Quanterra Q935 STS-1, FBA-23 GPS Clock	01/96	Continuous frame relay 9.6 k baud terminal, redundant modem on dial-up as backup	Collaborative with UC Santa Cruz therm/baro installed 1997 warpless baseplate added 1997
16	PKD	35.945 N 120.541 W	Quanterra Q935 STS-2, FBA-23 GPS Clock	07/96	Continuous frame relay 9.6 k baud terminal ethernet	Via UC radio modems and frame relay circuit. therm/baro installed 1996

Figure 2.3: Stations of the Berkeley Digital Seismic Network (cont'd) *Courtesy of D. Rapkin.*

	Station	Coordinates (degrees)	Instruments	Date of Upgrade or Installation	Data Telemetry	Notes
17	FARB	37.698 N 123.000 W	Quanterra Q4120 CMG-40T, FBA-23 GPS Clock	03/97	Continuous frame relay ethernet	Via redundant radio modems. therm/baro installed 1997
18	WENL	37.623 N 121.757 W	Quanterra Q4120 STS-2, FBA-23 GPS Clock	06/97	Continuous frame relay, ethernet 9.6 k baud terminal	therm/baro installed 1997
19	CVS	38.392 N 122.462 W	Quanterra Q4120 STS-2, FBA-23 GPS Clock	04/98	Continuous frame relay, ethernet 9.6 k baud terminal	therm/baro installed 1998
20	BDM	37.941 N 121.813 W	Quanterra Q4120 STS-2, FBA-23 GPS Clock	11/98	Continuous Frame Relay 9.6 k baud terminal ethernet	therm/baro installed 1998
21	POTR	38.203 N 121.932 W	Quanterra Q4120 STS-2, FBA ES -T GPS Clock	12/98	Continuous Frame Relay 9.6 k baud terminal ethernet	therm/baro installed 1998

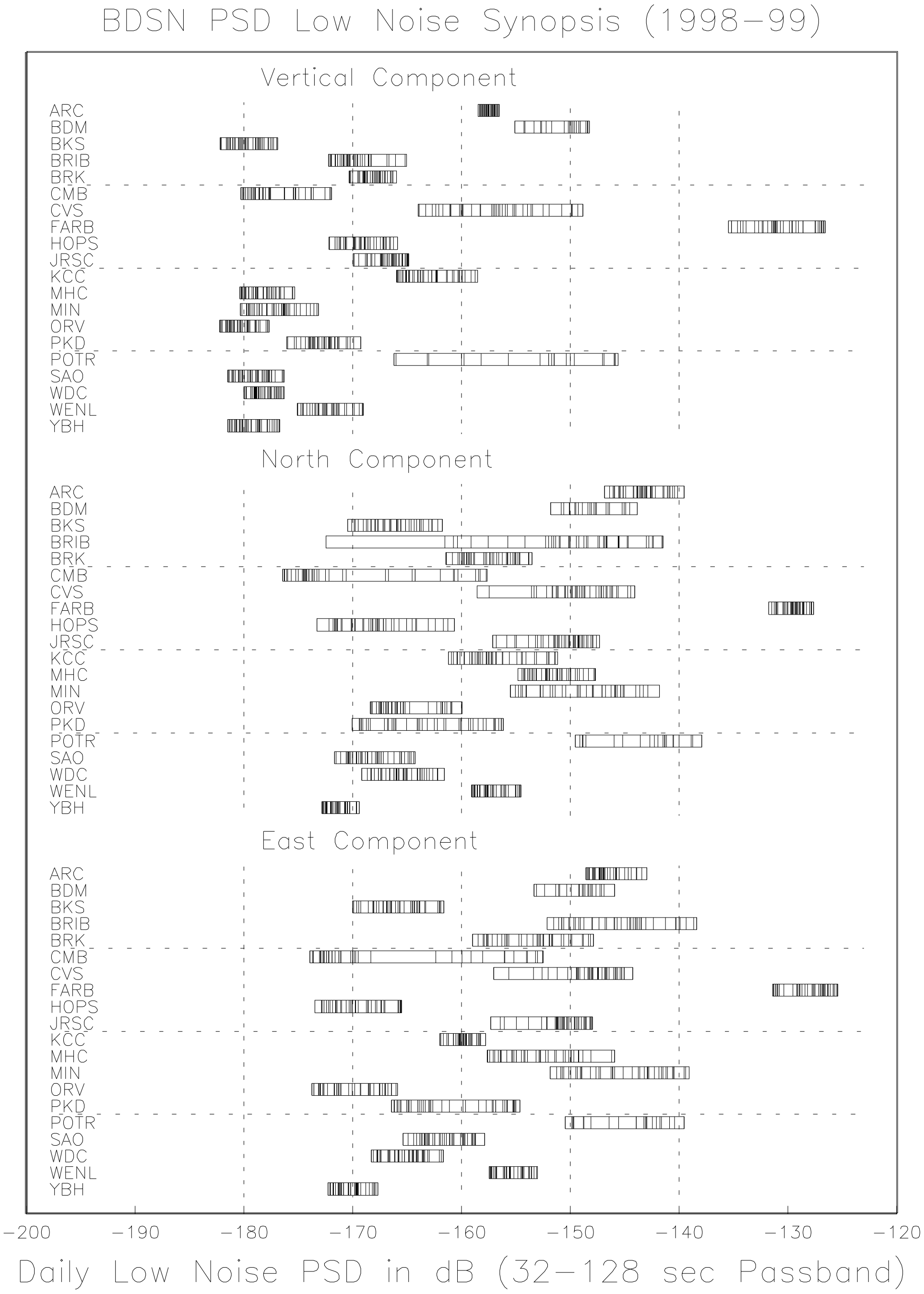

Figure 2.4: PSD noise analysis for BDSN stations, by channel, in the period range from 32-128 s. *Courtesy of B. Uhrhammer.*

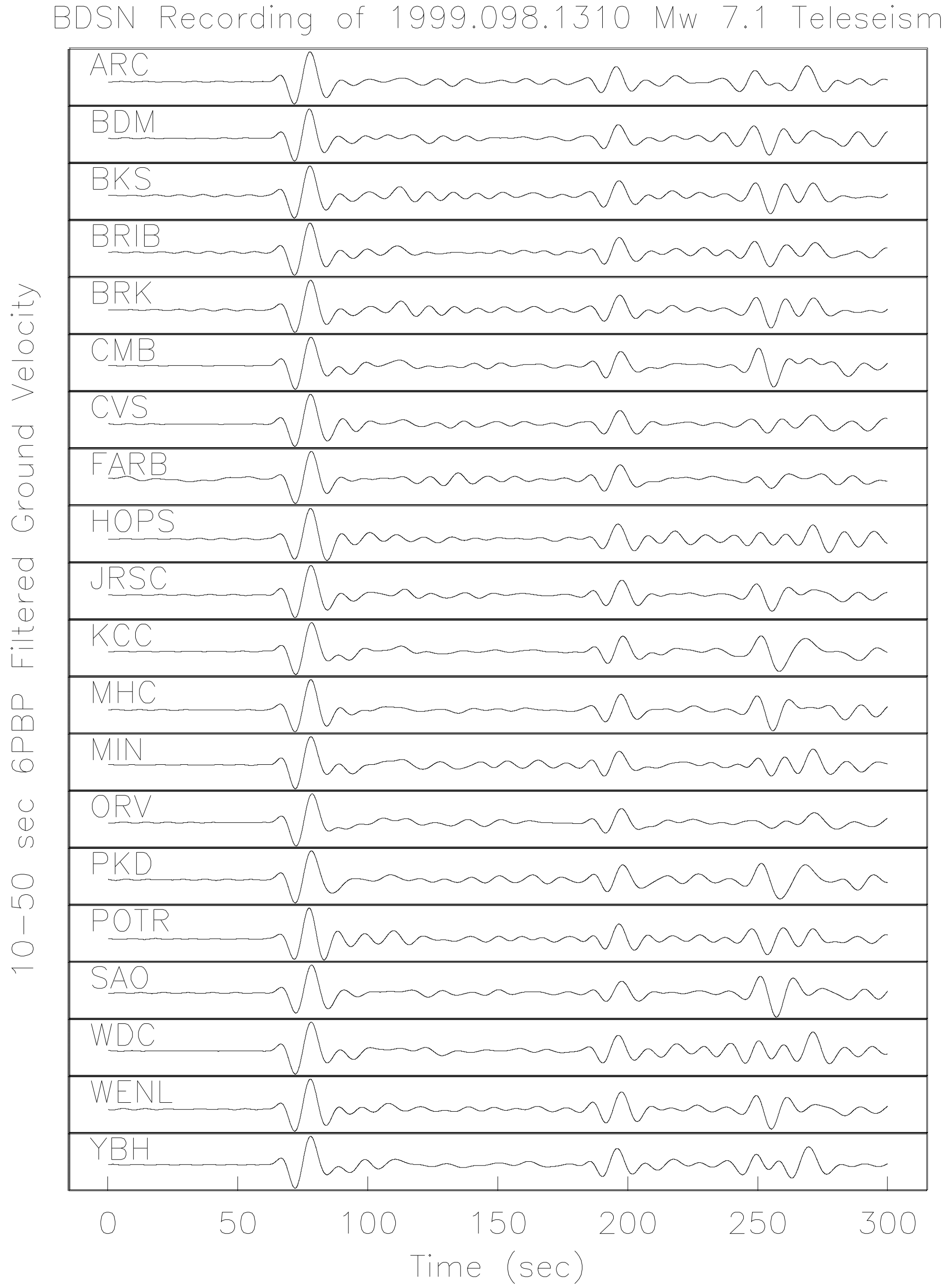

Figure 2.5: The figure shows a BDSN stack of a P-wave train for a Mw 7.1 deep focus (565 km) teleseism recorded by 20 BDSN broadband stations. The teleseism occurred along the NE China Border region at 13:10 UT on April 8, 1999 and it is 76 degrees from Berkeley. The 5 minute record section shows the P/PcP (at 70 sec), pP (at 190 sec), and sP/PP (at 250 sec) phases with the station waveforms shown alphabetically. Note that the P/PcP and pP phases are coherent across the the BDSN while the sP/PP phases interfere with each other to produce an incoherent waveform across the BDSN. *Courtesy of B. Uhrhammer.*

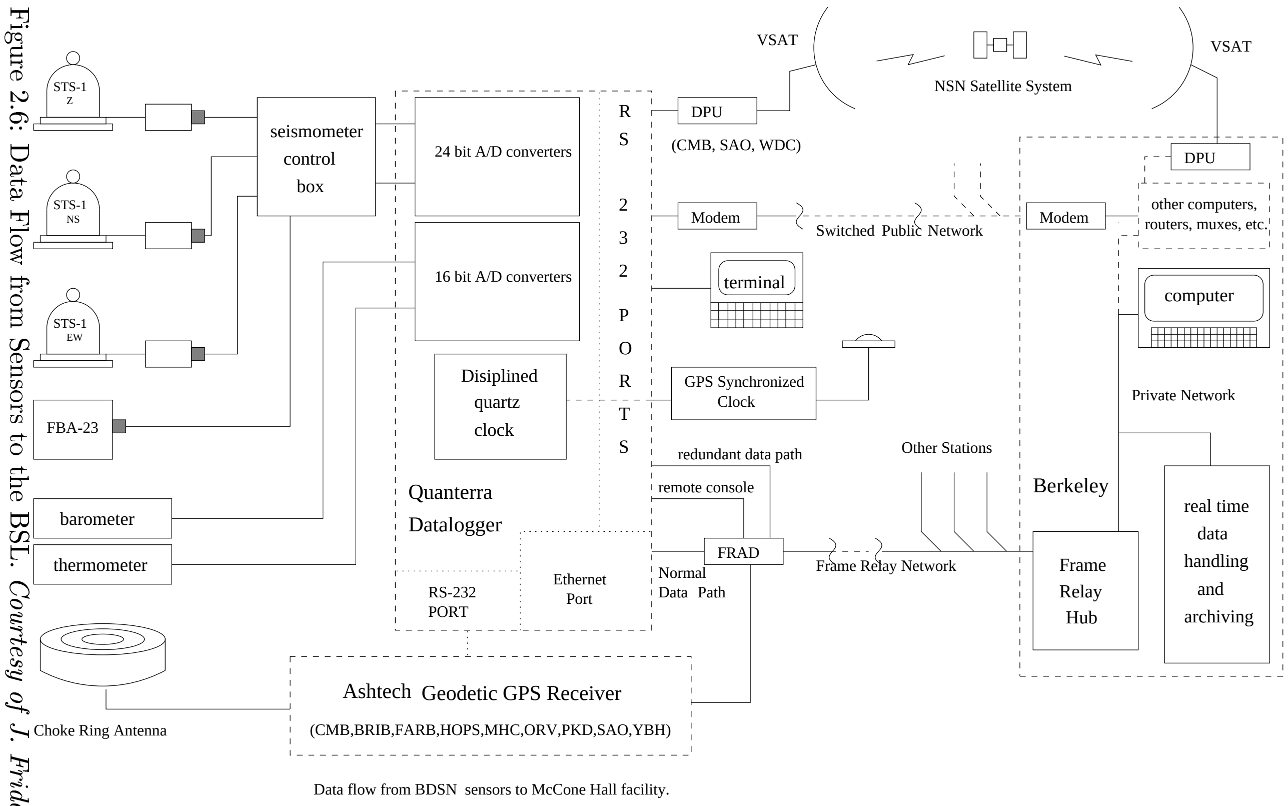

Figure 2.6: Data Flow from Sensors to the BSL. *Courtesy of J. Friday.*

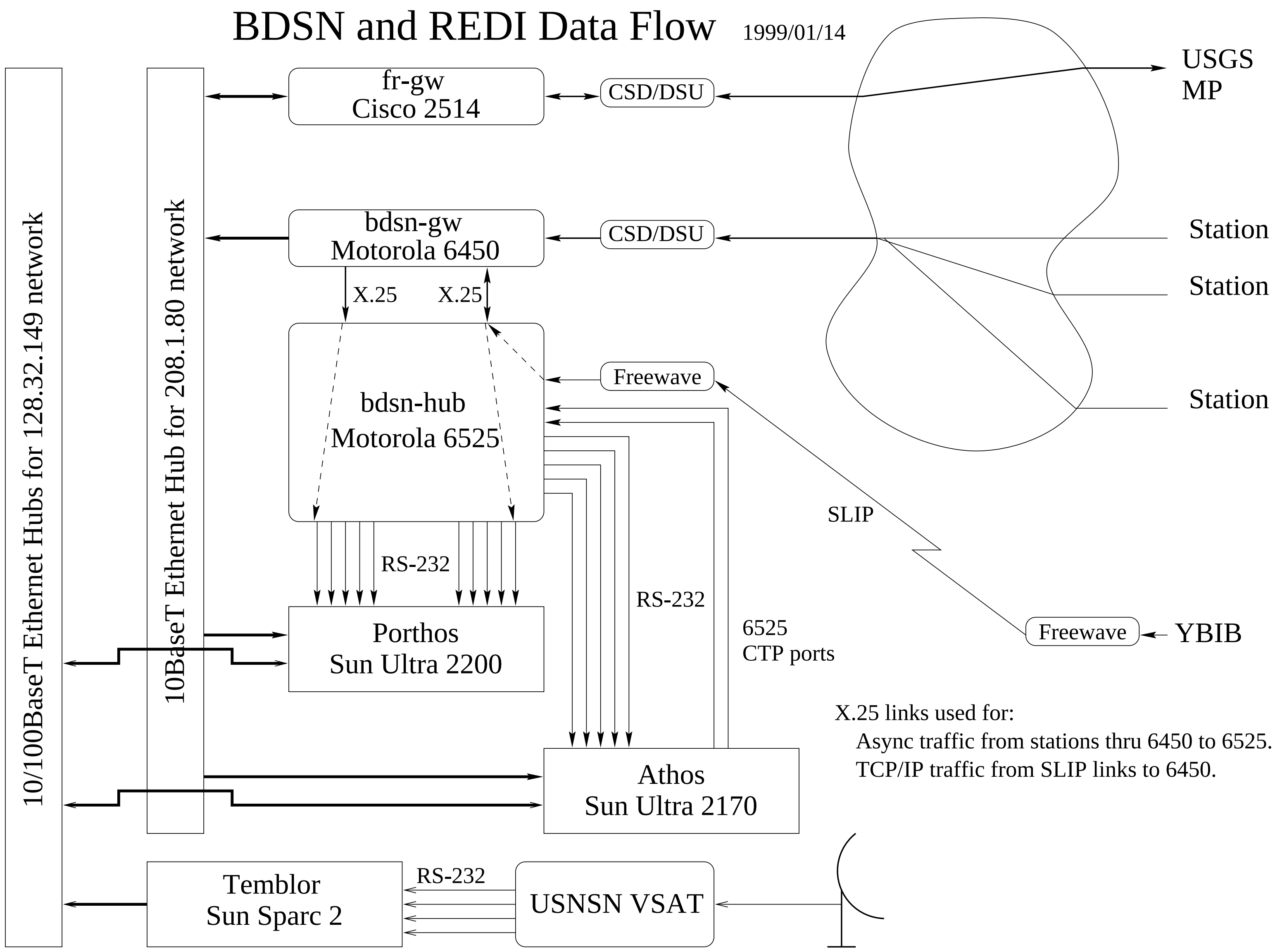

Figure 2.7: Data Flow within the BSL. *Courtesy of D. Neuhauser.*

Sensor	Channel	Rate (sps)	Mode
Broadband	UH	0.01	C
Broadband	VH	0.1	C
Broadband	LH	1.0	C
Broadband	BH	20.0	C
Broadband	HH	80.0 or 100.0	T
Strong-motion	LL	1.0	C
Strong-motion	BL	20.0	C
Strong-motion	HL	80.0 or 100.0	T
Thermometer	LK	1.0	C
Barometer	LD	1.0	C

Table 2.1: Typical data streams acquired at each BDSN site, with channel name, sampling rate, and sampling mode. C indicates continuous; T triggered. The LL and BL strong-motion channels are not transmitted over the continuous telemetry but are available on the Quanterra disk system if needed.

along a sandstone ridge, the highest and most dense rock in the delta area. The seismic instruments are located within a 1960's era Nike missile silo that is currently used to store records. The massive concrete silo features walls greater than one-meter thick and is buried three meters beneath the surface. This structure provides very good thermal stability, which is further enhanced by 10 centimeters of foil-faced, closed-cell foam covering the seismometers.

A GPS receiver was also co-located at the Potrero Hills- OEA Aerospace site, as part of the BARD network, with the station name of POTB. The GPS system is thus able to utilize the same power and telemetry systems as the seismic instruments.

Station BDM features a Q4120 data logger, STS-2 broadband seismometers, FBA-23 accelerometers and 56k baud continuous telemetry to Berkeley. A GPS clock provides external reference timing.

5. New Site Search and Development

During 1998-99 the search for new locations to potentially add stations to the BDSN continued. Because of the on-going nature of our research, only sites that offer long-term (> ten years) presence are considered. Proximity to utilities (phone and commercial power), geology, and station distribution are considered in prioritizing the areas to explore for new stations. Two sites were identified as potentially interesting only to be discounted after subsequent noise testing found them to have large background resonances or ground tilts. At the time of this writing two new sites have been permitted for BDSN station development.

The new site MOD (Modoc County California) is located in the northeast corner of the state, 10 kilometers south of the California/Oregon border, and 20 kilometers west of the California/Nevada border. Due to the extreme remoteness of the area, no broadband or short period instruments have been located within 100 km of this site.

The instruments are being located in an underground adit with approximately 5 meters of overburden for thermal stability. Because the adit is located on private property, discussion and negotiation with the landowner took nearly two years to successfully conclude. The final agreement assures that the BSL will occupy the site for at least the next ten years.

The second new site, in Humboldt County, is expected to replace the current site ARC. The new site is located on quarry property owned by a timber company. The site was previously used for a post-event portable instrument experiment. In addition to hard and dense surface outcrop, the site is attractive due to its proximity to both commercial phone and power. Again, the BSL has sought a long-term presence with the landowner.

In addition to the two new sites (Modoc and Humboldt Counties) the BSL engineers are working with the USGS to develop subsystems, characterize instruments, and establish installation procedures for the CREST (Cooperative Reporting of EarthquakeS and Tsunamis) Project in northern California. In particular, the BSL is collaborating with the USGS on two sites for joint operation. KMP (Mt. Pierce) and KCP (Cahto Peak) will be collaborative USGS/BSL installations with data transmission to both Berkeley and Menlo Park. Unlike other CREST sites, these stations will use Quanterra dataloggers (typical CREST sites use RefTek systems).

6. References

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