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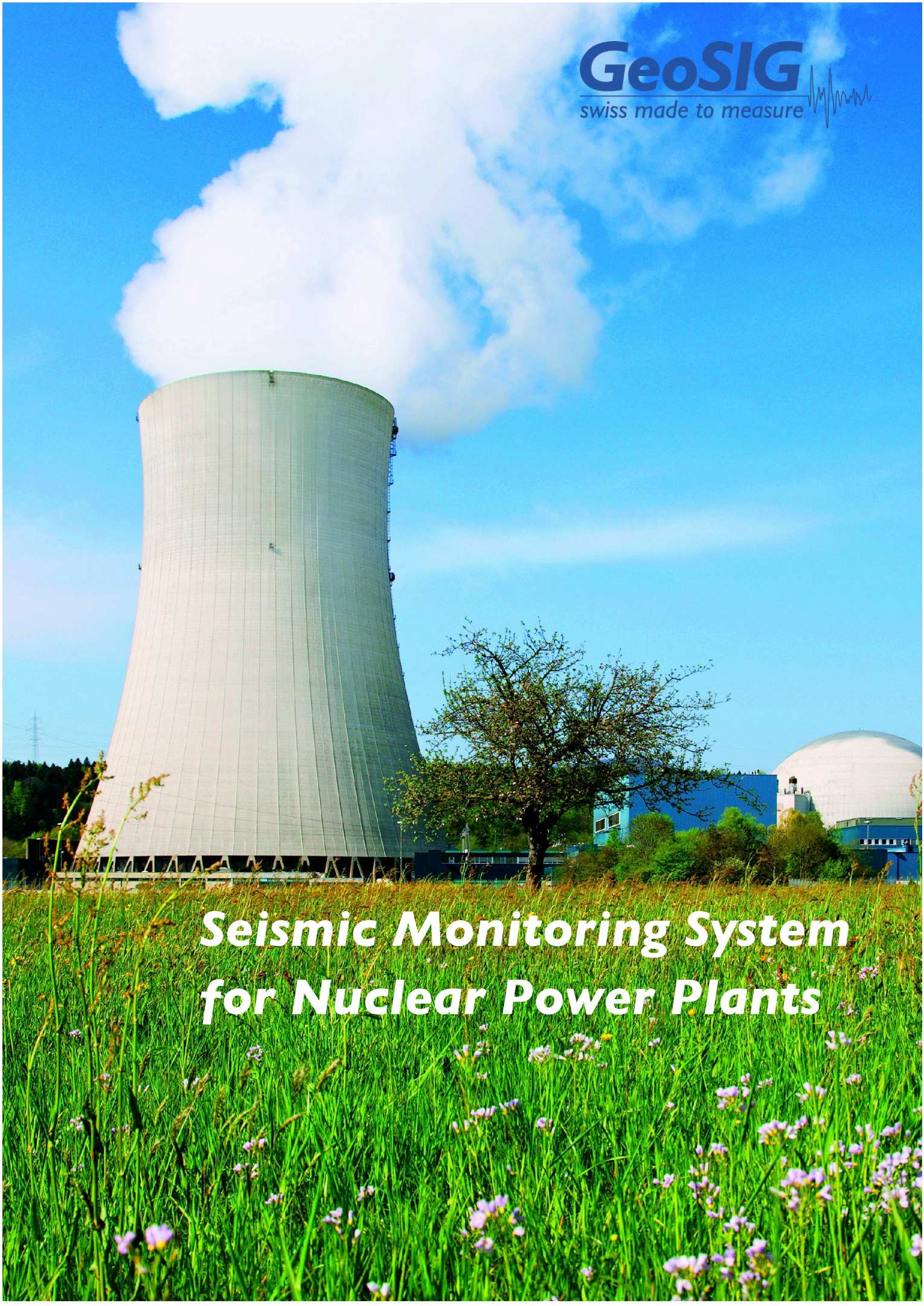


Seismic Monitoring System for Nuclear Power Plants

CONTENT

INTRODUCTION

According to regional, national and international regulations, Nuclear Power Plants (NPP) need to be able to mitigate potential effects of an earthquake.

Such mitigation can be achieved by utilising specific instrumentation for monitoring the earthquake ground motions and the response of the plant features to these motions.

This type of instrumentation is called Seismic Monitoring System (SMS).

Main functions of the SMS are:

- Detection of any (significant) earthquake at plant location
- Provide data records of acceleration at defined locations
- Perform OBE/SSE exceedance evaluation
- Provide a report to the plant operator after an event
- Periodical self test execution

GeoSIG delivers complete SMSs for the NPP applications. These systems;

- Comply fully or exceed regional, national and international nuclear regulatory requirements
- Come with comprehensive certification and documentation, which can as well be supplied from scratch for any particular requirement.
- Include powerful industrial computer for complex data processing based on different algorithms including response spectra analysis
- Perform automatic analysis and evaluation of the earthquake impact on monitored structures
- Provide comprehensive and fast notification and reporting features
- Warrant the robustness, reliability and functionality to serve it main purpose
- Include self diagnostic and testing features to assure continuous system readiness to act once in a life
- Present simplicity of operation, maintenance and upgrade

This document provides an overview of the SMS supplied by GeoSIG.

Upon request several more detailed documents are available, such as:

Sample Operator Report

Sample Design Report

Qualifications and Certificates

Regulatory Compliance

Reference Letters

Detailed Technical Notes on Example Systems

Terms and Conditions

OVERVIEW

The core of the **GeoSIG Seismic Monitoring System** (SMS; or SAS for Alarm System) is a Central Processing Unit (CPU) rack mounted in a seismically and EMC safe cabinet together with an industrial PC and relevant peripherals.

Detection / Recording Units (DRU's) consisting of accelerometers, seismometers or complete seismic station packages are placed at remote locations that are connected to the CPU through shielded copper or fibre optic cables.

The system has been designed in a way that it is not bound to a single topology. There could be only the sensors or both sensors and data acquisition out in the field.

GeoSIG, **unlike any other supplier, can offer three different and versatile solutions** for the seismic instrumentation of Nuclear Power Plants.

Decentralized Recording

Sensors and recorders are on sites

Increased reliability due to independent recording
Error free digital data transmission within the plant
Optimised cost of data cables
Preferable for new installations

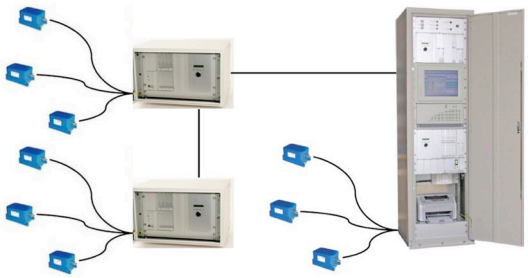
One is the **Decentralised System**, where each measuring point has a seismic sensor together with a dedicated recorder and there is a system central controlling the overall operation and providing system intervention and maintenance.

Second one is the **Centralised System** where only the seismic sensors are located at the measuring points and all other functionality are provided by the system central.

Centralized Recording

Only sensors are on sites

Simple devices in controlled area (analog sensors)
Simplified diagnostics and maintenance
In most cases, existing cables can be reused
Preferable for system upgrade projects

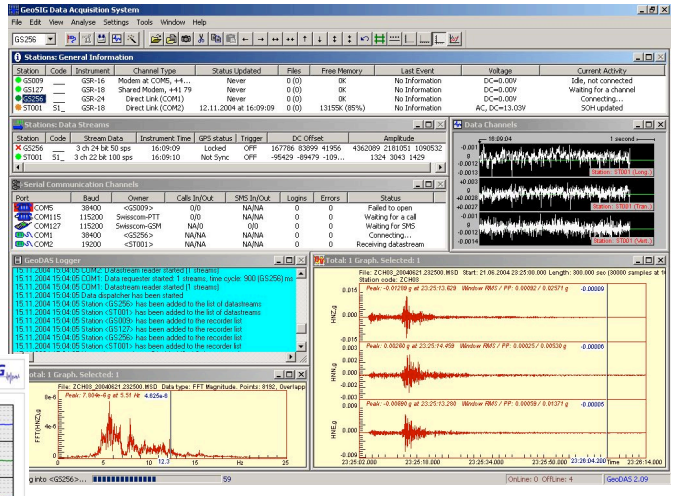


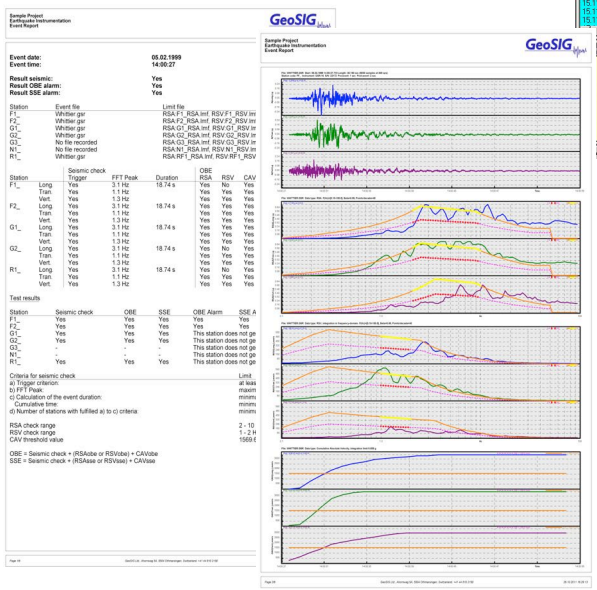
Cost optimized solution suitable for monitoring of nuclear power plants operating multiple units

And finally the **Cascaded System**, which is a combination of the decentralised and centralised systems to provide a more flexible deployment.

The system provides high modularity and flexibility so that an upgrade is simplified and that as much as possible existing elements can be reused.

State of the art **GeoDAS** software is utilized in the CPU. GeoDAS monitors all DRU's in parallel, as a result of the dedicated serial communication links that are provided by the system hardware.





For each measuring channel the recording threshold and the alarm limit values can be set individually. Detailed response spectrum limits can be fully defined along with other parameters as required by relevant regulations or customized user requirements.

Continuously monitoring the DRU's, the CPU detects seismic events, generates associated alarms and automatically processes the recorded data. It performs periodical tests on the system and monitors the system-wide state of the health as well as analyses the detailed cause of any malfunction. **A fully automated Detailed Operator Report is provided a few minutes after the occurrence of an earthquake**.

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SYSTEM CENTRE

SMS, Seismic Monitoring / Alarm System
GeoDAS Software

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SMS / SAS Seismic Monitoring / Alarm System

Features*

- **Recording, advanced analysis and annunciation according to project specific or international regulations**
- **Automatic exceedance evaluation**
- **Reporting and alerting via relays, visual and audible tools as well as printed matter**
- **Project specific Automatic Event Processing (AEP), Nuclear (NPP) or other features**
- **Upto 48 remote stations or sensors**
- **20 to 24-bit event based and/or continuous recording**
- **Common timing and triggering within the system**
- **Completely over-voltage protected**
- **Continuous system-wide SOH monitoring**
- **Seismically and EMC proven design**
- **Comprehensive configuration of the whole system via the enhanced computer interface**

***The information provided is a typical overview. For each project a specific description is provided outlining the relevant system.**

Outline

The core of the SMS / SAS is a Central Processing Unit (CPU) with a multi-channel digital recorder system rack mounted in an industrial cabinet together with an industrial computer and relevant peripherals.

Accelerometers, seismometers, complete seismic stations or sensor packages, which are referred to as Detection / Recording Units (DRU's) are placed at remote locations can be connected to the CPU.

The system has been designed in a way that it is not bound to a single topology. There could be only the sensors or both sensors and data acquisition out in the field. Advantages of these topologies are briefly explained in the specifications section.

The system has a great modularity and flexibility so that an instrumentation upgrade is simplified and that as much as possible existing elements can be reused.

The CPU monitors all DRU's in parallel, as a result of the dedicated communication links that are provided by the system hardware.

By monitoring continuously the DRU's, the CPU detects seismic events, generates associated alarms and automatically processes the recorded data. Also it performs periodical tests on the system and monitors the system-wide state of the health as well as analyses the detailed cause of any malfunction. The result of the data processing is provided in a report a few minutes after the occurrence of an event.

State of the art GeoDAS software is utilized in the CPU. For each measuring channel the recording threshold and the alarm limit values can be set individually. Detailed project limits can be fully defined along with other parameters as required by relevant regulations or customized user requirements.

ISO 9001
REGISTERED FIRM

Specifications SMS / SAS Seismic Monitoring / Alarm System

Centralized Recording

Advantages:
Simple devices in controlled area (analog sensors).
Simplified diagnostics and maintenance.
Higher compatibility with existing systems for upgrade.

De-centralized Recording

Advantages:
Independent recording units increase redundancy and reliability.
Link from remote to central can use Fiber Optics.
Digital transmission between remote and central locations.

Cascaded / Hybrid Recording

Combination of the decentralised and centralised systems to provide a more flexible deployment.

Typical System Specifications

The below specifications provide a typical overview. For each project a specific description is provided outlining the relevant system.

Sensor
SMS/SAS system offers the most flexible sensor connectivity options to cater for the needs of any measuring requirement. Any matching type of sensor can be connected to the system.

Digitiser

A/D Converter:	20 to 24 bits
Dynamic Range:	108 to 146 dB
Sampling rates:	100 to 500 SPS per channel
Bandwidth:	40% of sampling rate

Data Recording

Pre-event-Time:	Adjustable *
Post-event-Time:	Adjustable *

Triggering

Type	Level (threshold) or STA/LTA trigger, project specific triggers also available
Filtering:	User configurable

Data Storage

Type:	2 -128 Gbyte per 3 channels and/or HDD, SSD in the computer

Data Analysis
GeoDAS software provides various analysis functions like filtering, FFT, response spectra, etc. Other commercially available evaluation software packages may alternatively be used.

Timing
Standard clock accuracy: Free running, based on TCXO
External time interfaces: GPS System accuracy < 1 µsec.

Indicators
LED, Push button and/or Flatscreen indicators, may vary with each project, based on requirements

Self Test / State of Health
Permanently active, self monitoring and user selectable, periodical system test including comprehensive sensor, memory, filter, real time clock, battery level and hardware tests.

Seismic Switch / Warning / Alarm Options
The warning option provides independent warning / error outputs (relay contacts) based on user selectable criteria.
As separate acquisition module in the CPU with its own power supply, remote sensor and cable; or independent DRU's with integral relays and CPU connection.

Communication Channel Options
Ethernet TCP/IP, landline, GSM/ GPRS/UMTS/3G, Serial

Power Supply

AC/DC Power supply:	230 VAC / 50 Hz or 115 VAC / 60 Hz
External battery option:	Rechargeable, 12 VDC, 24 to 100 Ah

Housing
19'' cabinet in different sizes, floor standing or wall mounted.

*: Any value is useable, as long as it does not lead to data loss because of incorrectly configured or conflicting parameters.

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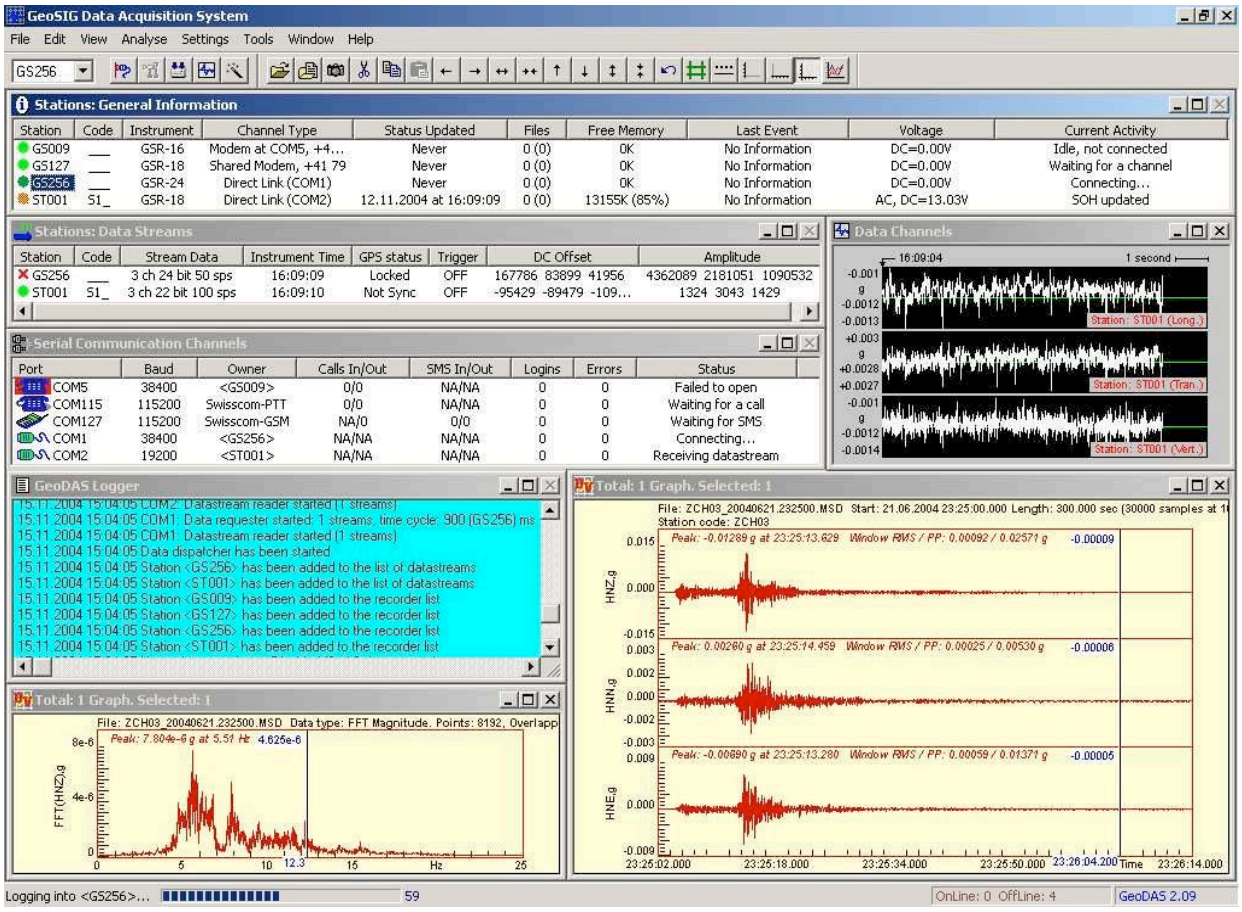
GeoDAS NPP Features

Introduction

This document summarizes the features and functionalities of the GeoDAS used in the NPP seismic Instrumentation Projects.

This document is intended be studied together with other GeoSIG technical documents relating to NPP instrumentation to grasp the full context and the concepts mentioned.

If supplied within the context of an NPP Seismic Monitoring System, a special version of GeoDAS software is delivered to be used to perform data analysis of the recorded time history, perform alarm and announcing if the analysis determines that the seismic event has exceeded software thresholds established by the structural engineers and operators of an NPP.



Summary of Operation

Site-specific parameters are set into the recorders in order to prepare the DRUs to detect and record any events. The event files are kept in the recorder memory, which is a flash memory card. As soon as new event occurs the relevant recorder settings like time, date, serial number, type of sensor and trigger level are attached to the data file are saved to the recorder's memory. This event file will be automatically downloaded to the CPU computer. Further the event files are processed and analysed for Seismic, OBE and SSE checks. Further analysis is possible with the ODV feature under manual mode.

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In normal operation mode of the system, the CPU downloads event files from each DRU automatically. At any time, a user can download any event recording manually by means of the Event Manager.

The recorders operate according to the specified settings, even without being connected to the CPU computer, since the data is saved in the recorders memory.

The system computer performs a Response Spectra Analysis (RSA) of the time domain record to determine the acceleration at the various frequencies. The structural SSE and OBE levels for the location of the accelerometer may be entered into the system and the RSA compared against the SSE and OBE levels established for each site.

When the RSA analysis exceeded the SSE and OBE levels the computer will generate a software alarm to the GNC, which will in turn activate the Alarms that a SSE and/or OBE level has been exceeded. The system may also be set up to automatically print out the time history, RSA with OBE & SSE levels, Fast Fourier Transform (FFT) and Cumulative Absolute Velocity (CAV) on the HP laser printer.

The OBE alarm (OBE exceedance) is a combination the calculated elements done by GeoDAS it can be one of the following combination:

- CAV Only: Cumulated Absolute Velocity
- CAV and OBE PSA: Cumulated Absolute Velocity and Pseudo Spectral Acceleration
- OBE PSA Only: Pseudo Spectral Acceleration
- OBE PSA and OBE SV: Pseudo Spectral Acceleration and Spectral Velocity.
- CAV and OBE PSA and OBE SV: Cumulated Absolute Velocity and Pseudo Spectral Acceleration and Spectral Velocity

Once the event data has been recorded in the individual Recording module it remains in the non-volatile flash memory until removed by an authorized operator. Once an event has occurred the event record will be automatically downloaded to the central system computer located in the central control panel where the GeoDAS software will automatically perform an analysis of the time history record. Within a few minutes the computer will have performed the preliminary analysis of the seismic event and if structural levels have been exceeded provide an appropriate alarm making the system fully compliant to the new NPP guideline and requirements.

The alarm threshold levels may be individually set on each channel. The recording alarm threshold will cause the time domain recording of all acceleration signals exceeding the alarm threshold.

Authorized structural engineers and managers have found it useful to access the computer via the LAN and download a particular event record for further analysis on their a computer at their desk. GeoSIG provides a site license for the use of the GeoDAS software package allowing the use of the analysis package on as many computers as the customer requires. GeoDAS allows limited and controlled access at various levels to maintain security and allow for the effective maintenance and operator control to the system.

GeoSIG recommends that the customer establishes internal operating procedures for system test and maintenance including a procedure for copying and archiving event records. A Read/Write CD is provided for that purpose. The system performance, hard drive disc file space, computer memory and recording module non-volatile memory has been sized to satisfy the system requirements and provide reliable long-term operation.

The software has two modes of operation:

- Standard, where the software is in the so-called “autodownload-mode”, downloading and analysing automatically any events
- Extended, where the user can stop the autodownload-mode and login to the DRUs manually

Seismic Check

After an event is recorded the CPU computer will retrieve the recorded data from the DRUs for further analysis. Any reserve units will not be used for seismic check. Automatic analysis after retrieval of data in the computer will decide if the event is seismic or non-seismic. The decision whether an event is seismic or non-seismic is based on several tests listed below.

Table 1. Seismic / non seismic event detection

Number	Tests for 'seismic event detection'	Non-seismic Event if…	Seismic Event if…
1	Number of DRU locations with recordings	Only 1 recorder triggered	2 of 6 recorders triggered
2	Duration	Duration is below 2 s	Duration is above 2 s
3	FFT	FFT shows frequency peak above 33 Hz	FFT shows frequency peak below 33 Hz

The operator can repeat any of the tests referred to in the above table in deciding whether the event is classed as seismic or not. In case of several DRUs triggered, the exact trigger times are compared. If the differences are below three seconds, the recordings are classified as one event. The limits for the seismic check parameters are as follows:

Table 2. Seismic check parameter settings and ranges

Parameter	Minimum	Maximum	Standard Setting
Number of DRU locations triggered	1	6	2
Duration [s]	1	10	2
FFT Peak [Hz]	5	50	33

The event is declared seismic if all criteria are fulfilled; otherwise it is treated as non-seismic.

Non-Seismic Event

After a non-seismic event the operator presses first the "ACK" button on alarm-panel to acknowledge the alarm and then presses the "RESET" button to clear the alarm so that:

Table 3. Non-seismic event actions

Alarm	Action
Alarm-panel:	"EVENT" indicator lamp goes out
Alarm Relays:	"EVENT" relay goes back to normal state
Monitor:	Displays the results of the performed seismic check

The parameters defining the criteria for qualifying the recorded event as "non-seismic" will need to be reviewed after a training period to verify that the filtering applies is correct. RSA, RSV and CAV calculations are performed, but no OBE/SSE exceedance result is shown and no alarm is generated.

Seismic Event

In case of the event is classified as seismic by the system, RSA, RSV and CAV calculations are performed and the results are compared with allowed levels for the following criteria to establish its degree of severity and activate further alarms / relays. Results of the tests are displayed on the CPU computer monitor and are also printed.

GeoDAS NPP Features

OBE/SSE Check

The OBE and SSE alarms are generated solely by the CPU computer utilizing GeoDAS and the alarm-logic. It simply converts the received string to the appropriate electrical signals to drive the relay and alarm lamps.

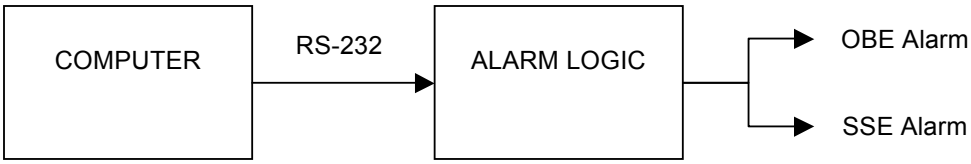


Figure 1. OBE/SSE Alarm topology

In case of the event is classified as seismic by the system, RSA, RSV and CAV calculations are performed f and the result is compared with allowed levels for the following criteria:

Table 4 Exceedance of individual OBE criteria

OBE/SSE Calculation	Criteria exceeded if…
RSA	• At least one component site level is exceeded
RSV	• At least one component site level is exceeded
CAV	• At least one component greater than 0.16 g-s[1]

For example, if Reference sensor is not available, although the event has been classified as seismic, the printed report will show an error message and data has to be retrieved locally from the DRUs by means of laptop in case the unavailability of reference sensor data is due to some communication problem.

The parameter setting for seismic and OBE/SSE can be entered through windows. The figure below shows the layout of the OBE settings window. The SSE settings can be entered in a window with the same layout, named “SSE Exceedance”.

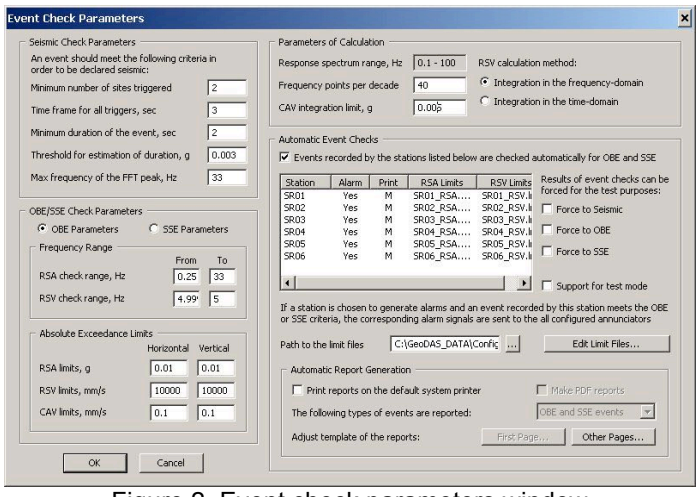


Figure 2. Event check parameters window

If the event calculation shows exceedance of OBE or SSE site levels, the computer sets the OBE or SSE alarm and the following alarm will occur. OBE or/and SSE alarm will be reset manually by the operator.

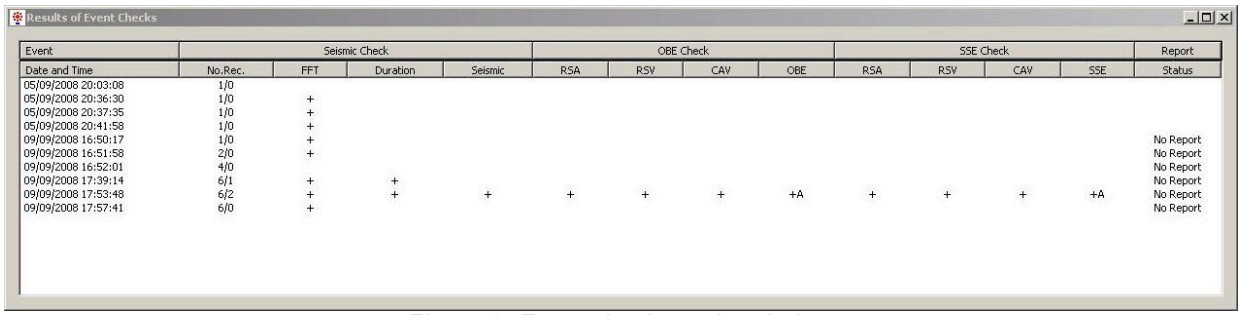
Table 5. OBE, OBE max. acceleration, CAV event actions

Alarm	Action
Alarm-panel:	• “OBE” or/and “SSE” indicator lamp flashes
Alarm Relays:	• “EVENT”, “OBE” or/and “SSE” relay active
Monitor:	• Displays the results of the performed OBE/SSE check

[1] The unit [g-s] is used in the NRC Regulatory Guide 1.166 and refers to integrated acceleration in [g] over time in [s]. Within the Seismic Instrumentation project all CAV values are treated in [mm/s]. 0.16 g-s corresponds to 1’570 mm/s.

Display of Processing Results

For each event recording, results of seismic, as well as OBE/SSE checks are displayed in a table. The below figure shows an example of the “event check results” window.



Event	Seismic Check				OBE Check				SSE Check				Report
Date and Time	No.Rec.	FFT	Duration	Seismic	RSA	RSV	CAV	OBE	RSA	RSV	CAV	SSE	Status
05/09/2008 20:03:08	1/0												
05/09/2008 20:36:30	1/0	+											
05/09/2008 20:37:35	1/0	+											
05/09/2008 20:41:58	1/0	+											
09/09/2008 16:50:17	1/0	+											No Report
09/09/2008 16:51:58	2/0	+											No Report
09/09/2008 16:52:01	4/0												No Report
09/09/2008 17:39:14	6/1	+	+										No Report
09/09/2008 17:53:48	6/2	+	+	+	+	+	+	+A	+	+	+	+A	No Report
09/09/2008 17:57:41	6/0	+											No Report

Figure 3. Event check results window

For each event, a context menu can be accessed (right-click) with the following functions:

- The printing of any report can be repeated or forced manually at any time after an event.
- Each event can be manually re-checked for Seismic, OBE or SSE.

After each event recording retrieved from the system that is classified as 'seismic', a report will be printed automatically by the system, giving a summary of the check results (first page) and detailed waveforms for each DRU (one page per unit).

An example report is illustrated in a separate document.

The software can be programmed such that the report will be printed also if an event is not classified as ‘seismic’. The waveforms included in the detailed waveform plots are:

1. Time-history (3 components)
2. RSA plot showing limits (3 components)
3. RSV plot showing limits (3 components)
4. CAV plot showing limits (3 components)

A report can be regenerated and reprinted at any time manually again. The connected printer is always switched on. Further more, the printing of a report for a specific event can be repeated or forced manually by the user. There will be a provision for the user to enter event-specific comment, such as earthquake magnitude.

GeoDAS NPP Features

Processing Time Estimation

The timeline of system triggering / analysis is indicating in the next table. It is based on typical record length of some 50 seconds (30 seconds shake + 10 seconds pre-event and 10 seconds post-events) acquired at 100 sps. The recorded file has a size of 45 kByte and has a download time of 12 seconds at 38400 bps.

Table 6. Step by step estimated elapsed time

Pos	Activity	Duration	Start	End
1	Earthquake waves hit the plant	0	00:00:00	00:00:00
2	From the continuous measurement stream, the trigger system, after applying band-pass filtering detects an acceleration exceedance.	Few ms	00:00:00	00:00:00
3	Seismic recorders report trigger to alarm module. Alarm module applies Boolean logic to define if recording must occur or not.	Few ms	00:00:00	00:00:00
4	Alarm module applies Boolean logic to define if an alarm has to be generated.	Few ms	00:00:00	00:00:00
5	Common alarm received in control room.	Few ms	00:00:00	00:00:00
6	The computer is continuously monitoring the recorders for new recorded event.	50 seconds	00:00:00	00:00:50
7	The computer detects recorded events. An event condition is declared and it will downloads files as soon they are ready.	6 x 15 = 90 seconds	00:00:50	00:02:20
8	Analyse process start by verifying if event is seismic (number of triggered stations, duration and main frequency).	10 seconds	00:02:20	00:02:30
9	OBE and SSE exceedance is checked.	30 seconds	00:02:30	00:03:00
10	OBE / SSE exceedance alarm generated is event is of seismic origin.	Few ms	00:03:00	00:03:00
11	The event report is printed.	30 seconds	00:03:00	00:03:30

The main control is alarmed that an event occurred immediately when the earthquake hit the plant [5].

OBE/SSE alarm is (in case of exceedance) generated after about 3 minutes [10].

The event report is typically available after 3.5 minutes [11].

Logging

Within the CPU computer the events and results listed below will be logged. This allows the user to have complete information about the alarms and the time they were performed.

Table 7. Logged information

Type	Logged information
System trigger	Source, date and time
OBE, OBE max. acceleration, CAV Alarm	Source, date and time
Power Loss	Source, date and time
System Error	Source, date and time
Test Results	Values, date and time

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RECORDERS

GMSplus, Independent Recorders
CR-6plus, Central Recording System

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GMS plus Measuring System

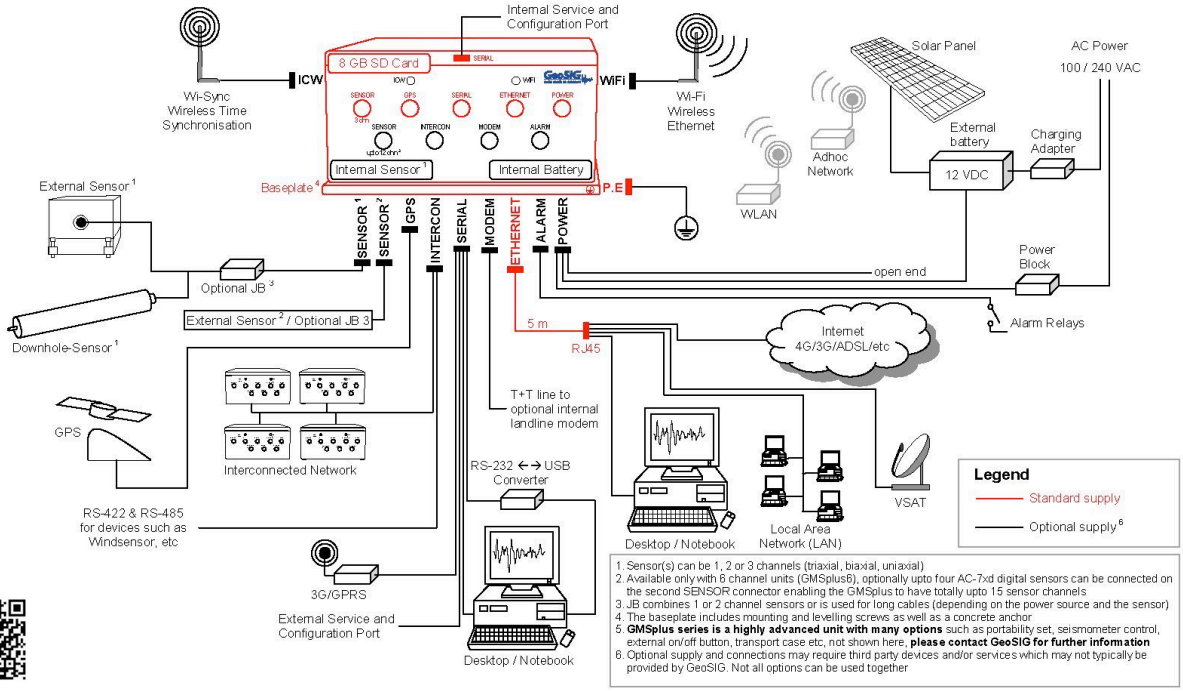
Features

- Second generation of NetQuakes Recorder
- 3 or 6 channels, up to 1000 sps sampling rate up to 15 channels using digital sensors
- Low noise individual 24-bit Δ–Σ ADC per channel
- Internal built-in and/or external sensors
- Wired Ethernet, Wi-Fi and Serial links
- Smart NTP timing, GPS time base, or time synchronisation via radio channel or cable
- Enhanced connectivity via landline modems, 3G cellular devices and satellite links
- Recording to SD or CF cards, up to 128 GByte
- USB interface for external storage and communication devices
- Continuous data recording to ringbuffers
- Flexible configuration of multiple triggers
- Simultaneous data streaming to several clients
- On board data processing and evaluation
- Rugged aluminium housing with levelling base plate for easy installation
- Configuration and status monitoring via Web Interface compatible with Smartphones
- Simple and secure communication over Internet with full remote management
- Internal battery, low power consumption
- Alarm output with up to 4 relays flexibly configurable for different types of events
- Easily configurable interconnected networks with common timing and triggering

Applications

- Broadband Seismic, Earthquake and Structural measuring and monitoring
- Real-time Seismology for Freefield and Urban Areas
- High Density Earthquake Monitoring Networks
- Shake / Hazard Mapping based on Instrumental Data
- Earthquake Early Warning[6] and Rapid Response
- Damage Estimation, Disaster Management
- Seismic Alarm and Safe Shutdown
- Ambient Vibration Testing (optionally fully wireless)
- Induced Vibration Monitoring and Notification
- Building Code Compliant Instrumentation

Supply and Connectivity



1. Sensor(s) can be 1, 2 or 3 channels (triaxial, biaxial, uniaxial)
2. Available only with 6 channel units (GMSplus6), optionally upto four AC-7xd digital sensors can be connected on the second SENSOR connector enabling the GMSplus to have totally upto 15 sensor channels
3. JB combines 1 or 2 channel sensors or is used for long cables (depending on the power source and the sensor)
4. The baseplate includes mounting and levelling screws as well as a concrete anchor
5. **GMSplus series is a highly advanced unit with many options** such as portability set, seismometer control, external on/off button, transport case etc, not shown here, **please contact GeoSIG for further information**
6. Optional supply and connections may require third party devices and/or services which may not typically be provided by GeoSIG. Not all options can be used together

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Specifications GMS^{plus}

Set-up and Configuration
An intuitive web interface is available for easy configuration with any web browser. Alternatively the configuration file in XML format can be edited on site through the instrument console, exchanged by replacing the memory card, remotely from a server or through SSH. Even if the configuration file can be manually edited at any time, a tool is provided to edit it securely.

Data Analysis
The GeoDAS software provides basic data evaluation in the field meeting the requirements of most scientific and engineering applications. Optionally GMSplus can perform certain analyses onboard.

Sensor
Various GeoSIG sensors as well as a number of other third party sensors can be housed internally or connected externally to the unit. In case of internal sensor, the levelling is done on the base plate of the GMSplus via its three levelling screws. The base plate is mounted using a single bolt during installation.

Digitizer

Channels:	3 or 6 optionally up to 15 using AC-7xd digital sensors
A/D conversion:	24 bit Δ–Σ converters individual for each channel
DSP:	32 bit output word length
Dynamic range:	146 dB (per bin @ 1 Hz rel. full scale rms) 137 dB @ 50 sps
Sampling rate:	1000, 500, 250, 200, 100, 50 sps per channel
Max. bandwidth:	DC to 250 Hz
Anti Aliasing Filter:	Analog and digital FIR (finite impulse response)

CPU

Processor:	ARM 400 MHz
RAM:	64 MByte
Operating System:	GNU/Linux

Triggering
Several Trigger Sets can be defined in the instrument. Each set can be flexibly configured regarding the source of trigger, main and advanced trigger parameters, trigger processing and selected channels for storage. A voting logic based on the monitored channels can be defined.

Trigger Filter
Fully independent high-, low- or bandpass trigger filters can be configured.

Level Triggering
User adjustable threshold.

STA/LTA Triggering
User adjustable STA / LTA values and STA/LTA trigger and detrigger ratio.

Event Recording

Pre-event memory:	1 to 720 seconds, typical
Post-event duration:	1 to 7200 seconds, typical

Event Summary and Parameters

Content:	PGA, PGV, PGD, SA (at 0.3, 1, 3 Hz)
Transmission delay:	User defined from trigger time

Ring Buffer

Usage:	User can request an event from any period of the ring buffer by specifying the start time/date and the duration from the console or remotely from a server.
Method:	Ringbuffer files with configurable duration which can be uploaded automatically to data server.

Data Stream

Protocol/Compatibility:	GSBU, SeedLink, compatible to Earthworm

Storage Memory

Size and Type:	8 GByte Removable SD Card, Optionally Compact Flash Card higher capacity up to 128 GByte on request FAT32 or EXT4 formatted
Management:	Intelligent management of memory card capacity using policies as per file type and ring buffer capacity specification.
Recording format:	miniSEED with extended information encapsulated into blockette 2000
Estimated Capacity:	Sampling rate [sps] x 0.4 [MB / day / 3 channel] (example: 40 MByte / day / 3 channel @ 100 sps) typical, since the data is compressed, capacity depends on the context of the data.

Self Test
- Permanent self monitoring of hardware and software components without affecting their normal operation.
- User-configurable periodical state of health (SOH) report based on comprehensive test of instrument, which can be requested at any time.
- User-configurable periodical sensor test.

Time Base

Internal:	Intelligent Adaptive Real Time Clock (IARTC)
External:	NTP, optionally GPS, Wired or Wireless Interconnection
Standard TCXO accuracy:	±0.5 ppm (15 s/year) @ +25 °C ±2.5 ppm (75 s/year) @ -10 to +50 °C Optionally higher accuracy TCXO's available.
Accuracy after learn:	< ±0.5 ppm (15 s/year or 2 ms/h)
Accuracy with NTP:	< ±4 ms typical, assuming reasonable access to NTP servers

Power Supply

Input voltage:	15 VDC (12.5 - 18 VDC) optional 9 - 36 or 18 - 75 VDC optional 90 - 260 VAC / 50 - 60 Hz to 15 VDC switched UL approved external power block
Power consumption:	130 mA @ 12 VDC for 3 channels 200 mA @ 12 VDC for 6 channels
Internal battery:	optional 7.2 Ah for > 24 h autonomy with intelligent charger, higher autonomy is optionally available with external batteries

Indicators

● Green:	Active Charge LED
● Green:	Run/Stop LED
● Yellow:	Event/Memory LED
● Blue:	Network link/Traffic LED
● Red:	Warning/Error LED

Communication

Configuration, Data Retrieval:	Via Ethernet, Wi-Fi, Serial line, Console, or directly via removable memory card.
Network requirements:	Fixed or Dynamic IP on Ethernet LAN and/or Internet connection with Ethernet interface optional OpenVPN Wi-Fi (b/g/n) network with WEP, WPA, WPA2 security and Enterprise Mode
Security:	GeoDAS proprietary protocol over SSL Checksum and software handshaking
Serial ports:	2 ports standard, + 3 ports optional
Baud rates:	Console: 115200 baud Serial Stream: 38400, 57600, 115200 baud

Alarm / Seismic Switch / Warning / Notification Option

Alarms:	3 independent or 4 common relay contacts for trigger alarm and/or error SMS notification is optionally available
Alarm levels:	Configurable based on event triggers (NO or NC selectable during order)
Relay Hold-On:	1 to 60 seconds (User programmable)
Capacity:	The contacts are suitable for a low voltage control. In case large load must be switched then external relays should be implemented.
Max voltage:	125 V / 250 mA

Interconnected Network Option
Wired or Wireless common time and trigger interconnection network, distributing GPS-grade time precision among several units is optionally available.

Modem Option
Internal or external modems of different types, including cellular 3G/4G modems, are optionally available.

Environment / Reliability

Operational temperature:	-20 to +70 °C*
Storage temperature:	-40 to +85 °C*
Humidity:	0 to 100 % RH (non condensing)
MTBF:	> 500'000 hours

Housing

Type:	Cast aluminium housing
Size:	296 x 175 x 140 mm (W x D x H)
Size with base plate:	296 x 225 x 156 mm (W x D x H)
Weight:	4.7 kg (optional < 4 kg) 0.3 kg internal sensor, 2.6 kg battery, 1.3 kg base plate, ask for other options
Protection:	IP65 (NEMA 4), optionally IP67 (NEMA 6)
Mounting:	Base plate with single bolt, surface mount. When base plate levelled and fixed, GMSplus can be replaced without re-levelling.
Easy Transport:	Optional portability accessories are available to facilitate short term measurements.

GMSplus series are produced in different types to suit particular specifications or regulations. Specifications mentioned in this datasheet may be different among different types.
*: use of an internal battery may degrade this specification.
°: contact GeoSIG for the optional Earthquake Early Warning functionality.

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GeoSIG
swiss made to measure

CR-6plus Multichannel Central Recording System

Features

- Unlimited number of channels by combining modular (12 x 3) 36 channel modules
- 137 dB dynamic range
- Individual 24-bit Δ–Σ ADC per channel
- Up to 1000 sps adjustable sampling rate
- Recording on microSD cards
- USB interface for external storage and communication devices
- Continuous and trigger based recording
- Simultaneous data streaming to several clients
- Wired Ethernet, optional enhanced connectivity via external landline modems, 3G cellular devices, satellite links and serial links
- TCXO time base with GPS or NTP synchronisation
- Configuration and status monitoring via Web Interface compatible with Smartphones/Tablets
- Simple and secure communication over internet or intranet with full remote management
- Optionally available as drop-in replacement for CR-4 Digitiser
- Connection of sensor cables on terminals
- Optional alarm output with up to 4 independent relays flexibly configurable for different types of events
- Extremely compact and modular

Applications

- Structural Health and Response Monitoring
- Earthquake and Seismic Monitoring
- Ambient Vibration Testing
- Induced Vibration Monitoring and Notification
- Building Code Compliant Instrumentation
- Seismic Alarm and Safe Shutdown

Front View

Rear View

Outline

CR-6plus is a modern multichannel central monitoring and recording system including a high performance data handling module, providing an extremely flexible 24 Bit multichannel recorder.

Its design is based on years of experience in creating solutions for earthquake, seismic, structural, dynamic and static monitoring.

Its modular architecture and industry standard interfaces offer high versatility, easy expansion, upgradeability, and long term availability of spare parts.

Connection of the sensor cables is extremely easy and fast with the versatile cable screw terminal design. All inputs and outputs of the CR-6plus are protected with a field proven over voltage protection (OVP) system.

Data from acceleration, velocity, displacement, strain, meteorological or any other type of sensors can be monitored and recorded with superior data quality.

The CR-6plus continuously monitors the real-time data, which can be recorded based on event detection and continuously. The continuous ring buffer size, the pre-event and post-event time, trigger thresholds and many other parameters are fully user configurable.

In addition to the real-time display of the measured data from each channel the system can provide statistical data such as mean, max, min, and peak values.

CR-6plus can optionally compare the monitored data to four fully independent alarm trigger criteria and provide relay outputs.

GeoDAS, a proven data acquisition and evaluation package developed by GeoSIG, complements CR-6plus providing a highly flexible user-friendly capabilities, and graphical, analytical and reporting tools with automation.

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CR-6plus Specifications

Overview

CR-6plus is a 19'' rack module consisting of Slot-in Modules (SiMs) inserted into vertical slots.
Each CR-6plus rack is expandable up to 36 channels and by combining several CR-6plus systems, hundreds of channels can be monitored.
System parameters of the CR-6plus are stored in the non-volatile system memory to allow automatic recovery.

Sensors

The CR-6plus offers the most flexible sensor connectivity options to cater for the needs of any measuring requirement. Any type of sensor complying with the CR-6plus signal input specifications can be connected on the conveniently available screw terminals.

CR-6plus Rack

Configuration:	Base SiM modules: - CR-6-SBC data handling SiM ARM Cortex A8, 800 MHz 128 MB Flash, 128 MB RAM - CR-6-OVPB over voltage protection SiM - CR-6-WDB system watchdog SiM Channel SiM modules: - CR-6-DS digitiser SiM - CR-6-OVPS sensor interface SiM
Channels:	up to 36 channels

Digitiser SiM

Configuration:	CR-6-DS Mounted at the front of the CR-6plus Rack up to 12 SiMs per one Rack
Channels:	3 channels per SiM
A/D Converter:	24 Bit Δ–Σ per channel with analog and digital FIR anti-aliasing filters
Dynamic range:	146 dB (per bin @ 1 Hz rel. full scale rms) 137 dB @ 50 sps
Sampling Rate:	Up to 1000 SPS
Bandwidth:	DC to 250 Hz

Sensor Interface SiM

Configuration:	CR-6-OVPS Mounted at the back of the CR-6plus Rack up to 12 SiMs per one Rack
Channels:	3 channels per SiM
Input Signal:	10 VDC differential 2.5 VDC ± 2.5 VDC single ended 0 - 20 mA current loop
Sensor Power:	12, ±12 or 24 VDC

Data Recording

Type:	Continuous and/or event based

Triggering

Type	Level or STA/LTA trigger
Pre-event-Time:	1 to 720 seconds, typical
Post-event-Time:	1 to 7200 seconds, typical
Trigger filtering:	User configurable lowpass, highpass or bandpass

Data Stream

Protocol:	GSBU, SeedLink (Earthworm compatible)

Storage Memory

Size and Type:	8 GByte removable microSD Card, Higher capacity available on request Large USB storage available on request FAT32 or EXT4 formatted
Management:	Intelligent management of memory card capacity using policies as per file type and ring buffer capacity specification.
Recording format:	miniSEED, optionally with extended information encapsulated into blockette 2000.

Power

DC Power:	15 VDC (12.5-18 VDC)
AC Power:	Available on request, AC/DC adaptor with 230 VAC / 50 Hz or 115 VAC / 60 Hz.
Consumption:	typically 15 W with 36 channels excluding the consumption of the connected sensors
Solar Panels:	Available on request.
External battery:	Available on request, 24 to 100 Ah with battery protection in case of low battery condition with automatic restart after power is restored.

Self-Test

User-configurable periodical sensor test and periodical state of health (SOH) report based on comprehensive test of instrument, which can be requested at any time.

Time Base

Internal:	Intelligent Adaptive Real Time Clock (IARTC)
External:	NTP or GPS
Std. TCXO accuracy:	±0.5 ppm (15 s/year) @ +25 °C ±2.5 ppm (75 s/year) @ -10 to +50 °C Higher accuracy available on request
Accuracy after learn:	< ± 0.5 ppm (15 s/year or 2 ms/h)
Accuracy with NTP:	< ± 4 ms typical, assuming reasonable access to NTP servers

Communication Channel

Standard:	Ethernet TCP/IP
Optional:	Internal landline modem External GSM modem External Satellite modem External GPRS modem External UMTS/3G modem

User Interface

An intuitive web interface is available for easy configuration with any web browser. Alternatively the configuration file in XML format can be edited on site through the instrument console, exchanged by replacing the memory card, remotely from a server or through SSH. Even if the configuration file can be manually edited at any time, a tool is provided to edit it securely.
Network based link allows the user optionally to interact with the unit over the Internet, from anywhere around the world.

Alarm (Optional SiM)

Alarms:	4 independent relay contacts for trigger alarm and/or error (NO and NC contacts available)
Relay Hold-On:	1 to 60 seconds (User programmable)
Contacts:	Suitable for a low voltage control. In case large loads must be switched then external relays should be implemented.
Max voltage:	125 V / 250 mA

Environment / Housing

Operational temperature:	-20 °C to +70 °C
Storage temperature:	-40 °C to +85 °C
Humidity:	0 % to 100 % (non condensing)
Rack Dimensions:	19'' rack, 3 HU, 350 mm depth
Housing:	Various fixed or portable housings available on request
Protection:	Housings with variable protection available on request

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SENSORS

AC-23 Servo-Accelerometer
AC-73 Force Balance Accelerometer

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Switzerland

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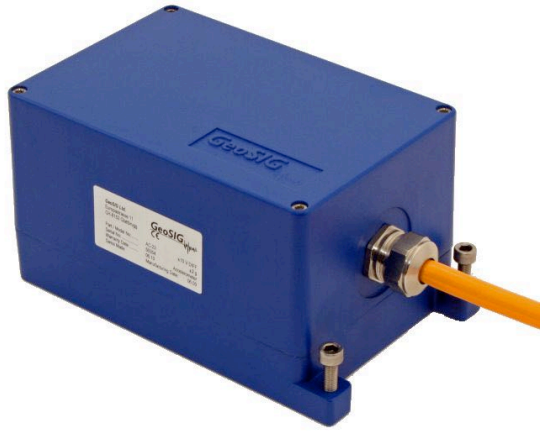
AC-23 / AC-22 / AC-21 Accelerometer

Features

- **Full Scale ± 0.1, 0.2, 0.5, 1, 2 and 4g jumper selectable**
- **Bandwidth 0.1 Hz to 100 Hz (optional 200 Hz)**
- **Dynamic range > 125 dB**
- **Excellent temperature stability**
- **Strong-Motion, Free field and Industrial applications**
- **Downhole version (AC-23-DH) is also available**
- **Different housing and mounting options are available**
- **Single Bolt Mounted Enclosure provides up to ± 10° of Levelling Adjustment**



Outline

The AC-23 package is a triaxial accelerometer sensor designed for Strong Motion and industrial applications where a high sensitivity is required.

The AC-2x series are state-of-the-art servo-accelerometers based on standard exploration geophone mass-spring system with electronic feedback. Having remarkable temperature and aging stability because of the very simple principle, the AC-2x rarely requires maintenance.

The outstanding dynamic range performance and linearity of the AC-2x which is more than 125 dB at ± 2 g full scale within the 0.1 to 50 Hz range, makes this accelerometer a perfect sensor for many applications.

Triaxial, biaxial and uniaxial configurations are all available in surface and downhole models, complementing the versatile useability of the AC-2x.

The AC-2x is housed in a sealed cast aluminium housing with the dimensions of 195 x 112 x 96 mm. The housing also offers a single bolt mounting system with three levelling screws. Stainless steel housings as well as internal mounting inside GSR-xxAH housing options are available.

With the help of the TEST LINE the sensor can be easily and completely tested. Full scale is user selectable on site by setting the internal jumpers.

The AC-2x accelerometer is directly compatible with the GeoSIG recorders.

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Specifications AC-23 / AC-22 / AC-21 Accelerometer

General Characteristics

Application: Strong Motion earthquake survey
Industrial applications requiring high sensitivity

Configurations:

	Triaxial	Biaxial	Uniaxial	Axes	Alignment**
AC-23 or AC-23i*:	■			X – Y – Z	H – H – V
AC-22-H or AC-22-Hi*:		■		X – Y	H – H
AC-22-V or AC-22-Vi*:		■		X (or Y) – Z	H – V
AC-21-H or AC-21-Hi*:			■	X (or Y)	H
AC-21-V or AC-21-Vi*:			■	Z	V

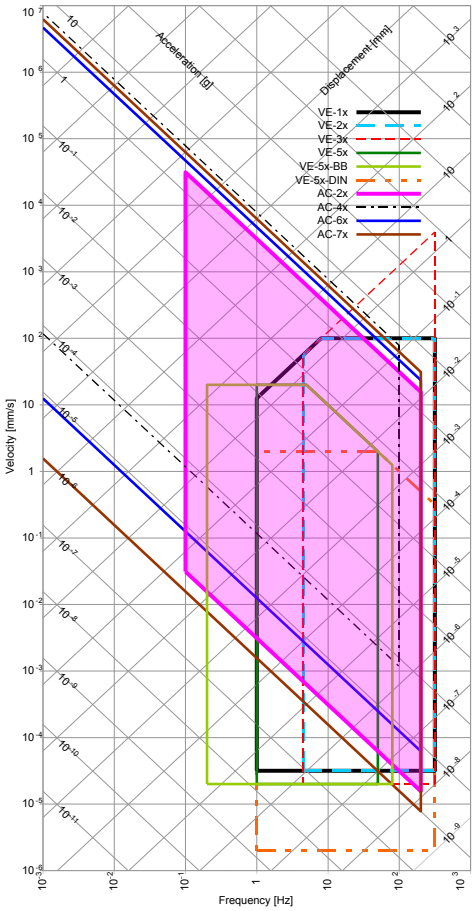
* i : Internal sensor ** H: Horizontal, V: Vertical

Full Scale Range: Jumper selected in range
± 0.1, ± 0.2, ± 0.5, ± 1, ± 2 and 4g
for ± 10 V diff at output
AC-23 NPP: ± 0.5, ± 1 and ± 2g

Sensor Element

Type: Servo-accelerometer based on geophones with feedback
Dynamic Range: >125 dB effective at ± 2 g full scale
Linearity: 0.1 %
Accuracy: ± 0.4 dB max over the bandwidth
Cross Axis Sensitivity: 1 %
Bandwidth: 0.1 Hz (1 pole) to 100 Hz (1 pole)
optional 200 Hz
Damping: 0.7 critical
Offset Drift: < 1 mV/^{0}C
Span drift: < 200 ppm/^{0}C
Full Scale output: 0 ± 10 V differential (20 Vpp)
optional 2.5 ± 2.5 V single-ended (5 Vpp)
0 to 20 mA current loop

Measuring Range: See Plot



Power

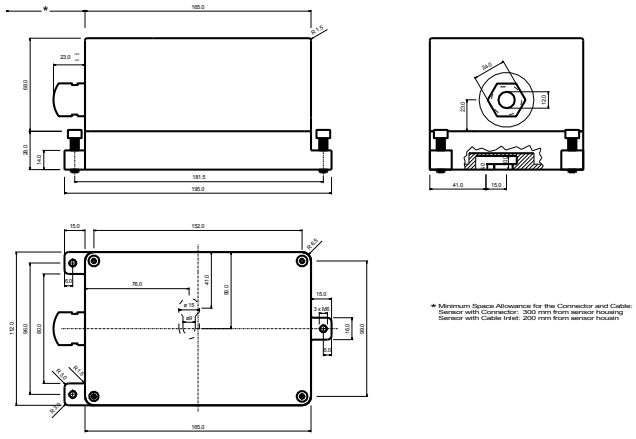
Supply Voltage: 12 VDC regulated (10 to 15 V)
Consumption: 40 mA @ 12 V
Mating: Binder / Coninvers type RC
Overvoltage Protection: All pins are protected

Connector Pin Configuration

Pin 1-2, 3-4, 5-6 Signal output for axis X, Y, Z
Pin 7-8 Test input, Digital test-pulse (0 – 12 V)
Pin 9-10 +12 VDC Power Supply
Pin 11-12 Auxiliary input
Case Shielded Ground

Environment/Housing

Housing Type: Cast aluminium
Sealed access cover
Housing Size: 195 x 112 x 96 mm
Weight: 2.5 kg
Index of Protection: IP 65
optional IP 68
Temperature Range: - 20 to 70 °C (operating)
- 40 to 90 °C (non-operating)
Humidity: 0 to 100 % (non-condensing)
Orientation: Floor or wall mounting (to be specified in order)
Mounting: Single bolt, surface mount, adjustable within ± 10°



Standard AC-23 Floor mounted, Full scale ± 2 g,
2 m cable with cable inlet and recorder mating connector, concrete anchor bolt and user manual on CD

Options

Cable & connector: Cable connector
Metallic, Shielded, IP67, 12 pins, male
optional MIL, Bendix PT07A 14-19P
Cable with shielded twisted pairs for any length (including mating sensor connector) with open end
Cables for connection to GeoSIG recorder
Connector on user specification mounted at cable end
Housing: Watertight IP 68 housing
Downhole housing (AC-2x-DH)
Stainless steel protective housing
As internal sensor
Mounting: Wall mounted

Ordering Information

Specify: Type of AC-2x, full scale range, and other applicable options

GeoSIG
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Web: www.geosig.com

GeoSIG
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AC-23 / AC-22 / AC-21-DH Downhole Accelerometer

Features

- ❒ **Full Scale ± 0.1, 0.2, 0.5, 1, 2 and 4g jumper selectable**
- ❒ **Bandwidth 0.1 Hz to 100 Hz (optional 200 Hz)**
- ❒ **Dynamic range > 125 dB**
- ❒ **Excellent temperature stability**
- ❒ **Strong-Motion, Free field and Industrial applications**
- ❒ **No field adjustment required**
- ❒ **Strong mechanical design**
- ❒ **Fits in 3 inch casing**

Outline

The AC-23-DH sensor package is a triaxial accelerometer designed for borehole applications regarding Strong Motion earthquake survey and monitoring.

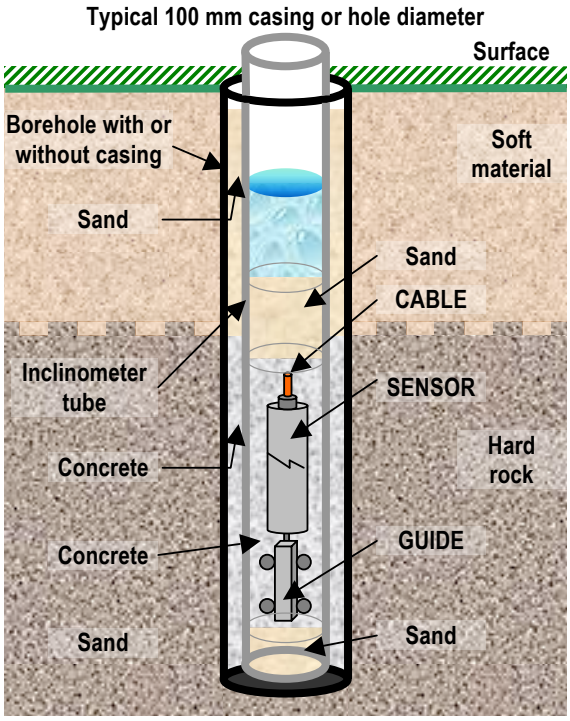
The AC-2x-DH sensors are servo-accelerometers based on a standard exploration geophone mass-spring system with electronic feedback. This type of sensor gives a very good stability versus temperature or aging because of the very simple principle.

The sensor does not require maintenance and has very low aging drift. With the help of the TEST LINE the sensor can be easily, completely tested.

The family of AC-2x-DH accelerometer is directly compatible with the GeoSIG recorders.

The downhole casing contains the entire sensor system. The sensor is connected through Overvoltage Protection stage to the recorder at the surface with a cable.

Using inclinometer tubes and the provided guiding wheels, the sensor can be oriented before insertion in the tube.



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Specifications AC-23 / AC-22 / AC-21-DH Downhole Accelerometer

General Characteristics

Application: Strong Motion earthquake survey, Industrial applications requiring high sensitivity.

Configurations:

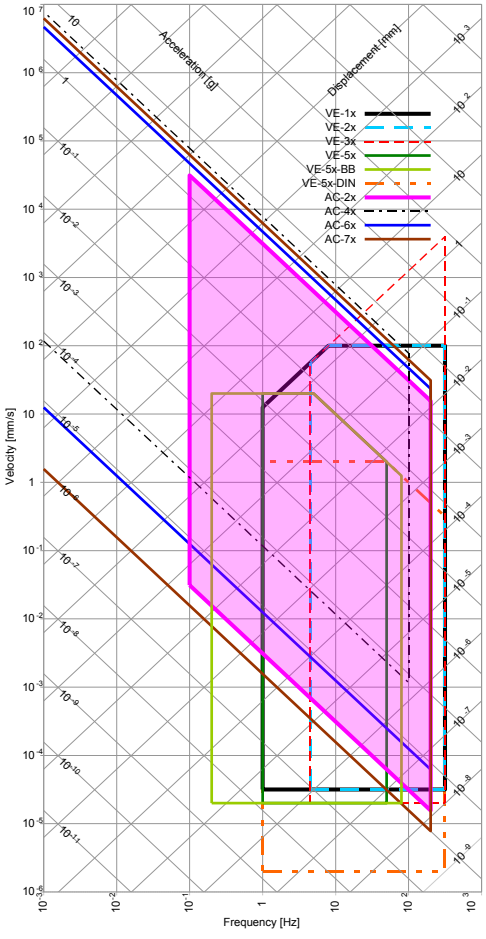
	Triaxial	Biaxial	Uniaxia	Axes	Alignment**
AC-23:	■			X – Y – Z	H – H – V
AC-22-H:		■		X – Y	H – H
AC-22-V:		■		X (or Y) – Z	H – V
AC-21-H:			■	X (or Y)	H
AC-21-V:			■	Z	V

** H: Horizontal, V: Vertical

Full Scale Range: Factory configurable to:
± 0.1, ± 0.2, ± 0.5, ± 1, ± 2 and ± 4g
for ± 10 V diff at output
AC-23 NPP: ± 0.5, ± 1 and ± 2g

Sensor Element

Type: Servo-accelerometer based on geophones with feedback
Dynamic Range: >125 dB effective at ±2 g full scale
Linearity: 0.1 %
Accuracy: ± 0.4 dB max over the bandwidth
Cross Axis Sensitivity: 1 %
Bandwidth: 0.1 Hz (1 pole) to 100 Hz (1 pole) optional 200 Hz
Damping: 0.7 critical
Offset Drift: < 1 mV/^{0}C
Span drift: < 200 ppm/^{0}C
Full Scale output: 0 ± 10 V differential (20 Vpp)
Measuring Range: See Plot



Interface

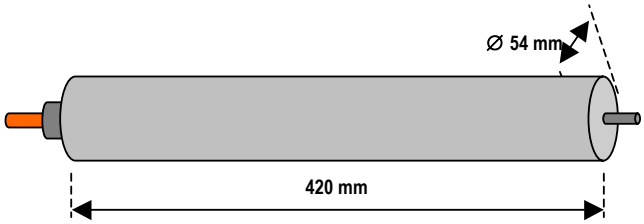
Power supply voltage: 12 VDC regulated (10 to 15 V)
Consumption: 40 mA @ 12 V
Connector: Metallic, Shielded, IP67, 12 pins, male mounted at end of cable.
Other connectors on request.
Mating: Binder / Coninvers type RC
Overvoltage Protection: All pins are protected

Connector Pin Configuration

Pin 1-2, 3-4, 5-6 Signal output for axis X, Y, Z
Pin 7-8 Test input, Digital test-pulse (0 / 12 V)
Pin 9-10 +12 VDC Power Supply
Pin 11-12 Auxiliary input (unused)
Case Shielded Ground

Environment/Housing

Housing Type: Aluminium cylinder, fully sealed
Housing Size: Diameter 54 mm, length 420 mm
Weight: 3.5 kg



Index of Protection: IP 68, up to 10 bars water pressure
Temperature Range: - 20 to 70 °C (operating)
- 40 to 90 °C (non-operating)
Humidity: 0 to 100 %
Orientation: Using 3” inclinometer casing (Figure 1) with included guidewheels (Figure 2).

Standard AC-23-DH Full scale ± 2 g, recorder mating connector and user manual on CD. Borehole cable length to be defined.

Optional Accessories

DH-TUBE 3” inclinometer casing as in figure 1 in sections of 3 meters with coupling elements.
Installation kit: All required tools and fixation consumables for up to 100 meters of casing.
DH-BALL Glass Balls for settlement of downhole sensor (25 kg bag)

Ordering Information

Specify: Type of AC-2x-DH, acceleration full scale, depth of borehole and total cable length.


Figure 1


Figure 2

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E-mail: info@geosig.com
Web: www.geosig.com

GeoSIG
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AC-73 / AC-72 / AC-71 Force Balance Accelerometer

Features

- ❒ **True Electro-mechanical Force Balance Accelerometer**
- ❒ **Digital AC-73D version available**
- ❒ **Dynamic Range 165 dB**
- ❒ **User selectable Full Scale range ± 0.5, 1, 2, 3 or 4 g**
- ❒ **Bandwidth from DC to 200 Hz**
- ❒ **Exemplary Offset stability**
- ❒ **Temperature and drift compensation**
- ❒ **Robust suspension system**
- ❒ **Single Bolt Mounted Enclosure with up to ± 10° of Leveling Adjustment**
- ❒ **Integrated Bubble Level**

Applications

- ❒ **Broadband Seismic, Earthquake and Structural measuring and monitoring**

Outline

The AC-73 sensor package is a true electro-mechanical triaxial downhole accelerometer designed for broadband earthquake monitoring and applications requiring highly sensitive and rugged sensors with minimum maintenance and a simple method for periodic testing.

The rugged mass suspension moving coil system improves the signal to noise ratio. The magnetic system and capacitive position sensors offer symmetrical controls for the accurate electronic centring of the mass. At rest the accelerometer mechanism is in balance and no electrical output is generated.

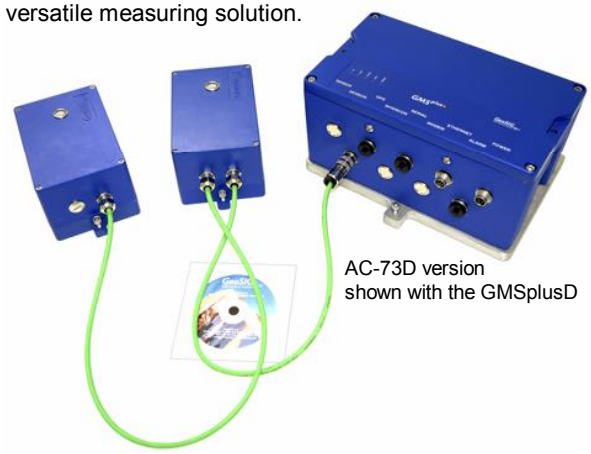
In case of a ground motion, AC-73 yields an electrical output proportional to the current used to keep the mass centred. This output signal is precisely calibrated to provide a signal at the utmost accuracy and with a lowest possible noise level. The symmetrical positioning system incorporated with the force balance accelerometer principle, the accelerometer faithfully keeps its scaling and calibration even under extreme conditions.

The DC response allows the sensor to be easily repaired, tilt tested or recalibrated in the field. With the help of the test line the AC-73 accelerometer can be completely tested assuring proper operation and accurate acceleration measurement. This test line is internally connected to the external world only when a given command is sent to the sensor to avoid any noise pick-up through the test input.

The AC-73 is equipped with electronic offset adjustment features that make its installation very user friendly. This powerful feature allows the users to install the AC-73 without mechanical offset adjustment and fine levelling.

The sensor can be powered from 9.5 to 18 VDC source with the advantage that its power input is insulated from the sensor's electronic ground. This avoids ground loops and reduces noise induced through the power supply.

All the best features of the analog AC-73 accelerometers are now offered with the new AC-73D version, having a digital interface that is directly compatible to operate with the GMSplusD series recorders with upto 1000 meter distances using standard Cat5e cables, providing an extremely compact and versatile measuring solution.



AC-73D version
shown with the GMSplusD

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Specifications AC-7x

General Characteristics

Versions: AC-7x: analog
AC-7xD: digital

Configurations***:

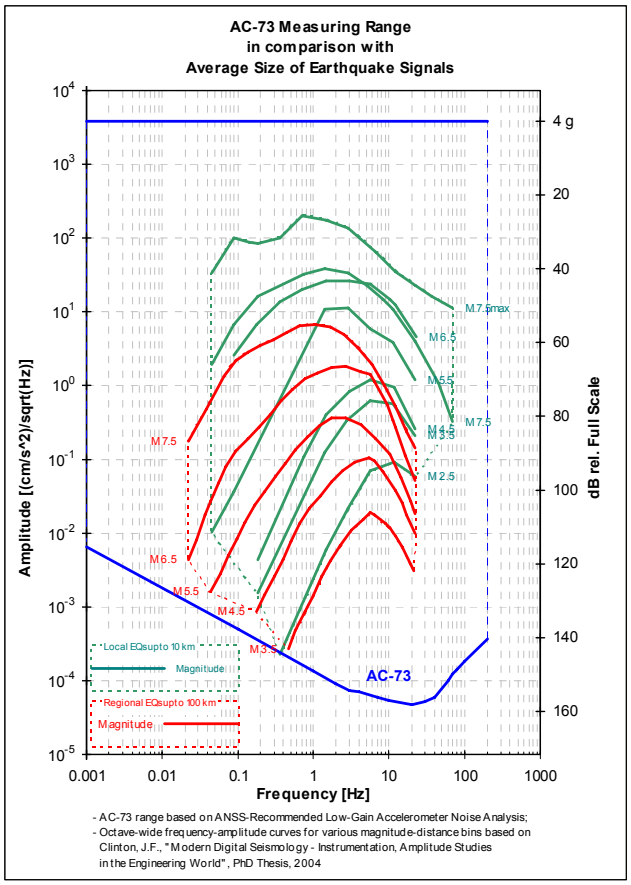
	Triaxial	Biaxial	Uniaxial	Axes	Alignment**
AC-73 or AC-73i*:	■			X – Y – Z	H – H – V
AC-72-H or AC-72i-H*:		■		X – Y	H – H
AC-72-V or AC-72i-V*:		■		X – Z	H – V
AC-71-H or AC-71i-H*:			■	X	H
AC-71-V or AC-71i-V*:			■	Z	V

* i : Internal sensor ** H: Horizontal, V: Vertical
***: add "D" after number of channels for digital version

Full Scale Range: ±2 std., ± 0.5, 1, 3 or 4 g
user selectable at field

Sensor Element

Type: True Electro-mechanical
Force Balance Accelerometer
Dynamic Range: 165 dB (per bin rel. full range)
156 dB (per bin rel. full scale rms)
134 dB (0.02 – 50 Hz, integrated PSD)
Nonlinearity: < 0.1 %
Cross Axis Sensitivity: < 0.5 %
Bandwidth: DC to 200 Hz
Damping: 0.7 ±0.1 critical
Offset Drift: 0.0005 g / °C
Span Drift: 200 ppm / °C
Full Scale Output[NAD]: 0 ±10 V differential (20 Vpp)
Hysteresis: < 0.001 % of full scale
Sensitivity: 2.5 to 20 V/g
Output impedance: 100 ohms



Power

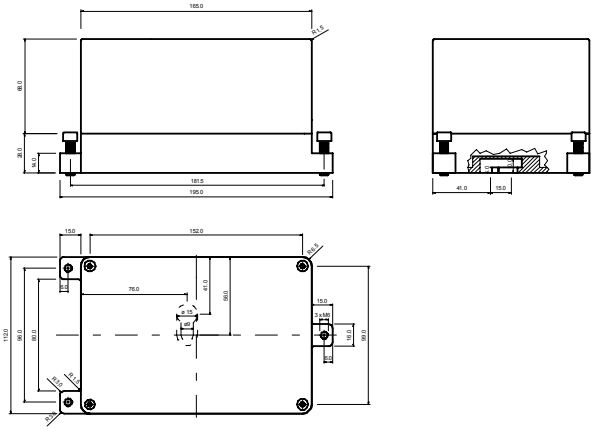
Supply Voltage: AC-7x: 9.5 to 18 VDC
AC-7xD: 48 VDC
Consumption: AC-73: 55 mA typical
AC-73D: 200 mA typical
Overvoltage Protection: All external interfaces are protected

Connector Pin Configuration

AC-73:
Pin 1-2, 3-4, 5-6: Signal output for axis X, Y, Z
Pin 7-8: Test input, Digital 0/12 V / GND
Pin 9-10: 12 VDC insulated power supply input
Pin 11-12: Reserved
Case: Shield connection
AC-73D: see user manual

Environment/Housing

Housing Type: Cast aluminium
Sealed access cover
Housing Size: 195 x 112 x 96 mm



Weight: 3.0 kg
Index of Protection: IP 65
optional IP 68[NAD]
Temperature Range: -20 to 70 °C (operating)
-40 to 75 °C (non-operating)
Humidity: 0 to 100 % (non-condensing)
Orientation: Can be configured for mounting in any position (please specify at order).
Mounting: Single bolt, surface mount, adjustable within ±10°

Standard sensor: Floor mounted, Full scale ± 2 g,
for external sensors: concrete anchor,
GeoSIG recorder mating connector and
AC-7x: 2 m cable with cable inlet
AC-7xD: cable inlet

Options

Full Scale Output[NAD]:
- 4 to 20 mA current loop

Cable & connector[NAD]:
- Frame connector (no cable inlet)
- Mating connector (for frame connector)
- Cable with shielded twisted pairs for any length with open end
- Connector on user specification mounted at cable end
- See separate cable & connector options sheet

Housing:
- Watertight IP68 housing[NAD]
- Stainless steel protective housing

Mounting:
- See separate sensor orientation options sheet

Ordering Information

Specify: Version and configuration of AC-7x, full scale range, and other applicable options

NAD: Not applicable for AC-7xD digital version.

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AC-73-DH / AC-72-DH / AC-71-DH Force Balance Accelerometer

Features

- True Electro-mechanical Force Balance Accelerometer
- Built-in compass as well as tilt, temperature and humidity sensors
- Extremely robust downhole housing
- Suitable for borehole diameters of 100 mm and larger
- Proprietary iSensor™ interface
- Dynamic Range 165 dB
- Full Scale ± 0.5, 1, 2, 3 or 4 g
- Bandwidth from DC to 200 Hz

Applications

- Earthquake and Structural monitoring
- Ambient seismic noise monitoring
- Oil and gas exploration
- Oceanbottom seismic monitoring

Outline

The AC-73-DH sensor package is a true electro-mechanical triaxial downhole accelerometer designed for broadband earthquake monitoring as well as applications requiring highly sensitive and rugged sensors with minimum maintenance and a simple method for periodic testing.

The rugged mass suspension moving coil system improves the signal to noise ratio. The magnetic system and capacitive position sensors offer symmetrical controls for the accurate electronic centring of the mass. At rest the accelerometer mechanism is in balance and no electrical output is generated.

In case of a ground motion, AC-73-DH yields an electrical output proportional to the current used to keep the mass centred. This output signal is precisely calibrated to provide a signal at the utmost accuracy and with a lowest possible noise level. The symmetrical positioning system incorporated with the force balance accelerometer principle, the accelerometer faithfully keeps its scaling and calibration even under extreme conditions.

The DC response allows the sensor to be tilt tested or recalibrated in the field. With the help of the test line the AC-73-DH accelerometer can be completely tested assuring proper operation and accurate acceleration measurement. This test line is internally connected to the external world only when a given command is sent to the sensor to avoid any noise pick-up through the test input.

The AC-73-DH is equipped with electronic offset adjustment features that make its installation very user friendly. This powerful feature allows the users to install the AC-73-DH without mechanical offset adjustment and fine levelling.

The advanced iSensor™ interface allows easy deployment using built-in hardware like compass as well as tilt, temperature and humidity sensors.

The sensor can be powered from 9.5 to 18 VDC source with the advantage that its power input is insulated from the sensor's electronic ground. This avoids ground loops and reduces noise induced through the power supply.

Specifications AC 7x-DH

General Characteristics

Configurations:

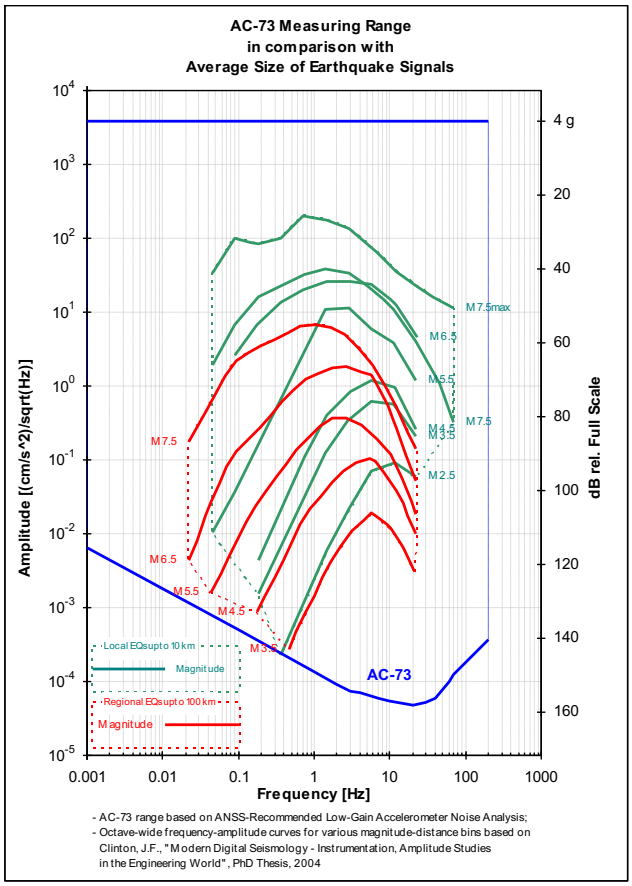
	Triaxial	Biaxial	Uniaxial	Axes	Alignment**
AC-73-DH:	■			X – Y – Z	H – H – V
AC-72-H-DH:		■		X – Y	H – H
AC-72-V-DH:		■		X – Z	H – V
AC-71-H-DH:			■	X	H
AC-71-V-DH:			■	Z	V

** H: Horizontal, V: Vertical

Full Scale Range: ±2 std., ± 0.5, 1, 3 or 4 g

Sensor Element

Type:	True Electro-mechanical Force Balance Accelerometer
Dynamic Range:	165 dB (per bin rel. full range) 156 dB (per bin rel. full scale rms) 134 dB (0.02 – 50 Hz, integrated PSD)
Nonlinearity:	< 0.1 %
Cross Axis Sensitivity:	< 0.5 %
Bandwidth:	DC to 200 Hz
Damping:	0.7 ±0.1 critical
Offset Drift:	0.0005 g / °C
Span Drift:	200 ppm / °C
Full Scale Output:	0 ±10 V differential (20 Vpp)
Hysteresis:	< 0.001 % of full scale
Sensitivity:	2.5 to 20 V/g
Output impedance:	100 ohms



- AC-73 range based on ANSS-Recommended Low-Gain Accelerometer Noise Analysis;
- Octave-wide frequency-amplitude curves for various magnitude-distance bins based on Clinton, J.F., "Modern Digital Seismology - Instrumentation, Amplitude Studies in the Engineering World", PhD Thesis, 2004

iSensor™ interface

iSensor™ interface is a state of the art innovative and proprietary hardware and software interface developed by GeoSIG, which allows through its special computer software, the operation, control, logging and data export for the built-in:

- compass
- tilt sensor
- temperature sensor
- humidity sensor

Power

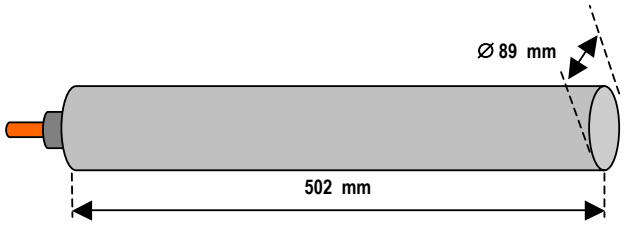
Power input:	Insulated
Supply Voltage:	9.5 to 18 VDC, single supply
Consumption:	80 mA @12 V
Overvoltage Protection:	All pins are protected with double stage barrier

Connector Pin Configuration

Pin 1-2, 3-4, 5-6	Signal output for axis X, Y, Z
Pin 7-8	Test input, Digital 0/12 V / GND
Pin 9-10	12 VDC insulated power supply input
Pin 11-12	iSensor™ interface (RS-485)
Case	Shield connection

Environment/Housing

Housing Type:	Stainless Steel
Housing Size:	ϕ 89 mm x 502 mm
Weight:	7.5 kg (typical configuration)
Index of Protection:	Watertight upto 15 bar (150 m)
Temperature Range:	-20 to 70 °C (operating) -40 to 75 °C (non-operating)



Standard AC-7x-DH Full scale ± 2 g, with cable inlet and surface junction box

Options

Cable & connector:
- See separate cable and connector options sheet
- Connector on user specification can be mounted at cable end

Surface control unit:
- iSensor interface

Ordering Information

Specify: Type of AC-7x-DH, full scale range, depth of deployment, cable length, and other applicable options

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EXAMPLE SYSTEM

Beznau NPP in Switzerland

Beznau Nuclear Power Plant
Seismic Instrumentation Network

Switzerland

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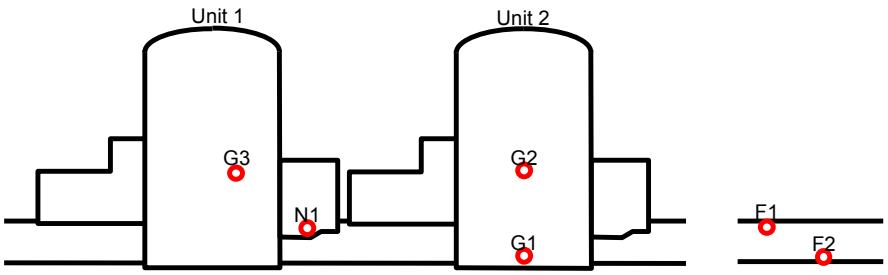
Project Overview

Axes	Sensors	Digitisers/ Recorders	Communication	System Center	Duration (weeks)
18	6	6	Cable/modem	1 Data Center	40



F1: Freefield at surface
F2: Freefield on bedrock
N1: State of Emergency building, mat foundation
G1: Security building, mat foundation
G2: Security building, operation floor level 340
G3: Security building, operation floor level 340

Scope:

Nuclear Power Plant (NPP) safety monitoring against seismic motions, and other ambient dynamic loads to:

(i) Evaluate and observe structural safety and integrity as well as safe operation,
(ii) Assess and compare the behaviour against the seismic design criteria,
(iii) Develop and improve emergency and safety measures as well as awareness,
(iv) Contribute to regional seismic database.

System:

AC-23 force balance accelerometers, GSR-18 digitiser/recorders and one Central Processing Unit (CPU).
All stations store the motion signals detected by the sensors in local recorders, for redundancy.
GeoDAS software is utilized to: i) monitor the stations, ii) download event recordings automatically, iii) check system state of health, which can be used to analyze the detailed cause of any malfunction, iv) Analyze downloaded data by means of seismic and OBE/SSE checks, v) issue alarms.
Recording threshold and the alarm limit values can be set individually for each measuring channel.
Alarm transmission and communication between stations and the CPU via fiber-optic cable.
Self-monitoring and testing facilities for periodic testing of the entire measurement chain.

Outputs:

Three alarm levels: trigger, calculated, system failure.
Laser printed seismic event records including 3 component time-history and RSA, RSV and CAV plots with limits.
Data is stored on event basis in case a dynamic event is detected.

Client:
Nordostschweizerische Kraftwerke (NOK)

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REFERENCE LIST

World Wide Nuclear Power Plants with GeoSIG Instrumentation

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Selected NPPs Instrumented with GeoSIG Instruments

In the past decades, GeoSIG Instruments have been delivered to more than 70 NPP's in more than 15 countries worldwide. Some of the NPP's around the world, which are instrumented with GeoSIG Instruments, are listed below.

Country	Project
Argentina	Embalse
Armenia	Metsamor
Belgium	Doel
Belgium	Tihange
Bulgaria	Kozloduy
Canada	Gentilly
Canada	Pickering
China	Tianwan
Czeck Republic	Temelín
France	Marcoule
Germany	KMK Mülheim-Kärlich
Hungary	Paks
Lithuania	Ignalina - Modernization
Lithuania	Ignalina
Slovak Republic	Bohunice
Slovak Republic	Mochovce
South Korea	ASTS for 6 Reactors
South Korea	Shin-Kori Unit 3 & 4 Extension
South Korea	Shin-Wolsong Unit 3 & 4 Extension
South Korea	ASTS for 20 Reactors
South Korea	Shin-Kori Unit 3 & 4
South Korea	Waste Storage Facility (LILW)
South Korea	Shin-Wolsong
South Korea	Shin-Kori Unit 1 & 2
South Korea	Wolsong - Upgrade
South Korea	Ulchin Unit 5 and 6
South Korea	Kori
South Korea	Wolsong Unit 1 & 2
Spain	José Cabrera (Zorita) - Upgrade
Spain	Trillo
Spain	Vandellos
Spain	José Cabrera (Zorita)
Switzerland	Mühleberg
Switzerland	Leibstadt Phase 2
Switzerland	Beznau Phase 2
Switzerland	Gösgen Phase 2
Switzerland	Gösgen Phase 1
Switzerland	Leibstadt Phase 1
Switzerland	Beznau Phase 1
Taiwan	Maanshan
USA	Susquehanna - Upgrade

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Country	Project
USA	Arkansas Nuclear One
USA	Beaver Valley Unit 2
USA	Braidwood
USA	Byron
USA	Callaway
USA	Clinton
USA	Connecticut Yankee
USA	Crystal River
USA	Davis-Besse
USA	Diablo Canyon
USA	Enrico Fermi
USA	Hanford N-Reactor
USA	Hatch
USA	Humboldt Bay
USA	Kewaunee
USA	LaSalle County
USA	Marble Hill
USA	Millstone Unit 3
USA	Monticello
USA	Palo Verde
USA	Peach Bottom
USA	Point Beach
USA	Prairie Island
USA	Rancho Seco
USA	Salem
USA	South Texas Project
USA	Susquehanna
USA	Trojan
USA	Wolf Creek
USA	Zion

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COMPANY PRESENTATION

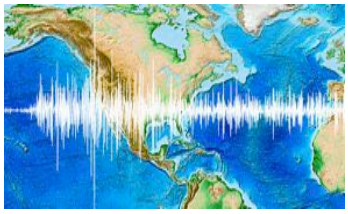
Company Brochure

GeoSIG, the Swiss manufacturer of systems and solutions for earthquake, seismic, structural, dynamic and static monitoring and measuring

GeoSIG Ltd provides superior instruments, state-of-the-art systems and solutions for earthquake, seismic, structural, dynamic and static monitoring and measuring.

Since 1992, having established a permanent and strong position at the top tier of the industry and with significant experience in the development of systems for scientific, engineering and industrial applications, GeoSIG has supplied thousands of systems in successful operation around the world.

Composed of highly dedicated and talented individuals with many years of experience in their fields, GeoSIG has developed a large variety of Strong Motion and Seismic Recorders, Sensors and Civil Engineering Monitoring Systems and provides high quality instruments and network systems.



The principle objective of GeoSIG is to provide measuring solutions that meet customers' requirements. This tenet is fulfilled by highly versatile products in terms of features, functions, quality and reliability at an optimum price to performance ratio.

The design and development of all GeoSIG systems are centred on obtaining the highest possible levels of performance, durability and reliability; qualities which are inherently associated with the words 'Swiss Quality'.

To assure continuing leadership, GeoSIG places a strong emphasis on incorporating the most advanced technologies.

GeoSIG has succeeded in bringing out excellent products and is recognised and well known in the seismic and civil engineering market place. GeoSIG Instruments have been designed from the outset with the future in mind. The open architecture, leading edge digital electronics, and the use of advanced engineering facilities have resulted in a system design with the power and flexibility to perform not only today's but tomorrow's instrumentation and monitoring requirements.

Numerous projects have been successfully completed ranging from single instruments to massive networks in more than 80 countries around the world.

More than 40 determined representatives have been assigned in more than 55 countries around the globe. This experienced and widespread representative network enables GeoSIG to be present round the clock in the service of their customers.

To complement its technical capabilities and to attain high levels of quality assurance, GeoSIG has invested extensively in support and infrastructure which has collimated in achieving ISO 9001 accreditation. In mid 1997 GeoSIG has been assessed and approved to the quality administration systems, standards and guidelines of BS EN ISO 9001: 1994. Following re-assessments in 2004 and in 2010 yielded approvals for BS EN ISO 9001: 2000 and BS EN ISO 9001: 2008, respectively, applying to the design, development, manufacture, supply and servicing of geophysical measuring solutions (QMS Quality Management Systems Limited, Certificate Number: GB2117).

GeoSIG Head Office is located in Schlieren, Switzerland, only 15 minutes away from the Zurich International Airport. This large facility incorporates the administration; commercial and project management; research, development and design; manufacturing, testing and repair as well as training amenities. This well organised constellation provides a focused and fully integrated activity.

GeoSIG recognises that the most valuable asset is the combined expertise, experience and talents of its team, affiliates and customers. Dedication, talent, knowledge and experience enable GeoSIG to continue being one of the principal suppliers of measuring solutions.

ISO 9001 REGISTERED FIRM

Where to Find

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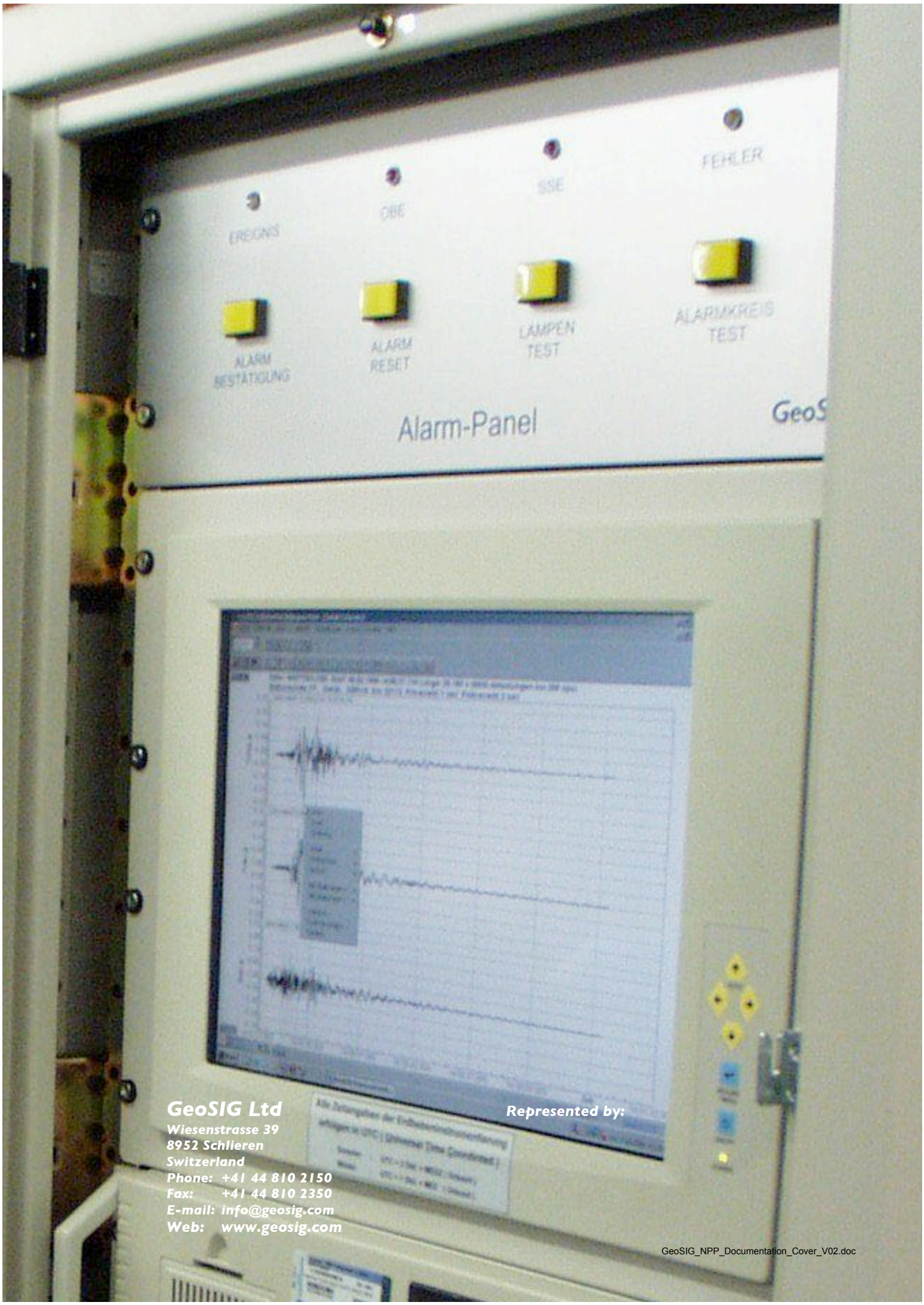

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Represented by: