ASPEN SYSTEMS
Open System Solution for Environmental Monitoring

Overview

ASPEN's Open System Solutions provide a comprehensive and integrated platform for seismic, strong-motion, geodetic GPS, and infrasound networks with both on-site archiving and telemetered data streams for central data processing and archiving.

In addition, the open platform design makes rapid dissemination channels of earthquake data available creating actionable information for emergency operators. This and the minimum latency design of all its components makes it the premier platform for earthquake early warning (EEW).

Features

- Modular and unique data neutral design.
- Highly customizable and scalable for different applications.
- Lowest intrinsic latency, suitable for Early Warning Systems.
- Relational Database Management System with unique on-line and off-line processing tools.

Aspen Stations

Aspen Stations consists of sensors (e.g., KMI BB Sensors & KMI FBAs) and dataloggers (e.g., Q330 & Rock Families), where sensors can be of any variety from seismic, geodetic, over infrasound to environmental type. Video feeds have been successfully integrated, as well. The power subsystem and communication equipment are sources from high-volume commercial-of-the-shelf (COTS) manufactures with industry-standard interfaces; this simplify maintenance and upgrades. Kinemetrics considers that proven reliability and required robustness are key for high data availability. The communication equipment can be of any kind as long as it support IP communication:

- In most cases, 3G/4G cellular modems gives the most scalable and less infrastructure intensive communication link that are fast and proven. Nowadays, mobile cells are ubiquitous and operation is cost effective.
- Where available, land lines provide very fast and robust communication links. These are very economical to operate.
- In remote locations a satellite modem (VSAT) is the com-equipment of choice although slower and more expensive to operate than the other com-links.
- Alternative communication solutions provide spread-spectrum, VHF, and UHF radios. These require, in general, more preparation to deploy the complete communication infrastructure

(e.g., repeaters, obtain frequency, etc.). However, operation cost could be very low. As hybrids solution in combination with other physical communication links, radios are still deployed.

A very successful station design is shown in Figure 1. It was used in the Transportable Array (TA) of the USArray. Over 2,000 installation were carried out with this station design. The Vault Interface Enclosure ([VIE]) added additional reliability by managing the power and communication system contributing to the 99.5% data return of the TA. In addition it provided interfaces to environmental sensors (meteorological station) and infrasound sensors.

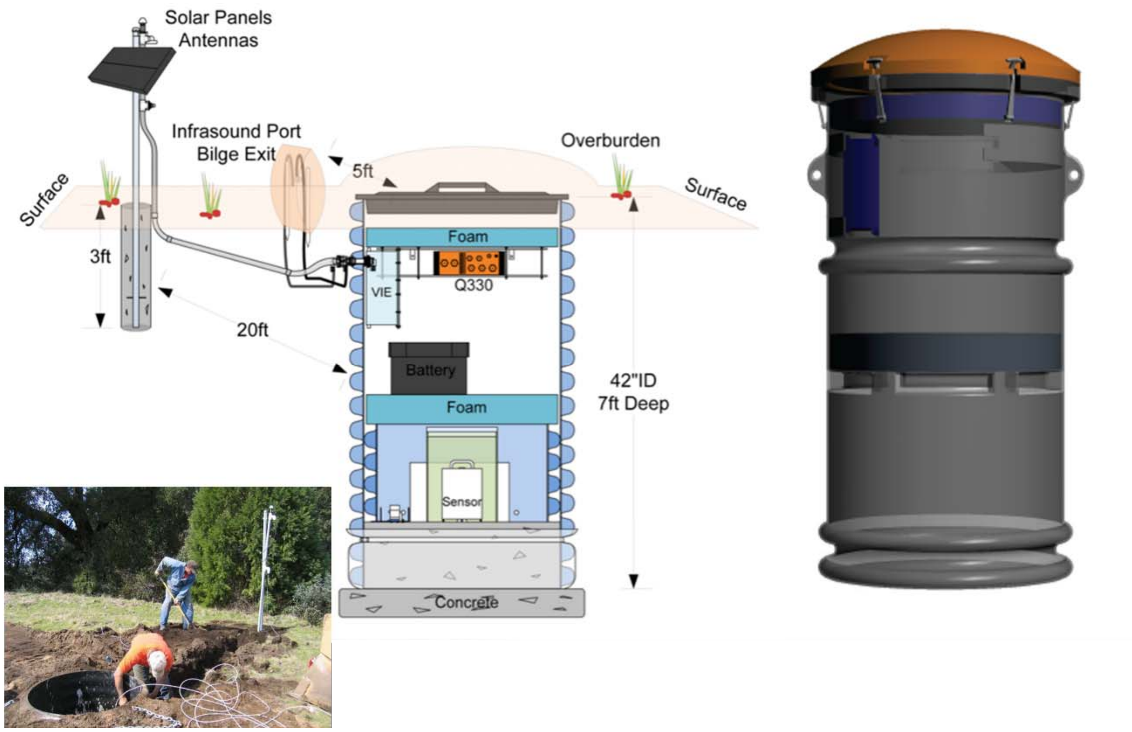

Figure 1: Station layout of the TA/USArray

An even easier to deploy design for temporary installations is Kinemetrics' **A**utonomous **R**eal-**Ti**me **St**ation (ARTIST). This all-aluminum surface station consisting of a lightweight Unistrut-structure with field enclosure, solar panels, and antenna. In general, the Mini Broadband Seismometer 2 (MBB-2) and/or Shallow Borehole EpiSensor (SBEPI) are paired with the ARTIST. The field enclosure houses the Q330S+ or Obsidian 4X datalogger, as well as the power and telecommunication subsystems.

Figure 2: ARTIST station for temporary deployments with real-time communication

Of course, the Aspen Station could be a sophisticated vault installations (Figure 3) with sensor pier, thermal insulation, grounding system (Figure 4), and fence. Such station design can be customized to the requirements of the network mission.

Alternatively, Aspen Stations integrate borehole sensors like the STS-5A in order to reduce ambient noise and temperature variations.

Figure 3: Seismic vault

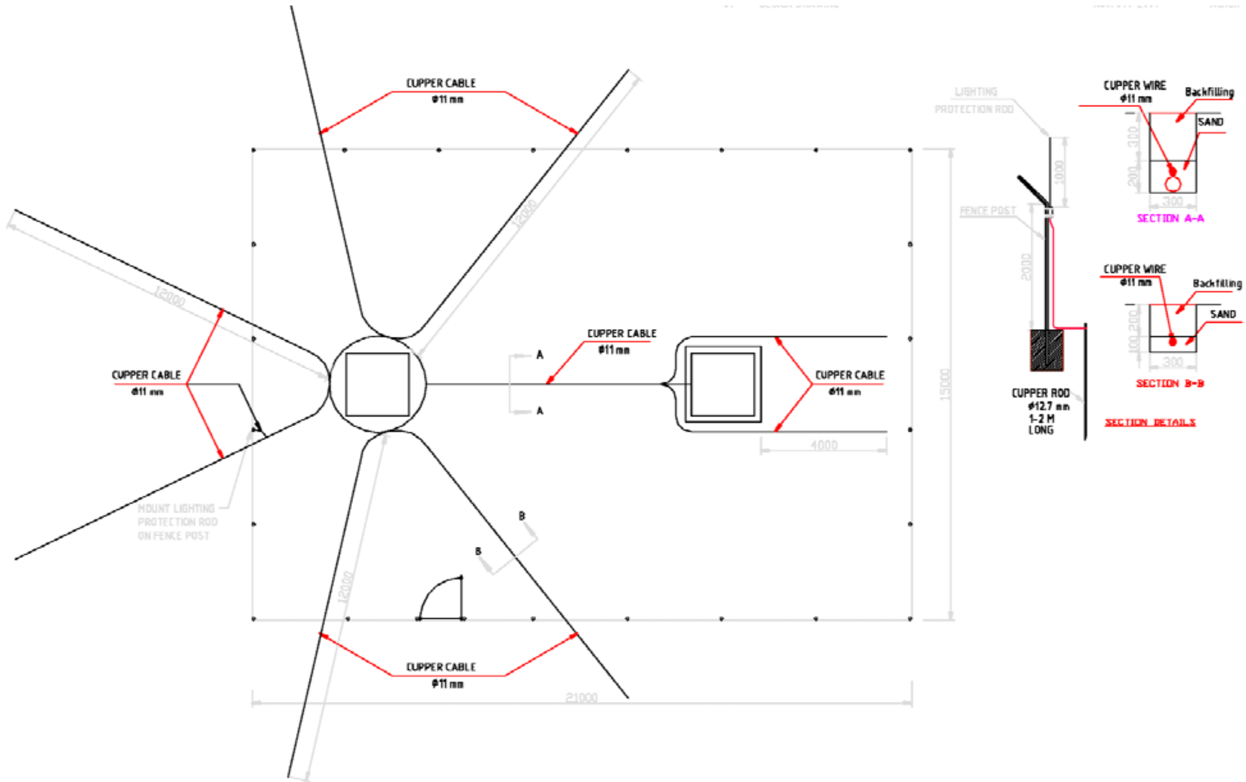

Figure 4: Schematic of grounding system

Aspen Data Center

The Aspen Data Center is highly scalable. For small research networks a LINUX workstation is sufficient for real-time data acquisition, processing, archiving, and off-line processing. On the other hand, the Aspen Data Center can consist of enterprise class servers connected to shared and tiered storage units and a virtualized environment acquiring hundreds of stations without missing a heartbeat. All on a Gigabyte LAN firewalled to the WAN and, if necessary, with secure VPN connections to the remote stations. In both cases, the brain and heart is Boulder Real Time Technologies' (BRTT) Antelope Environmental Monitoring Software. It is the only commercial of the shelf data acquisition and processing software in the seismology market place. As such it is well documented and professionally maintained; it has a defined annual update cycle (release data 1 May).

Antelope Software

The Antelope is scalable software package with enterprise-grade core infrastructure for real-time data acquisition of seismic and environmental sensors and seismic data analysis. It has been in development for over a decade.

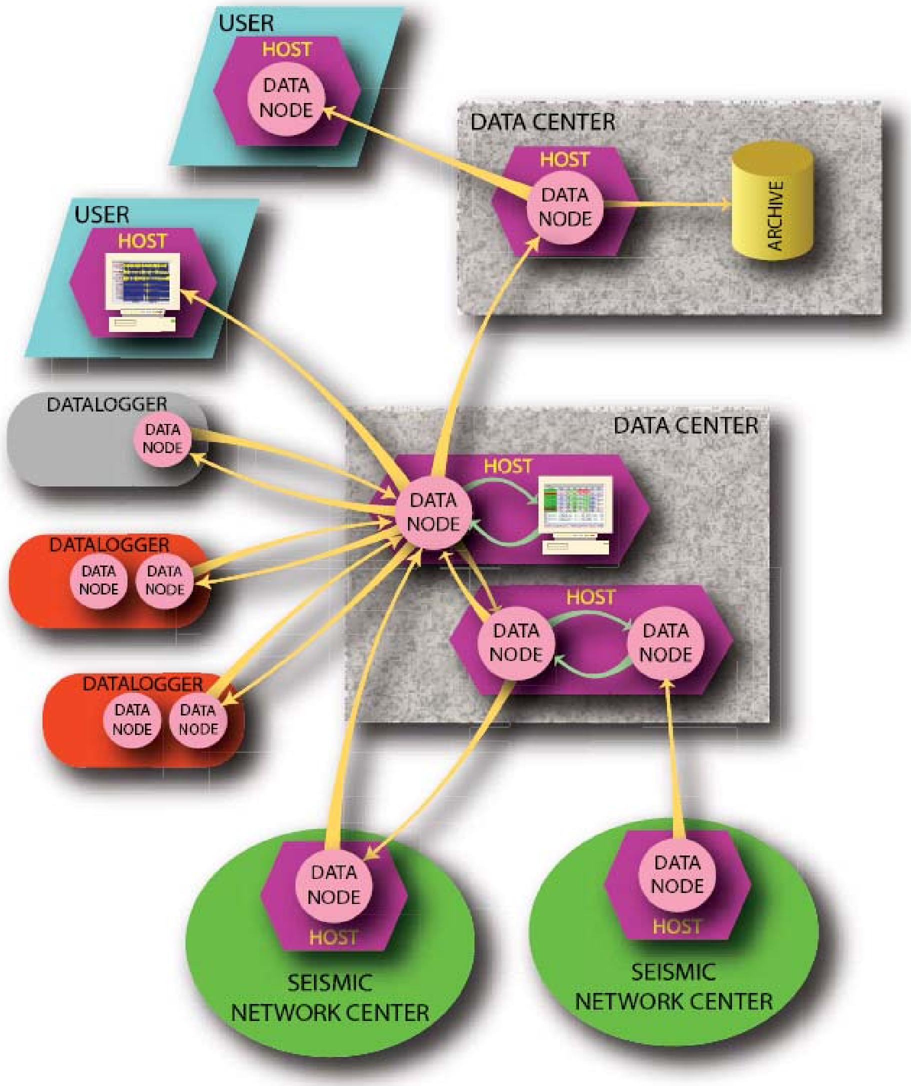

Figure 5: Basic design of the Antelope Real-time System (ARTS)

Antelope's key features are:

- Open architecture, with both closed and open-source components
- High performance and reliability
- High scalability
- High interoperability
- Minimum processing and communications latencies (early warning)
- Productive development environment for new/extended functionality (fully documented toolbox)

- Coherent engineering throughout creates highly robust, highly functional, low cost-of-ownership system – only available from commercial code

The Antelope Real-Time System (ARTS) was developed to address minimum-latency data driven acquisition, processing and distribution of seismic data on modern virtualized servers. BRTT's software designers were particularly interested in designing a system that could minimize the manual human interaction needed to accomplish "basic" seismic data tasks: data acquisition, data archiving, routine network processing distribution, and sharing of data and processing results to/from all interested parties. This implied a very robust system; a system with high levels of automation. This includes preventing data gaps by re-requesting data packets; and if they occur, processing continues without impact, as well as when data feeds reappear. One can think of ARTS as a network of interconnected "data nodes" with a combination of firmware, software and communication where Antelope is acting as the connectors (= middleware) between these nodes. A special type of data node is a "datalogger" which is the source of seismic data within the system (see Figure 5).

ARTS was designed with minimum processing latency in mind - therefore, with fast streaming dataloggers such as the Q330 & Rock Families, it represents an excellent platform for earthquake early warning (EEW) systems. ARTS provides a modular real-time data processing environment; data can be processed in arbitrary fashions with built-in and custom or customized data processing modules. Generic parameter files for the processing modules allow the user the flexibility to modify and tune the performance parameters. ARTS has the unique ability to provide real-time data distribution – multiple client programs can read data from one or more sources. The central data service of ARTS is the Object Ring Buffer (ORB). Programs read and write data packets from and to it. Once defined as an object any type of data packet with arbitrary format and size can be given to an ORB, and then another module can request and used them. The ORB server is a multi-threaded program (programmed and compiled as such) so that it can serve very high numbers of packet requests and packet writes.

The main interface for the operator is the real-time monitoring GUI "rtm" (see Figure 6). It allows interacting and managing the real-time system. The GUI shows the usage of the current system resources. It shows the running processes; it indicates their memory and CPU usage, the amount of packets that they write and/or read from the ORB, and the latency against the wall clock. It provides access to the parameter files to configure the processing modules. One can stop and restart a module for maintenance. The GUI allows configuring buttons for processes that run from time to time or do not need to be automatically started at boot, for example the waveform display (Figure 7) or the event display interface (Figure 8).

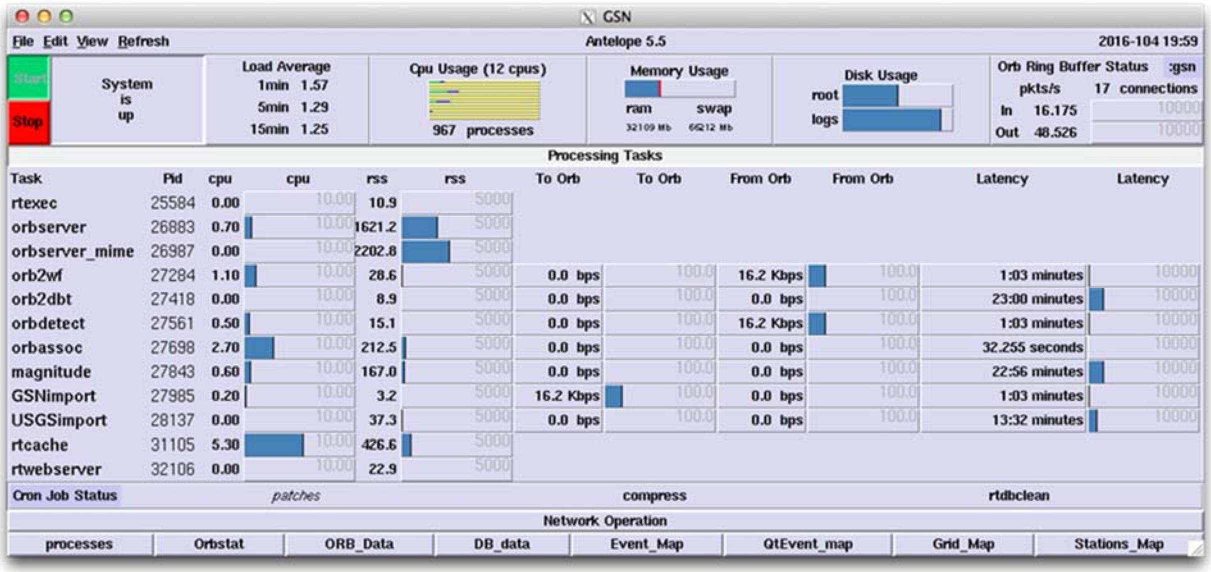

Figure 6: Real-Time monitoring GUI

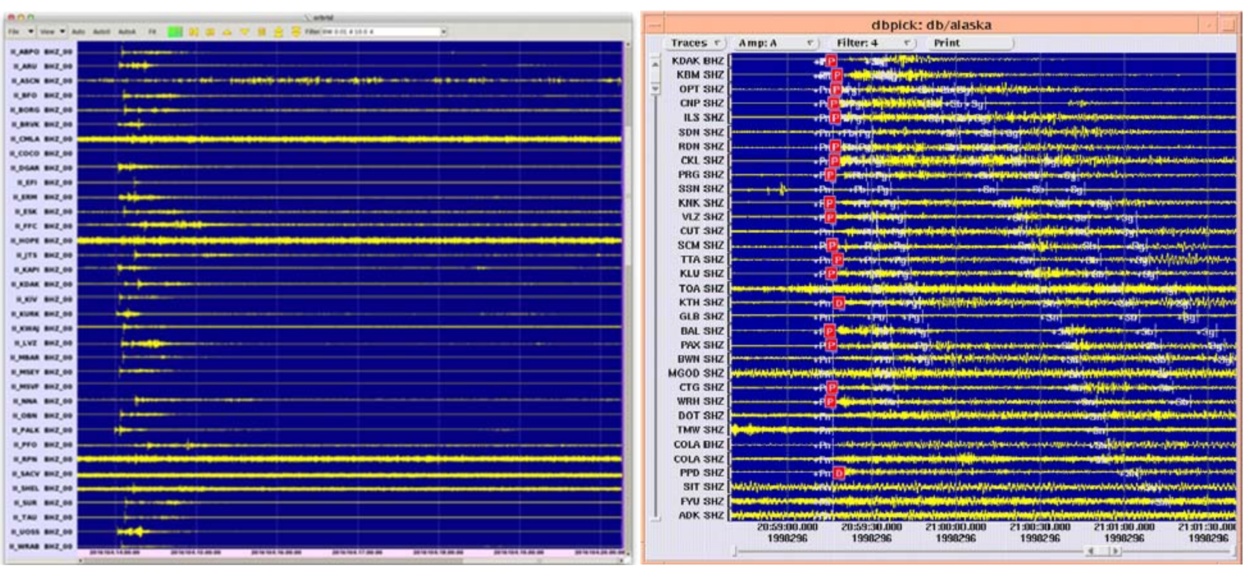

Figure 7: Real-Time waveform display of programs orbrtd and orbmonrtd

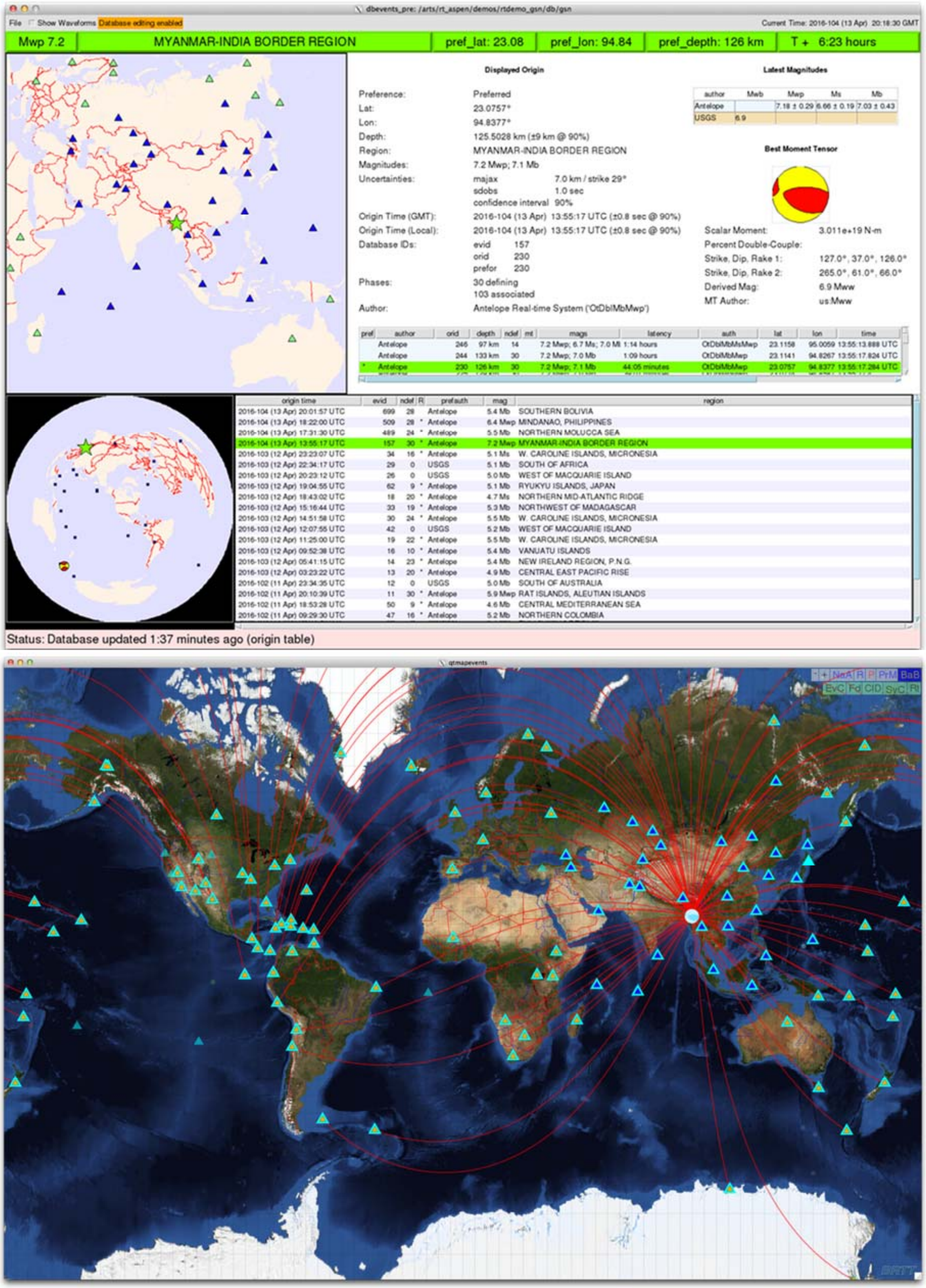

Figure 8: Event display

The network operator and technical staff may mostly be interested in the SOH display (see Figure 9). This GUI also makes available the command and control interface. This GUI (see Figure 10) interacts with the remote datalogger to issue mass-position re-centering or calibration signal, to interrogate datalogger status and configuration, to enable debugging mode. Log-messages that are scrolling in the windowpane can be frozen in order to be evaluated.

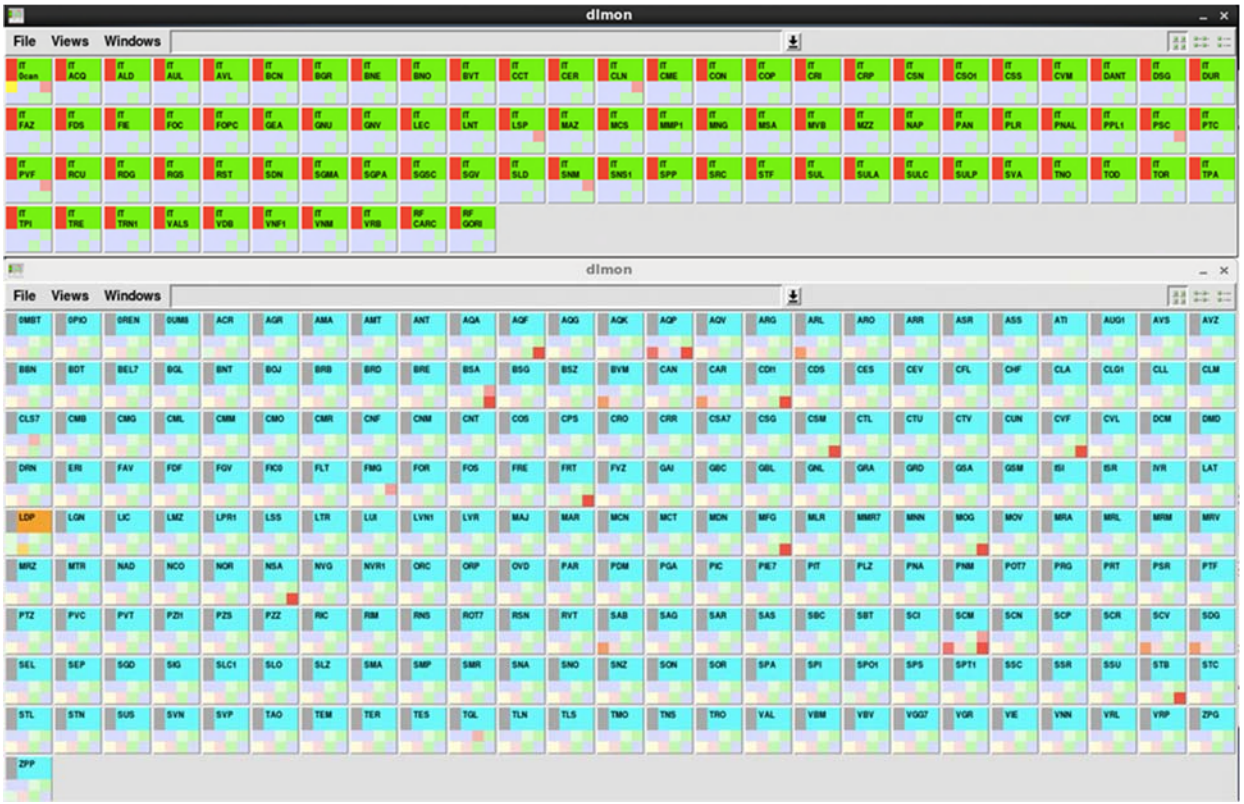

Figure 9: Datalogger monitoring GUI in icon-view

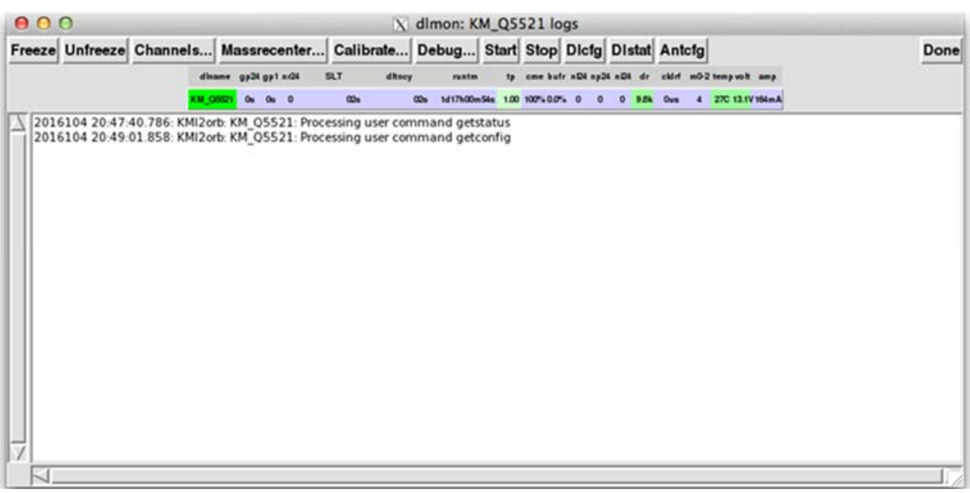

Figure 10: Command & Control GUI

The other main component is the Antelope Seismic Information System (ASIS). It consists of off-line processing tools and the embedded Datascope Relational Database Management System (RDBMS). The schema-independent RDBMS is optimized for real-time monitoring and coherently engineered with real-time tools. A database schema file defines the actual relations between and the content of the database tables. Datascope uses the globally accepted CSS 3.0 schema for seismic data. The system includes simple ways to carry out standard database operations: subsets, joins, and sorts. The record defining keys in the database tables may be simple or compound. Views are easily generated with automatic indexing. Complicated sorts, joins, and subsets can be formed evaluating general expressions. There are C, Fortran, Tcl/Tk, Perl/Tk, PHP, Python, and MATLAB interfaces of the database routines. In addition, command-line utilities provide access to the database. There are Graphic User Interface (GUI) tools for building and updating the meta database (see Graphic User Interface of dbbuild), as well as editing and exploring it.

A whole set of other database tools are dedicated to database evaluation and maintenance providing reports or keeping a health database. A special case is the integration of “old” data to fill gaps with data recovered from the datalogger. As this is a rigorous process in order to avoid overlaps it is a semi-automated process from downloading files from the datalogger to sub setting records to merging them into the production database.

The RDBMS features are:

- Datascope is small, conceptually simple, and fast.
- Datascope has interfaces to many compiled and scripting languages, a command line interface, and GUI interfaces. This gives users widely ranging access methods into the databases, in contrast to most other commercial database systems which only provide access through a specialized "query language", such as SQL. The wealth of Datascope interfaces is appealing to most scientists and engineers who do not have the time to become database experts.
- Datascope provides most of the features of other commercial database systems, including:
    - data independence
    - schema independence
    - view generation through joins, subsets and sorts
    - automatic table locking to prevent database corruption when multiple users are updating a database
- The organization of tables (relations) and fields (attributes) within a Datascope database is done through a schema file. The schema, in addition to specifying the fields of tables, and the format of individual records in every table, provides a great deal of additional information, including:
    - short and long descriptions of every attribute and relation
    - null values for each attribute
    - a legal range for each attribute
    - units for an attribute
    - primary and alternate keys for each relation
    - foreign keys in each relation

ASIS is used by the analyst with an interactive hypocenter location GUI in order to review and relocate earthquakes. The GUI is designed to facilitate the processing of many earthquakes (e.g., Alaska Earthquake Center locates every year more than 40,000 earthquakes with 3 employees).

Display Center & Situation Room

National and facility monitoring networks acquire data in real-time in order to generate earthquake data like hypocenter and magnitude or peak ground acceleration. These are useful data for the seismologist. In order to become valuable information for emergency response and decision makers these need to be reliably and instantly disseminated. Therefore the Aspen Data Center goes beyond the requirements of the network operator by integrating display walls and situation room settings. There, earthquake or other environmentally critical information, can be displayed in the context of other information feeds (e.g., video, field reports, crowd sourcing, GIS etc.) that help to manage the emergency situation.

Benefits

- Compatibility to all major seismic networks in the world.
- Rich and documented APIs for interfacing client's own programs.
- Fast field equipment and Data Center deployment.
- Extreme reliable proven performance, offering the lowest Total Cost of Ownership (TCO).

The Antelope software is already operating in more than 110 instances worldwide. Because of its open-architecture design, it offers interoperability between other seismic software packages, for example, SeisComP and Earthworm. Some examples of "seedlink" and "ew" data exchange are given in Table 1.

In addition, CD1/1.1 sender and receiver are included in order to support the monitoring community.

To Earthworm			From Earthworm		
AEIC (Alaska)	->	USGS	Caltech	->	ANZA (UCSD)
ANF	->	various	Caltech	->	ANF
UNR (Reno)	->	UUSS (Utah)	AWO (Alaska)	->	AEIC (Alaska)
To SeisComP (seedlink)			**From SeisComP**		
ORFEUS (Europe)	->	various European networks	various European networks	->	ORFEUS (Europe)
DMC (IRIS)	->	many	various	->	DMC (IRIS)
			BMG (Indonesia)	->	MMD (Malaysia)

Table 1: Interoperability of Antelope with other software packages

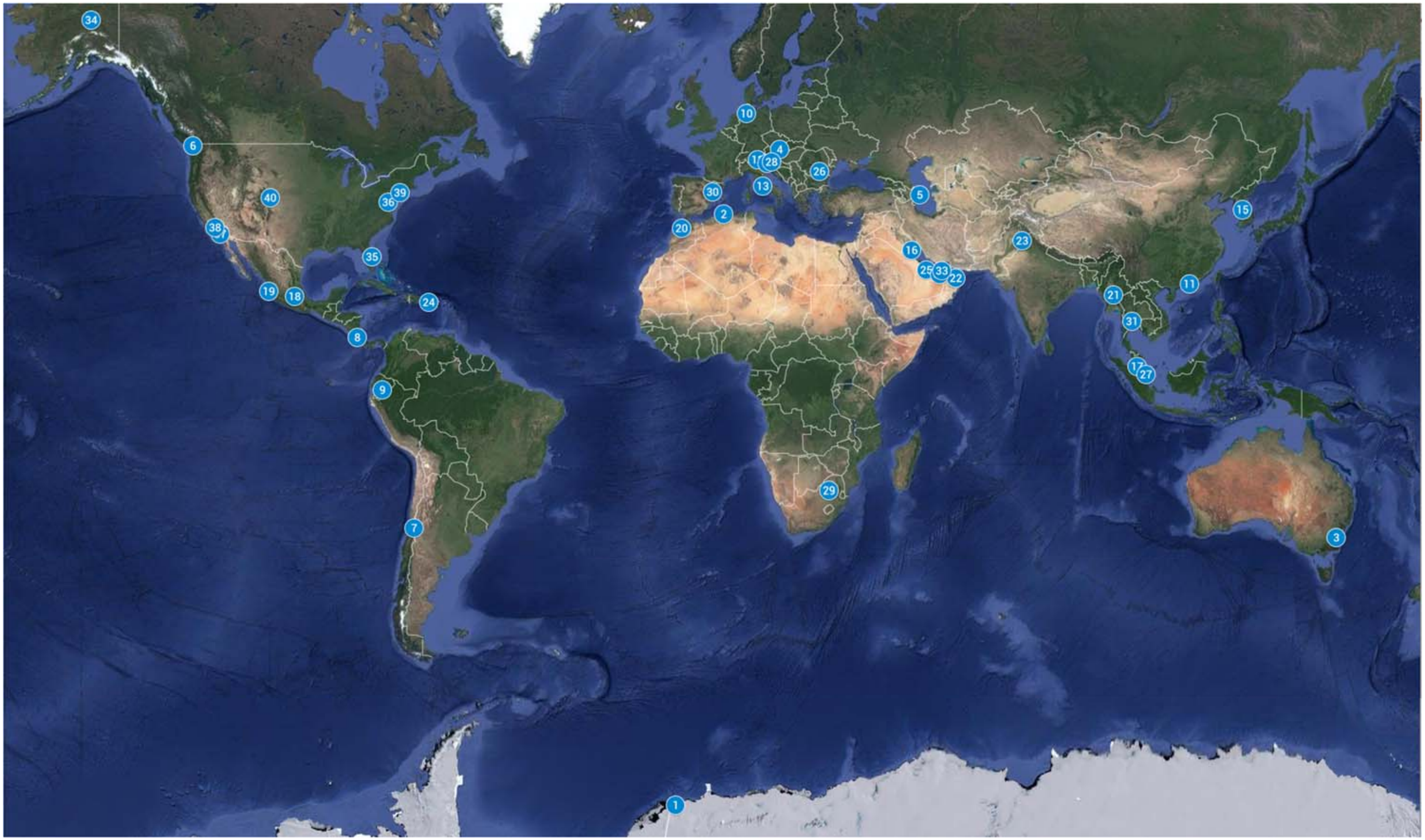

Figure 11: Installed Aspen Systems