OPEN SYSTEMS & SERVICES
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# Systems for SHM

Sound waves with a frequency below 20 Hz, the limit of human hearing, are called infrasound. As all sound waves, Structural Health Monitoring (SHM) is the process of assessing the state of health (e.g., damage) of instrumented structures from measurements. The goal of SHM is to improve safety and reliability of civil infrastructure systems by detecting damage before it reaches a critical state, or to allow rapid post-event assessment.


Traditionally, damage is detected through periodic maintenance and post-event visual inspection by qualified personnel. Visual inspections impose high costs and inconvenience on structural system owners and users alike. In buildings, for instance, visual inspections may require the removal of non-structural components such as interior partition walls and fire proofing. Prolonging expensive downtime, such resources (qualified inspectors) may not be immediately available after a damaging event, especially for dense urban areas. In the case of a slow onset of damage (e.g., corrosion), SHM systems can alert engineers prior to structural failure preventing collapse.

Essential to SHM is the ability to detect and locate damage from measured structural responses. This is a challenging issue and there are several competing techniques emerging from the SHM community. For example, some prevalent approaches include:

- Vibration-Based (tracking modal properties)
- Model Updating (automated FEM updating)
- Monitoring Critical Response Quantities (inter-story drift, damage index, fragilities)
- Wave Propagation

System requirements may vary depending on selected SHM approaches. Vibration-based SHM, for example, requires a relatively sparse deployment of accelerometers, a high dynamic range, and well synchronized data (e.g., 1ms). Wave propagation, on the other hand typically requires dense deployments and very high sample rates (e.g., 500sps). Regardless of approach, all SHM systems need to be robust and long-lasting – a bridge may last over 100years!

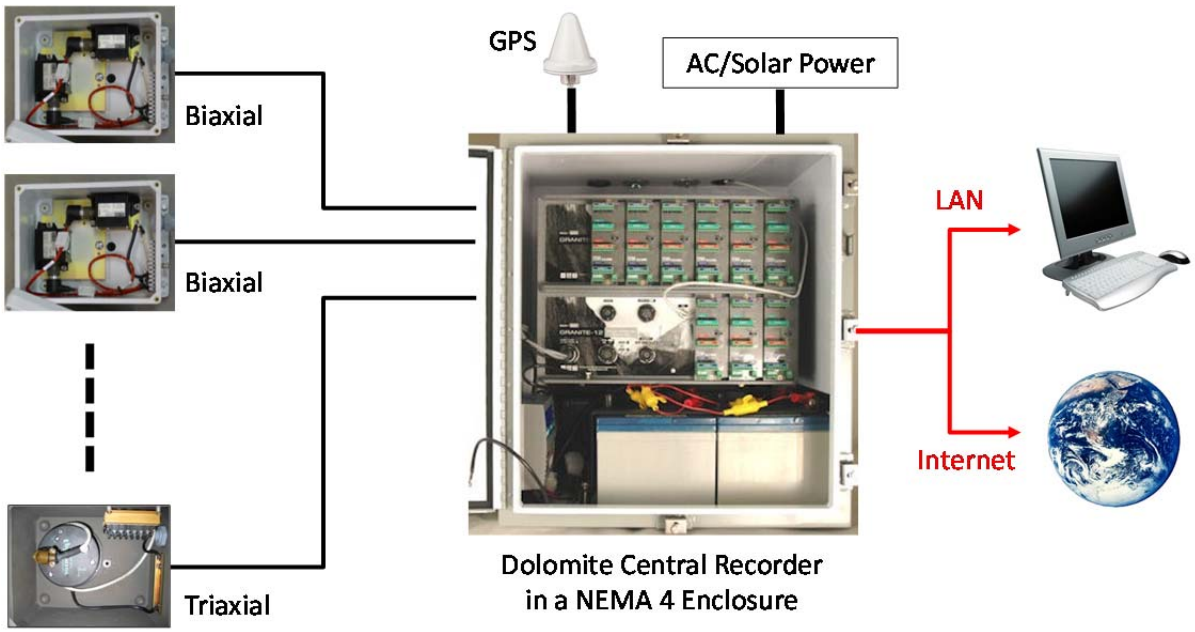
Kinemetrics Systems are designed to provide the best quality data acquisition and processing system while satisfying the many SHM requirements. Kinemetrics Systems are based on robust and versatile Rock instruments running Rockhound software which is ideal for enabling multiple SHM approaches. The Rock digitizer can sample up to 2000sps and achieves a timing accuracy less than 1μs. The sensor of choice is the EpiSensor; a force balance accelerometer that has low noise (155dB), high-bandwidth (DC to 200Hz), a user selectable range (±0.25 to ±4g), and a market leading life span (10+ years). The rare union of high-quality and robustness found only in Kinemetrics Systems is the hard-won result of continuous field testing from decades of deployments in rough environments often found in many seismic monitoring applications. Two example Kinemetrics Systems are illustrated here:

- A central Dolomite recorder system with up to 36 channels
- A system of distributed four-channel Basalt stations

Configurations for both permanent and temporary deployments are presented. Datasheets are available for more details and specifications on the Rock Digitizer and EpiSensor.

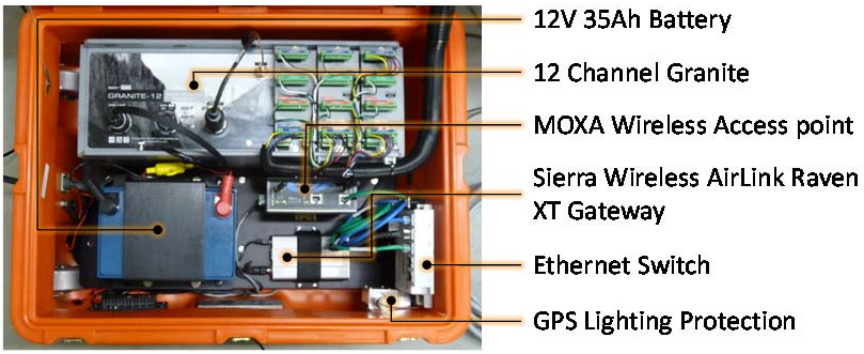
# CENTRAL DOLOMITE RECORDER SYSTEM

This system consists of a centralized recording unit based on the Kinemetrics 12, 24, or 36-channel Dolomite and the EpiSensor. Typically, the Episensors are housed in an enclosure that can accommodate uniaxial (1x ES-U), biaxial (2x ES-U), and triaxial (1x ES-T) configurations. Analog sensor cables are required between the EpiSensors and the Dolomite with a maximum distance of 1000m.



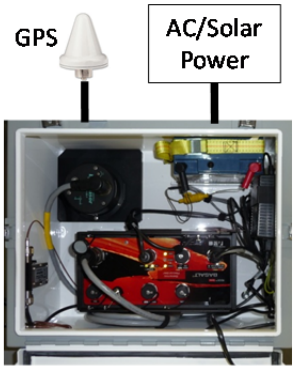

The Dolomite has GPS for precise timing and can be connected to a private LAN or the outside world through any TCP/IP appliance. The central recording unit, batteries, and AC/DC charger are typically housed in a floor/wall mountable NEMA 4 enclosure (figure above) which is ideal for indoor and outdoor permanent installations. Kinemetrics can also package this system in a rugged portable Hardigg enclosure (figure below). For these portable systems, wireless communications are often required. The example below displays both a 3G Gateway for internet access via GPRS and a Wireless Access Point for LAN. Here, the EpiSensors are connected through weatherproof connectors on the lid. Key advantages of this system are:

- Easy installation of Dolomite and sensors with wall/ground mountable enclosure with predefined connection points
- Single IP address and fewer event files (depending on data format)
- Single power source (no DC power requirement at sensor locations)
- Built-in battery backup
- Single timing source (GPS)
- No need for an additional COTS networking equipment (Switch/Router)
- Easy maintenance
- Accessibility (rare or no need for visit the sensor sites)

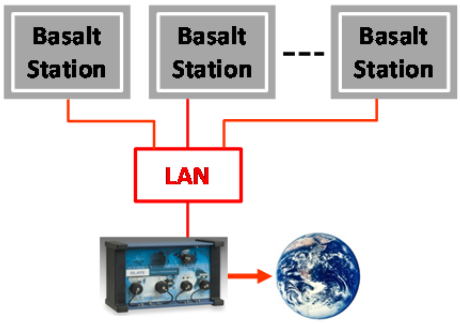


# DISTRIBUTED BASALT STATION SYSTEM

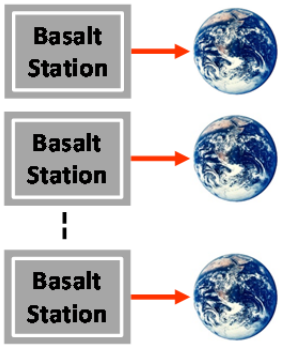
This system consists of a distributed network of Basalt stations. Each Basalt station comes with an internal or external triaxial EpiSensor and can be housed in a NEMA 4 or portable Hardigg enclosure. To charge the battery, either AC or Solar power is required at each station. For highly accurate and absolute timing, it is necessary to bring GPS signal to each of the Basalt stations.




Basalt Station with ES-T in NEMA 4 Enclosure

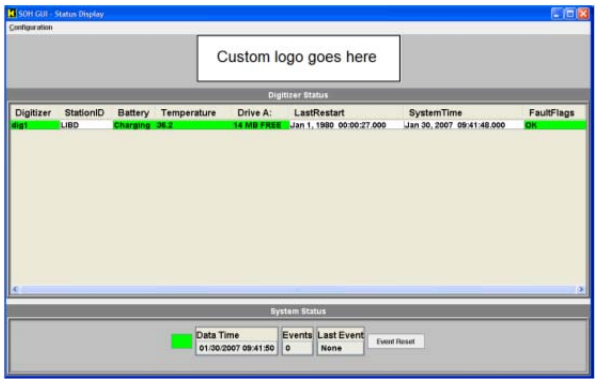



Each station on LAN with Slate Data Concentrator connected to Internet




Each station has own Internet connection

Two possible network configurations are shown above. In the right figure, each Basalt station acts independently and is accessible via its known public (or private) IP address. Alternatively, as shown in the middle figure, the stations are networked over a LAN to a data concentrator, such as Kinemetrics Slate Field Processor, which can then have a single public (or private) IP address. This setup provides a single source of data and immediate status of the entire Basalt network. If a computer with a graphics display is used (such as a PC), then Rockhound software comes with a GUI to display SOH for the network of Basalts stations (figure below). The key advantages to this system are:




- System robustness due to distributed network of Basalt stations
- No single point of failure vulnerability
- No need to run expensive analog cables
- High system redundancy with local data storage on each Basalt and global storage at Slate/computer
- Versatility in deployment capabilities
- Easy maintenance
- Multiple scalable network configurations
- Fourth channel available for each station

The networked system is highly scalable and can be easily combined with other systems. For example, a central dolomite can be easily included into the network.

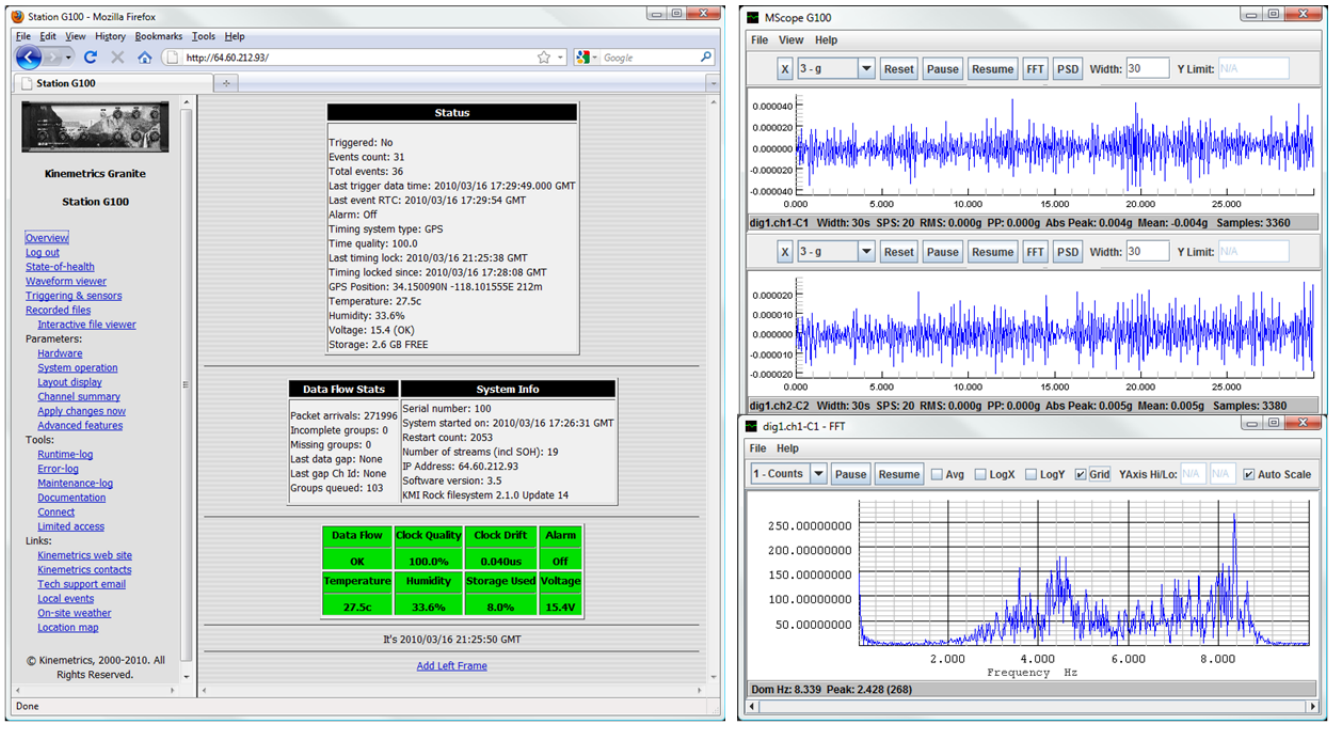
All Kinemetrics Rock instruments (Basalt, Granite, Slate, etc.) come with Rockhound software. This essential software package enables real-time SHM as well as critical system SOH monitoring and is described next.

# ROCKHOUND SOFTWARE PACKAGE

Rockhound is a Java-based open-architecture user-extensible real-time data collection and processing software package. It comes loaded with many built-in capabilities such as:

- Real-time data streaming from multiple sources including ring buffers on other rock instruments
- Easy web interface for access to data and system configuration
- Data post processing
- System SOH status display and notification
- Storage management
- Continuous or triggered event recording
- Email and SMS alarm and event notification
- Email and FTP data file sender
- Multiple data format archiving
- General purpose I/O interface
- Customer developed module enhancement

The figure below displays a screen shot of the web interface (left) showing system overview information such as digitizer status and several SOH parameters. The navigation bar on the left provides access to system features such as parameter configuration, connection tools, and real-time data viewer (upper right). Also shown is a plot generated from the useful real-time FFT tool (bottom right).




Rockhound capabilities are extensible by allowing users to create custom modules. For example, one might want to create a module that extracts modal properties from data in real-time. In fact several open-source modules have been developed by the user community and are publicly available. Surely SHM tools are soon to follow…