

Seismic Data Recorder

DATA-CUBE³

User Manual

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1. Introduction

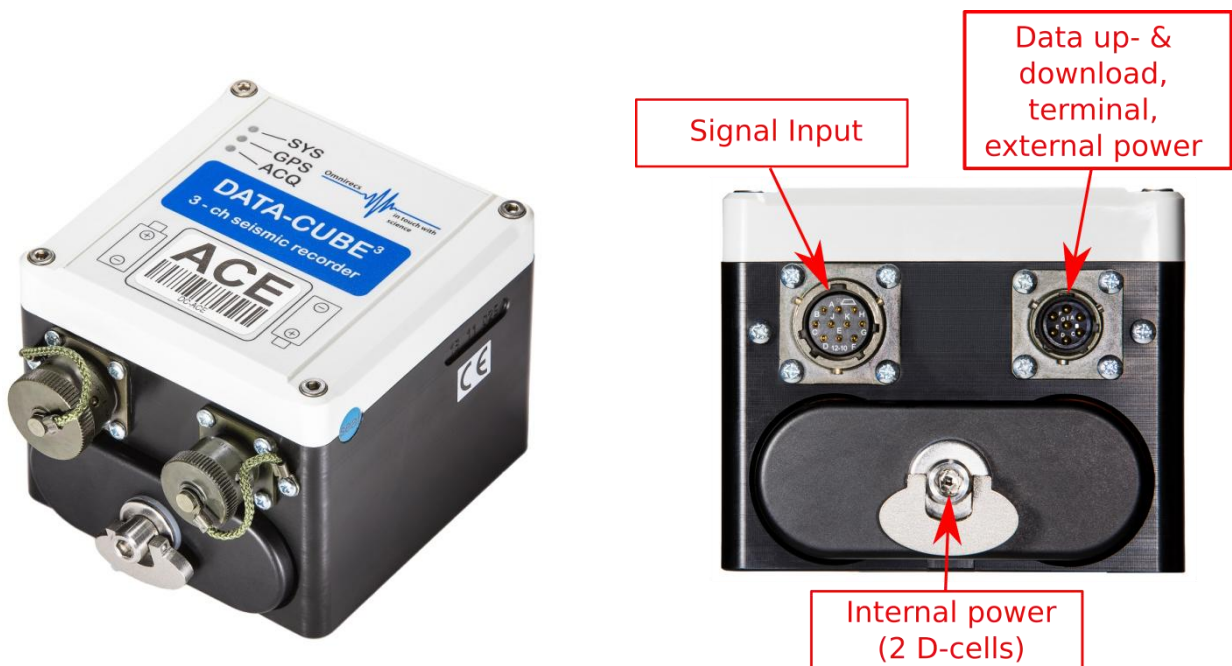
The DATA-CUBE³ is a 3-channel, 24-bit seismic data recorder. It was initially developed at GFZ Potsdam until 2011, later enhanced and introduced to the international market by Omnirecs, now produced and distributed by DiGOS. The DATA-CUBE³ is a great candidate for different seismologic applications by its unique combination of features.

This document provides a overview of the different DATA-CUBE³ types & applications, software, available cables and sensor signal converters as well as detailed usage information.

2. DATA-CUBE³

The DATA-CUBE³ is available as Type 1 (int) and Type 2 (ext). Choosing the right DATA-CUBE³ type depends on the intended application and usage scenarios. Both types are electronically identical except for the internal vs. external GPS antenna and internal/external power supply.

2.1. DATA-CUBE³ Type 1 (int)



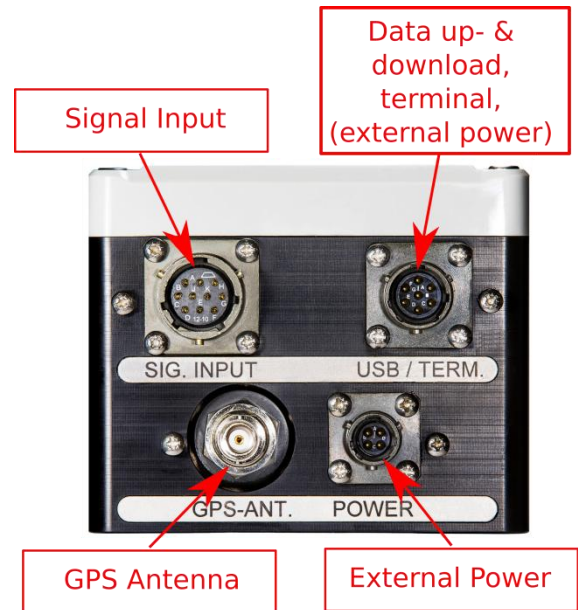
Features:

- Internal GPS antenna located under top cover
- Internal power supply (2x D-cells for up to 2 weeks operation) or external power supply

Typical applications:

- Active seismic measurements and short campaigns with a recording time of up to ~2 weeks (continuous recording of 3 channels @ 100sps using 2 D-cell alkaline batteries)
- Outdoor installation with direct *visibility* of GPS satellites
- Optionally: Long-term, outdoor deployments with external power supply (internal batteries are to be removed)

2.2. DATA-CUBE³ Type 2 (ext)



Features:

- External GPS antenna
- External power supply only

Typical applications:

- Long-term, passive seismic measurement campaigns and experiments for unattended operation of up to ~280 days (continuous recording 3 channels @ 100sps)
- Outdoor, vault or indoor installation

2.3. Custom-built Types

In the past, some users required special versions of the DATA-CUBE³ with different configurations. As an example the following modified types have been manufactured:

- DATA-CUBE³ Type 1 e/a: Internal power supply by 2 D-cells and an external GPS antenna
- DATA-CUBE¹: Only 1 ADC channel to support an infrasound sensor or a 1-channel geophone
- DATA-CUBE³ Type 2: Custom firmware for additional external auxiliary sensor
- DATA-CUBE³ Type 2: Included electronics to adapt for a dedicated sensor signal level for an order of a larger number

Please contact us if you require special adaptations.

3. Accessories

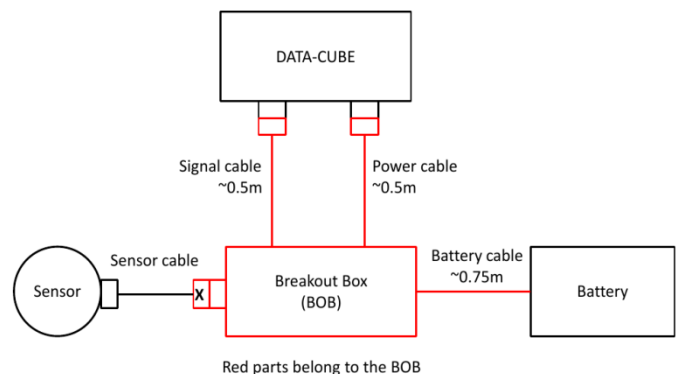
3.1. Software and Configuration

The following software tools are available and are delivered with the DATA-CUBE³ at no additional fees:

- **CubeMonitor:** Used to check the proper function of the DATA-CUBE³ and noise at the installation/deployment site (monitor cable required). Available for Windows only.
- **CubeTools:** Software package to convert recorded raw data into SEG-Y or miniSEED format. Available for Windows and Linux.
- **State-of-Health routine:** Used to retrieve live state-of-health data during the measurement (GPS information, state of battery, etc.).
- **Example configuration file:** Used as a template to create a custom configuration of the DATA-CUBE³ recorder according to the requirements of the experiment (see section 4 below).

3.2. Breakout Box (BOB)

A breakout box (BOB) is necessary if the DATA-CUBE³ is used together with an active sensor. The BOB powers the sensor and adjusts the voltage level of the sensor output to match the voltage input range of the DATA-CUBE³. This grants maximum flexibility and allows connecting a wide range of sensors to the DATA-CUBE³ like BB seismometers or infrasound devices.



The breakout boxes are custom-made by DiGOS according to the sensor output signal specification. Additionally, the breakout box can be manufactured with the correct connector for the sensor or a corresponding socket for an already existing sensor cable.

A low power protection can be included into the BOB if required. This is useful if the DATA-CUBE³ is powered by external batteries that must be protected from deep discharging.

Please note that Geophones that are distributed by DiGOS do not require a breakout box!

3.3. Cables

The following cables are available:

Power cable

This cable is used to feed the DATA-CUBE³ with external power (5-24V DC). The input is protected against reverse poling. Connector and pin-out are different between DATA-CUBE³ Type 1 and 2. The D-cell batteries must be removed when powering DATA-CUBE³ Type 1 by external power!

USB up-/download cable (light grey)

This cable is used to upload a new configuration file to the DATA-CUBE³ or to download recorded data from the internal storage. When connecting the DATA-CUBE³ via this cable to a computer it will appear as an external drive. It is not necessary (yet possible) to additionally power the DATA-CUBE³ when connecting this cable. The DATA-CUBE³ will receive power from the computer via USB to enable access to the internal storage.

Please note: Recording of the DATA-CUBE³ stops automatically when connecting this cable! The recording will continue automatically when the cable is disconnected again.

Monitor cable (black)

This cable is used to check the proper operation of the DATA-CUBE³ and to observe the noise level of an installation / deployment site. The necessary software CubeMonitor is delivered with the DATA-CUBE³ and runs on Windows only.

Sensor cable

A sensor cable is either delivered by the sensor manufacturer or can be ordered from DiGOS for most common sensors.

Please contact us if you require special cable modifications.

3.4. Geophones

Different types of geophones can be ordered from DiGOS:

- Available natural frequencies: 4.5Hz, 8Hz, 10Hz or 14Hz
- 1 component (vertical) or 3 components (1 vertical & 2 horizontal)
- 3m cable (or custom length)



3 component geophone

The geophones are connected to the DATA-CUBE without an additional breakout box.

3.5. Mass Data Download

A Mass Data Download package is available parallel data download from up to 6 DATA-CUBE³ units. The package comes with a powered USB 3.0 hub and Windows/Linux software. The software detects when a DATA-CUBE³ is connected to the computer and automatically starts downloading the recorded data to a pre-configured directory. It informs the user when the download of a DATA-CUBE³ is completed to connect the next unit.

3.6. Batteries & Power Supply

Standard batteries or power supplies are depending on the deployment settings/requirements. Therefore, the batteries are user obligations and are not provided by DiGOS. However, DiGOS supports and offers design, engineering and installation for more complex multi-parameter, multi-sensor stations also as turnkey solutions.

Please contact us if you want to benefit from our expertise in your campaign, experiment or project.

4. Pin-out

Please note: The following pin-out tables are describing the data sockets of the DATA-CUBE³!

10-way socket (female): signal input from sensor (type 1 and 2)

Pin	A	B	C	D	E	F	G	H	K	J
Signal	Ch1 Input+	Ch1 Input-	Ch2 Input+	Ch2 Input-	Ch3 Input+	Ch3 Input-	NC	Analogue GND	NC	NC

7-way socket (male): USB/Terminal/External Power (type 1 and 2)

Pin	A	B	C	D	E	F	G
Signal	USB + 5V	USB + D	USB - D	GND	Terminal Tx 3.3V	Terminal Rx 3.3V	Power 5-24V DC

4-way socket (male): External Power (type 2 only)

Pin	A	B	C	D
Signal	Power 5-24V DC	NC	NC	GND

Please note that the corresponding connectors (plugs) must have the opposite gender.

5. Power Budget (examples)

The power budget has been estimated based on power consumption measurements of DATA-CUBE³ type 1 at laboratory conditions and on using two “Duracell Procell MN1300” batteries with a capacity of 39.6Wh.

DATA-CUBE³ type 1, measuring all 3 channels @ 100sps

GPS Cycle F_TIME Min	GPS on GPS_TI min	GPS on duration min/h	GPS off duration min/h	Sum power mW	Runtime duration days
15	5	20	40	147	11.2
15	4	16	44	140	11.8
15	3	12	48	133	12.4
30	5	10	50	129	12.8
30	4	8	52	125	13.2
30	3	6	54	122	13.5
30	2	4	56	118	14.0
59	59	59	0	219	7.5

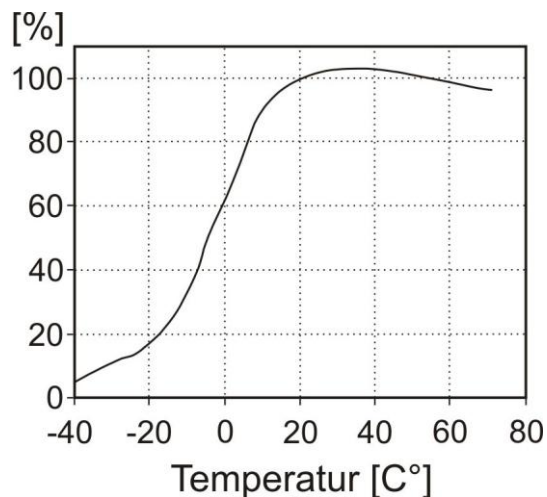
Current while GPS on: 73mA / 219mW
 Current while GPS off: 37mA / 111mW
 Battery capacity: 39.6Wh

DATA-CUBE³ type 1, measuring only 1 channel @ 100sps

GPS Cycle F_TIME Min	GPS on GPS_TI min	GPS on duration min/h	GPS off duration min/h	Sum power mW	Runtime duration days
15	5	20	40	114	14.5
15	4	16	44	107	15.4
15	3	12	48	100	16.6
30	5	10	50	96	17.2
30	4	8	52	92	17.9
30	3	6	54	89	18.6
30	2	4	56	85	19.4
59	59	59	0	186	8.9

Current while GPS on: 62mA / 186mW
 Current while GPS off: 26mA / 78mW
 Battery capacity: 39.6Wh

Please note that the real runtime in the field can vary and is strongly depend on different parameters like environmental temperature, real capacity and age of batteries. Please see the battery capacity vs. temperature diagram below to estimate the runtime of the DATA-CUBE³ Type 1



Battery capacity depending on temperature for “Duracell Procell MN1300” alkaline batteries

Additionally, the values of F_TIME and GPS_TI should not be a multiple of 60. This can lead to undefined behaviour for internal reasons.

6. Recording Times & Data Storage

The internal data storage capacity of the DATA-CUBE³ is up to 32GB. A 16GB version is available mostly for historic reasons. The following table provides an estimation of recorded raw data. It assumes a typical noise level of the measured data:

3 channels @ 100 sps	1 channel @ 800 sps
~ 1.3 kB/s	~ 3.5 kB/s
~ 78 kB/min	~ 208 kB/min
~ 4.68 MB/h	~ 12.48 MB/h
~ 112.32 MB/d	~ 300 MB/d

The maximum continuous recording time is estimated from the data above:

	3 channels			1 channel
	100 sps	200 sps	400 sps	800 sps
16 GB (historic)	142 days	71 days	35.5 days	53.3 days
32 GB	284 days	142 days	71 days	106.7 days

Please note: The real maximum continuous recording time may be less than the values above by 2-3%. The user must make sure to download the recorded data and clean the internal storage before the memory is filled up. Otherwise, the DATA-CUBE³ stops recording when the internal storage is full.

7. Counts and Voltage

The signal input range of the DATA-CUBE³ is $\pm 2.048V = 4.096V_{pp}$.
For 24 Bit ADC this equals 0.000 000 244 140 625V per count at gain 1 ($4.096V / 2e24$).

The following table shows the volts per count for different gains:

Gain	Volts per count
1	244.140625 nV
2	122.070313 nV
4	61.035156 nV
8	30.517578 nV
16 (default)	15.258789 nV
32	7.629395 nV
64	3.814697 nV

This represents the value at the input side of the DATA-CUBE.

Please note that if a BOB is used, the output of the sensor is calculated by multiplication with the denominator of the dividing ratio given at the BOB. The value of the electromagnetic constant of the seismometer must be taken into account, too, if the ground velocity is the value of interest.

8. ADC Performance

The ADC performance is given for 100sps operation mode.

	Gain 1	Gain 16	Gain 64
High Resolution SNR	125.6 dB	122.2 dB	113.5 dB
Effective Bits	22.4 Bit	21.8 Bit	20.3 Bit
Low Resolution SNR	122.6 dB	120.7 dB	113.0 dB
Effective Bits	21.9 Bit	21.5 Bit	20.2 Bit

9. Operation

9.1. Configuration

This is an example of a default configuration file. It is to be adapted for the experiment and uploaded to the DATA-CUBE³ via USB before deployment in the field. Please refer to the configuration file manual for a detailed description of the configuration file.

```

*****
*
* Configuration File for the 1 & 3 Channel DATA-CUBE
*
* Software V0.1
*****
* Syntax:
* - Lines beginning with a star '*' are comments (and are ignored)
* - Empty lines are not allowed
* - Parameter keywords are of six capitalized characters,
*   directly followed by an equal sign
* - The parameter value starts at column #8
* - Line length is limited to 70 characters *
*****
***** !!! Parameters for 3 channel Cubes only !!! *****
*****
** Active Channels 1 = ch1 // 2 = ch1 & ch2 // 3 = ch1 to ch3
CH_NUM=3
*
** Amplifier Gain 1, 2, 4, 8, 16, 32 or 64
P_AMPL=16
*
** AD Converter Mode 0 = Low power // 1 = High resolution
C_MODE=0
*
** Amplifier Chopping 0 = off // 1 = on
A_CHOP=1
*
*****
***** General parameters for 1 and 3 channel Cubes *****
*****
** Project Name Project name of max. 20 characters
E_NAME=N/A
*
** Sample Rate 50, 100, 200, 400, (800@1ch) sps
S_RATE=100
*
** Digital High Pass 0 = off // 1 = on
A_FILT=0
*
** FIR Filter 0 = Linear phase // 1 = Minimum phase

```

```
A_PHAS=0
*
** Time Base Correction 0 = off // 1 = PLL // 2 = DIFF
PLL_XO=0
*
** Geographic position lat, lon, alt; to speed up satellite search
*GPS_PO=>SIP+52+013+0000
*
** GPS Mode 0 = cycled // 1 = continuously
GPS_ON=0
*
** GPS & Flush Interval 3 to 60 minutes
* (GPS interval only in cycled mode)
F_TIME=30
*
*****
***** Parameters relevant for GPS cycled mode only *****
*****
** GPS OFF after 0 = 'GPS_TI' // 1 = 60 GPS fixes max.'GPS_TI'
GPS_OF=0
*
** GPS ON Time: 3 to 60 minutes
GPS_TI=5
*
```

9.2. Getting Started in the Lab

- Connect the DATA-CUBE³ via the light grey USB cable with a computer. The DATA-CUBE³ will appear as a USB storage device and the configuration file can be accessed. If desired edit the configuration file and change the values like sampling rate, gain, number of channels, interval of active GPS according to your requirements. A brief description can be found in the configuration file itself. Please refer to the configuration file manual for a detailed description.
- Safely remove the USB storage from your Windows computer or unmount the drive in Linux before disconnecting the USB cable.
- Insert the batteries with correct polarity (DATA-CUBE³ Type 1) or connect an external power supply (DATA-CUBE³ Type 1 or 2).
- Wait typically 3-5 minutes for reception of the GPS signal at an open sky location. When only the red and blue LEDs are blinking at 1 sec interval the DATA-CUBE³ is operating ok. After the DATA-CUBE³ has received a GPS lock once, it can acquire data without GPS signal as well (e.g. for installations inside tunnels or buildings). Only red LED is blinking when the GPS signal is lost.
Important notice: **It is mandatory that the DATA-CUBE³ receives a GPS signal after the deployment at least once before being switched off. This allows a proper resampling in the post-processing.**

9.3. Field Installation

DATA-CUBE³ Type 1

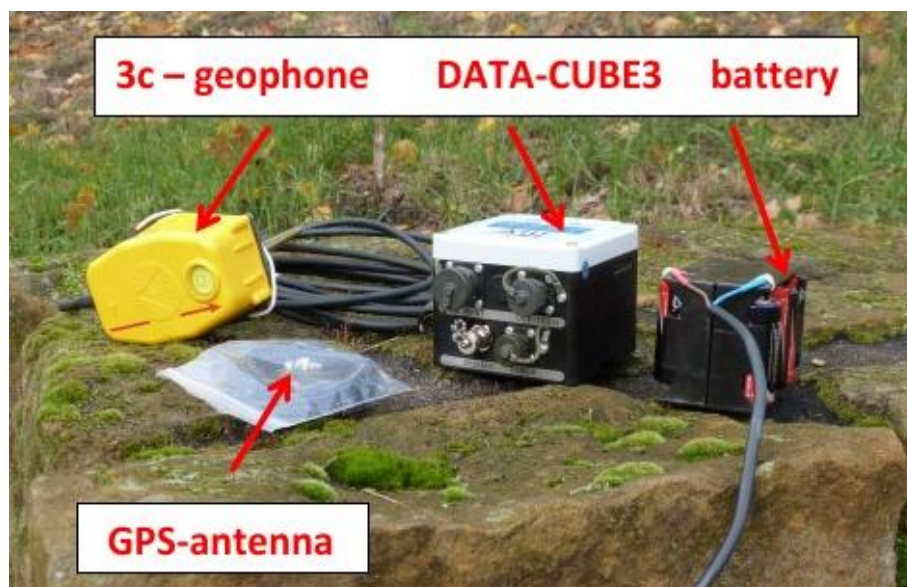
- Insert the batteries into the battery compartment and check for correct polarity!
- Connect the sensor with the upper left socket (10-way) for data recording.
- Wait typically 3-5 minutes for reception of the GPS signal at an open sky location if the coordinates in the configuration file match your location by a radius of about 300km. It might take much longer if for example the coordinates do not match the values in the configuration file. Adopting the correct GPS coordinates in the configuration file will speed up the GPS synchronization drastically.

- The DATA-CUBE³ is OK & recording when the red and the blue LEDs are blinking at 1 sec interval.
- Optionally: To check the function of the DATA-CUBE³ and to see the current noise you can connect the black 7-way cable to the upper right socket and connect it to a laptop. The DATA-CUBE³ type 1 must be powered by internal batteries during this check. The software CubeMonitor will show the live recorded data.
- If the correct operation of the DATA-CUBE³ has been verified, it should be wrapped into a plastic bag and dug into a shallow hole. Make sure that the top side is uncovered! Otherwise the built-in GPS antenna will not receive a signal.

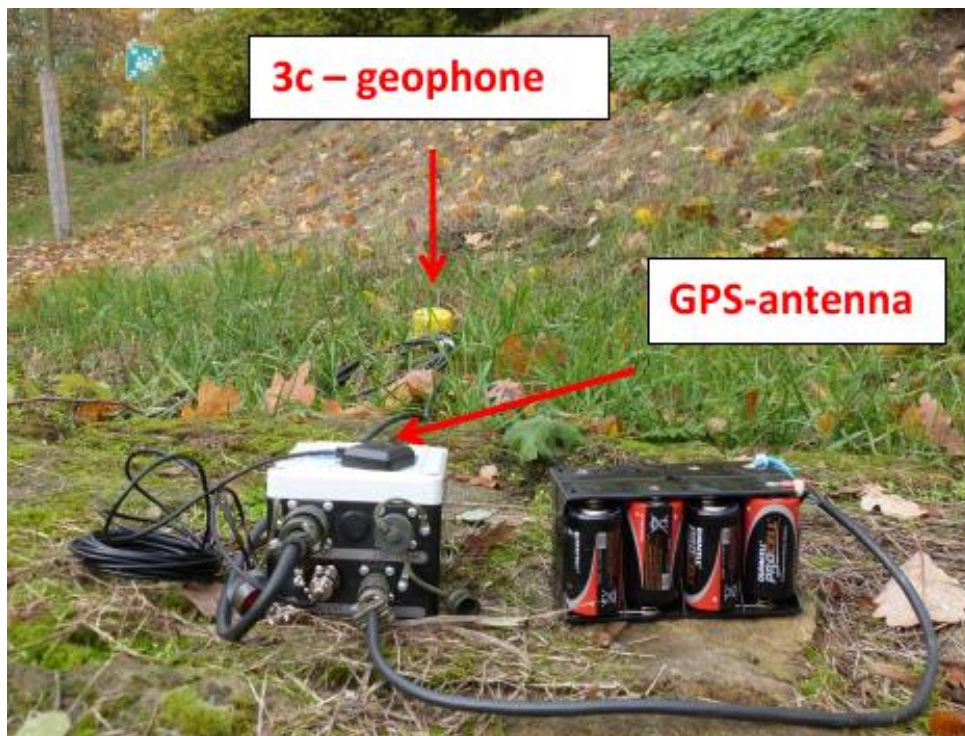
DATA-CUBE³ Type 2

- Connect the external power supply with the DATA-CUBE³ using the 4-way socket.
- Connect the external GPS antenna using the BNC socket and place it outside if the DATA-CUBE³ will be installed in a shelter, vault or building.
- Connect the sensor with the upper left socket (10-way) for data recording.
- Wait typically 3-5 minutes for reception of the GPS signal if the coordinated in the configuration file match your location by a radius of about 300km. It might take much longer if for example the coordinates do not match the values in the configuration file. Adopting the correct GPS coordinates in the configuration file will speed up the GPS synchronization drastically.
- The DATA-CUBE³ is OK & recording when the red and the blue LEDs are blinking at 1 sec interval.
- Optionally: To check the function of the DATA-CUBE³ and to see the current noise you can connect the black monitor cable and connect it to a laptop. The software CubeMonitor will show the live data which is recorded.
- In case the DATA-CUBE³ will be placed outside, it should be wrapped in a plastic bag. The external power supply (e.g. battery) must be protected as well.

Installation example:



All components for DATA-CUBE³ and Geophone installation



Connect the devices and wait until red & blue LEDs are blinking synchronously!



Wrap the DATA-CUBE³ into a plastic bag

9.4. LEDs

The LEDs indicate the status of the DATA-CUBE³.

SYS	GPS	ACQ	Status	Interpretation What to do?
ON	Blinking fast	Blinking fast	Error: Batteries are empty	→Use new batteries
OFF	OFF	Blinking fast	Error: SD card full or damaged	→Data download or don't use this DATA-CUBE ³
OFF	Blinking slow	ON	Error: No GPS reception	→Check conditions of GPS reception
OFF	Blinking fast	Blinking fast	Error: GPS problem (protocol)	→Don't use this DATA-CUBE ³
OFF	Blinking fast	OFF	Error: GPS problem (module)	→Don't use this DATA-CUBE ³
OFF	OFF	ON	Wait for GPS signal	→Wait max. 5 min & check GPS reception again
OFF	Blinking 1Hz	Blinking 1Hz	Acquisition ok, GPS ok	→OK
OFF	OFF	Blinking 1Hz	Acquisition ok, GPS lost	→OK, but uses internal clock only (no GPS)

9.5. Monitoring

The CubeMonitor software allows a live view of the sensor data for noise monitoring and verification of a DATA-CUBE³ installation. This software runs on Windows platforms only.

In order to use the CubeMonitor software the following steps are required:

1. Download the CubeMonitor software from <http://digos.eu/downloads-docs/>
2. Extract the contents of the ZIP file
3. Install the FTDI drivers. This step is required only once per computer. It might be necessary to assign a dedicated COM port to the FTDI interface on some computers. Please check the system settings.
4. Connect the DATA-CUBE³ via the Monitor cable (black) with the computer.
5. Start the CubeMonitor.exe

9.6. Data Download & Conversion

The data download from a DATA-CUBE³ to a computer very easy. Connect the DATA-CUBE³ using the (grey) USB cable with the USB interface of the computer. It will appear as a new external USB drive. Subsequently, the data from DATA-CUBE³ can be copied the computer. Please note that the recording stops as soon as the USB cable is connected!

The recorded data is stored in a simple way on the internal DATA-CUBE³ file system:

- Daily folders with the naming “YYMMDD”
- Daily file in the daily folder with the naming “MMDDHHMM.’no-of-recorder” (time value is given in UTC)

The DATA-CUBE³ records the data samples as well as time information in a raw binary format. DiGOS provides the following info & conversion software to convert this raw data into standard data formats like miniSEED, SEG-Y or ASCII:

- **cubeinfo**: Summarizes the content of a DATA-CUBE³ file recording
- **cube2mseed**: Converts DATA-CUBE³ files to miniSEED format
- **cube2seggy**: Converts DATA-CUBE³ files to SEG-Y format
- **cube2ascii**: Coverts the DATA-CUBE³ files to ASCII format

The CubeTools software package can also be used to cut out individual events like earthquakes, explosions, specific time windows from raw data. This allows the operator to save processing/conversion time and only analyse the relevant data. The resampling of measurements in case of lost GPS signal is supported by the

CubeTools. A detailed usage description of the conversion tools is included in the CubeTools software package (please see download information below).

All CubeTools software utilities are command line programs. They were programmed in Java and require an installed and working Java Runtime Environment (JRE 1.5 or newer). The software has been tested Windows and Linux.

Please make sure to download and operate the latest release of the CubeTools software package which can be downloaded from the DiGOS website at:

<http://digos.eu/downloads-docs/>

10. General Usage Information

10.1. Safety Instructions

Improper use voids the warranty and can damage or even burn the electronics of the DATA-CUBE³! Besides general recommendations of electronics usage, the user must pay attention to the following, additional usage information:

All pins are not protected against overvoltage!

Do not connect RS-232 of the DATA-CUBE³ directly to a computer!
The DATA-CUBE³ uses low voltage RS-232.

Do not open the DATA-CUBE³! It voids the warranty and can damage internal parts!

The DATA-CUBE³ Type 1 is designed to be operated with 2x Alkaline D-cells only! The DATA-CUBE³ electronics is designed for less than 3V internal battery supply only! Higher voltages will damage the DATA-CUBE³. Do not use e.g. Li batteries!

Do not connect external power supply when using DATA-CUBE³ Type 1 with internal batteries! Make sure to remove the batteries from the compartment first!

Do not specify F_TIME and GPS_TI as a multiple of 60 in the DATA-CUBE³ configuration file! Use the value 59 instead.

10.2. Additional Information

All DATA-CUBE³ recorders are thoroughly tested by DiGOS prior to shipment. The recorders have proven reliable and trouble-free operation in many deployments worldwide. However, DiGOS excludes any liability for data loss due to hardware malfunction or operation errors.

11. Technical Specifications

A/D converter

- Type: Delta-Sigma 24 Bit
- ADC resolution: 24 Bit per channel
- ADC channels: 3
- ADC dynamic range: 125db @ 100sps (128db @ 50sps)
- Effective resolution: 22.4 bit @ 100sps @ gain 1 (typical)
- ADC sample rates: 50, 100, 200 or 400sps in 3 channel mode, 800sps in 1 channel mode
- ADC gain selection: 1, 2, 4, 8, 16, 32, 64
- ADC noise level: 10 μ V/sqrt(Hz)
- Full scale input: 4.096Vpp @ gain 1
- Input impedance: 100kOhm
- Signal input voltage: Adjusted by customized breakout box according to sensor specification

Time base

- Type: GPS synchronized free running internal quartz
- GPS: GPS receiver built-in
- GPS accuracy: 1 μ s
- GPS antenna: Internal (type 1), external included with 5m antenna cable (type 2)
- Free running accuracy: <0.01ms with processing (resampling with CubeTools, see section 9.6)
<10ms for 20 days without processing

Data storage

- Storage type: SDHC memory card (internal)
- Capacity: 32GB (ca. 280 days @ 100sps)
- Recording type: Continuous recording
- Recording format: Raw (miniSEED & SEG-Y offline converter software included)

Local user interfaces

- Serial port: Monitoring, additional sensor modules on request
- USB 2.0: Configuration, setup, data download (16MB/s)
- LEDs: Indicating status of system, acquisition, GPS timing and data storage

Connectors

- Sensor: MIL-C-2684 A12-10S
- Power/Communication: MIL-C-2684 A10-07P (type 1)
- Communication: MIL-C-2684 A10-07P (type 2)
- Power: MIL-C2684 A08-04P (type 2)
- GPS antenna: BNC female (type 2)

Power supply

- Input voltage: 5-24V DC
- Battery: Internal (2x D-cell) or external via separate cable (type 1)
External via separate cable only (type 2)
- Power consumption: 120mW (rated for 100sps & GPS active 5min per 30min)

Physical

- Size: 100 x 100 x 83mm (830ml)
- Weight: 890g (type 1), 850 (type 2)
- Operating outdoor temperature: -20 – 70°C (lower temperature version available)
- Housing: Reinforced plastic
- Shock resilience: 5g (sinus)
- Waterproof: IP67 (1m water depth for 48 hours)