



**EARTH
SYSTEM**
GEOTECHNICAL SOLUTIONS



VERTEBRA

Modular Inclinator System



The VERTEBRA System



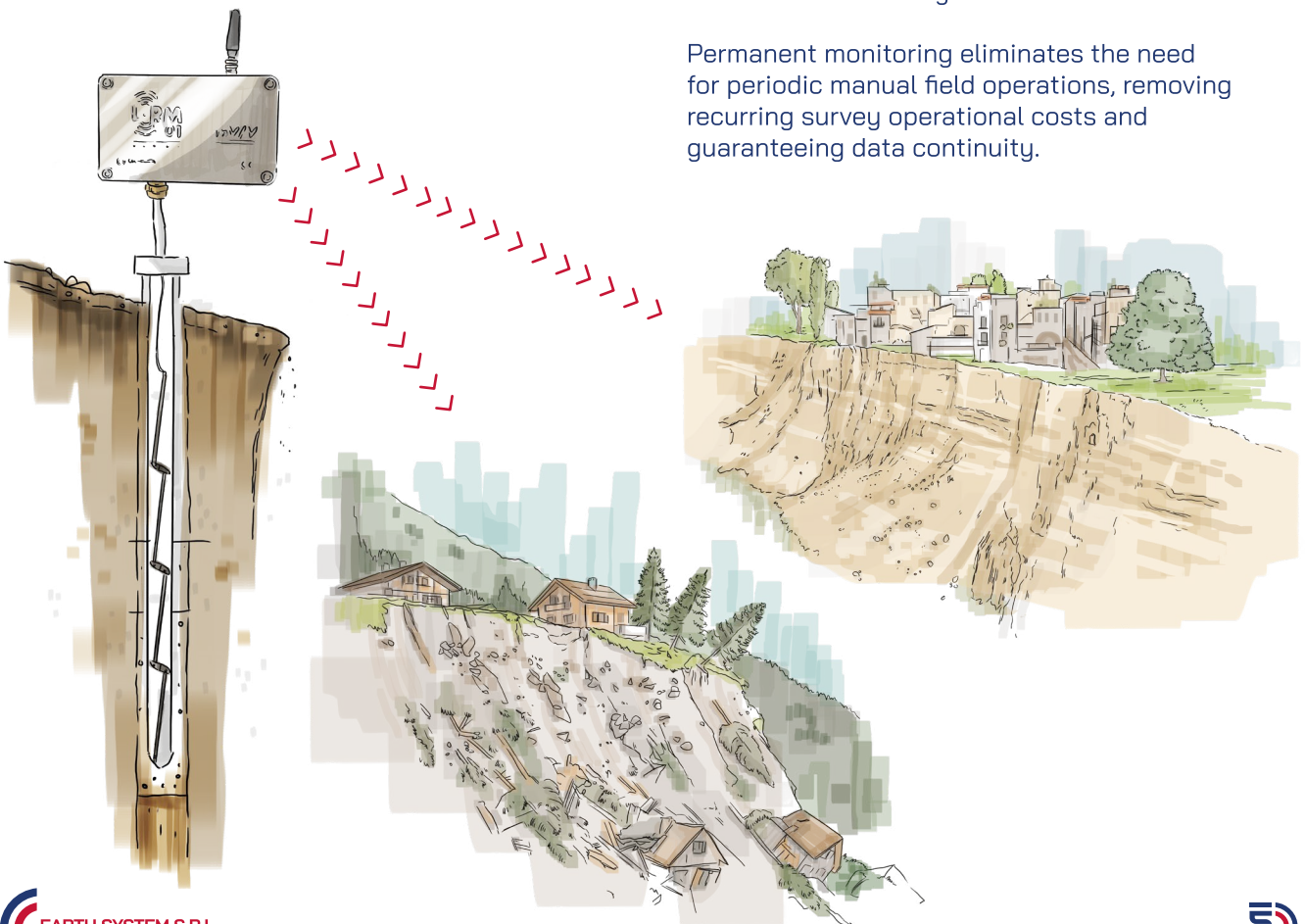
VERTEBRA is a modular inclinometer system consisting of a chain of probes equipped with MEMS sensors, designed for continuous and distributed monitoring of deformations and lateral displacements within inclinometer or piezometer casings.

The system comprises a **series of measuring nodes mechanically and electrically connected to each other**. Each node represents an independent measuring point, integrating a biaxial MEMS inclinometer sensor alongside the electronics required for data acquisition and communication.

The concatenated arrangement of the probes allows for the 3D reconstruction of the casing geometry along the entire monitored depth, **detecting any changes in tilt and deformation**.

Furthermore, analyzing the sequence of measurement points makes it possible to locate the exact depth of moving zones and track their evolution over time. Compared to traditional inclinometer systems—where measurements are typically performed using a movable probe—VERTEBRA enables **permanent, distributed monitoring** while maintaining all measuring points online simultaneously.

Permanent monitoring eliminates the need for periodic manual field operations, removing recurring survey operational costs and guaranteeing data continuity.

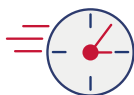


Key Strengths



TOTAL MODULARITY

- Each node is independent. The chain is assembled directly on site and can be reconfigured over time: individual elements can be added, removed, or replaced without replacing the entire system.



FAST INSTALLATION

- The 2-wire, non-polarized electrical connection using magnetic connectors eliminates wiring time and minimizes the risk of assembly errors.



LIGHTWEIGHT & STABLE

- The use of carbon fiber rods and stainless steel joints ensures high rigidity, dimensional stability, and an extremely low weight to facilitate borehole deployment.



DUAL COMMUNICATION ARCHITECTURE

- Data transmission to the acquisition unit (G802 or other compatible dataloggers) can be achieved either via a direct wired connection or wirelessly via LoRa radio for maximum operational flexibility.



CONTINUOUS & AUTOMATIC MONITORING

- Unlike periodic measurements with movable probes, VERTEBRA provides permanent, real-time tracking of the entire deformation profile.

Technical Specifications

- Measurement Technology: **High-precision 3D MEMS sensor** integrated into each node, measuring both **tilt and temperature**.
- Mechanical Structure: **Carbon fiber rods interconnected by articulated joints. Adaptable to inclinometer/piezometer casings (Ø 2"½ - 4").**
- Wiring and Power Supply: **Non-polarized 2-wire bus on magnetic connectors using Power Line Communication technology (PLC, Modbus RTU).**
- Transmission and Management: **Dedicated HW Interface connectable to Dataloggers (via cable or Wireless LoRa) and seamlessly integrable with the Geo-Atlas web platform.**

Sensor and Mechanical Specifications

Measurement range: 0–360°
Sensor type: 3D MEMS
Output signal: Angle in degrees
Resolution: 0.005 mm / 500 mm
Repeatability: ±0.002°
Non-linearity: 0.1% F.S.
Operating temperature: -40 °C to +70 °C
Temperature resolution: ±0.2 °C
Noise: 22.5 mg/vHz
Material: Carbon fiber rod, AISI 304 stainless steel joint
Weight: 130 g (500 mm gauge length including joint), 190 g (1000 mm length including joint)
Rod diameter: 20 mm

Wireless Module Specifications

Frequency bands: 863–870 MHz, 902–928 MHz, 22 dBm RF power
Communication range: As per LoRa communication guidelines
Power consumption: 7 µA (standby), 22 mA (active), 177 µA (average)
Battery type: 3.6 V lithium (non-rechargeable, replaceable)
Battery life: Up to 46,000 acquisitions
Sampling frequency: 1/59 minutes, 1/23 hours, 1/10 days
Configuration: via G802 Gateway-Datalogger

Mechanical Structure and Modularity



The inclinometer chain consists of **structural elements made of carbon fiber**, selected for their lightweight properties, high rigidity, and dimensional stability.

The individual elements are connected via articulated mechanical joints, enabling the chain to follow casing deformations without introducing excessive constraints to the relative movement of the components.

The nominal node pitch can be configured at 500 mm or 1000 mm, depending on the monitoring requirements and desired resolution.

The structure is fully modular: probes are supplied as single units and can be assembled directly in the field to reach the required length.

THIS FEATURE ALLOWS USERS TO:

- **Configure the number of nodes based on the target monitoring depth;**
- **Modify the total length of the chain;**
- **Add or remove individual elements;**
- **Replace a single node without replacing the whole chain;**
- **Adapt the system to different installation configurations.**

Each node has a low mass (on the order of a few hundred grams), allowing long chains to be assembled while keeping the total weight minimal. The structure can be adapted to casings with an internal diameter typically between 2"½ and 4".



Sensors and Operating Principle



Every VERTEBRA node integrates a **biaxial MEMS inclinometer sensor capable** of detecting tilt variations along two orthogonal axes.

When the surrounding ground or structure undergoes deformation, the inclinometer casing locally changes its geometry. The individual elements of the chain follow this deformation and adjust their orientation accordingly.

Tilt measurements from each node, combined with their corresponding depth, are used to reconstruct the deformation profile of the entire casing.

THE SYSTEM ALLOWS USERS TO DETERMINE AND MONITOR:

- 1** Depth-dependent tilt variations;
- 2** Lateral displacements;
- 3** Localized deformations;
- 4** Depth and development of movement zones;
- 5** Time evolution of deformations;
- 6** Movement trends and rates.

The high density of measurement points distributed along the vertical axis provides a **detailed representation of deformation**, making the system especially suitable for monitoring progressive phenomena such as landslides, structural deformations, excavations, embankments, and other geotechnical applications.



Electrical Connection and Communication



One of the key features of VERTEBRA is its **complete modularity** from an electrical standpoint.

Inter-node connection is achieved via a non-polarized **2-wire cable**—used simultaneously for both power supply and data transmission—using magnetic connectors.

The absence of polarity simplifies assembly and significantly reduces the risk of field installation errors.

Furthermore, the connector solution is engineered to operate in **wet and high-humidity** environments, typical of underground casing installations.

The system features **auto-configuration** capabilities, automatically detecting active nodes along the chain and managing system setup seamlessly.



Hardware Interface and Acquisition



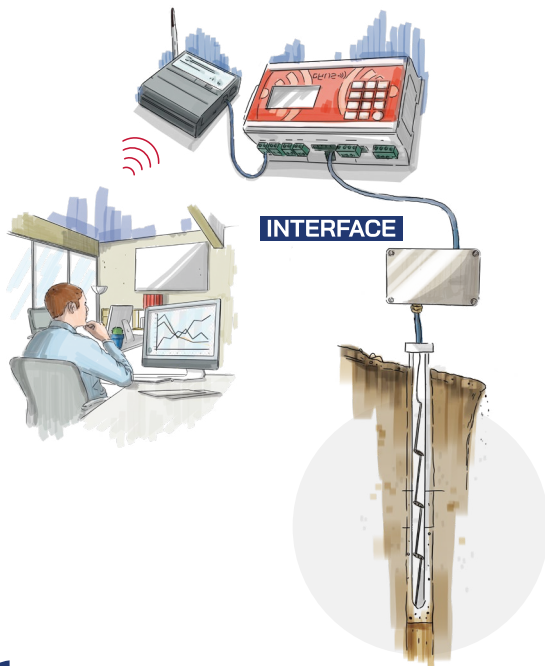
The VERTEBRA inclinometer chain is acquired through a dedicated **Hardware (HW) Interface**, acting as the bridge between the sensor chain and the data acquisition/transmission system.

The HW Interface manages node communication, measurement acquisition, and data transfer to the management unit.

THE CONNECTION BETWEEN THE VERTEBRA CHAIN INTERFACE AND THE DATALOGGER CAN BE ESTABLISHED IN TWO MODES:

— Wired Connection

Communication is established via a physical cable connection—an ideal solution when the acquisition unit is installed close to the inclinometer chain or when physical wiring is available.

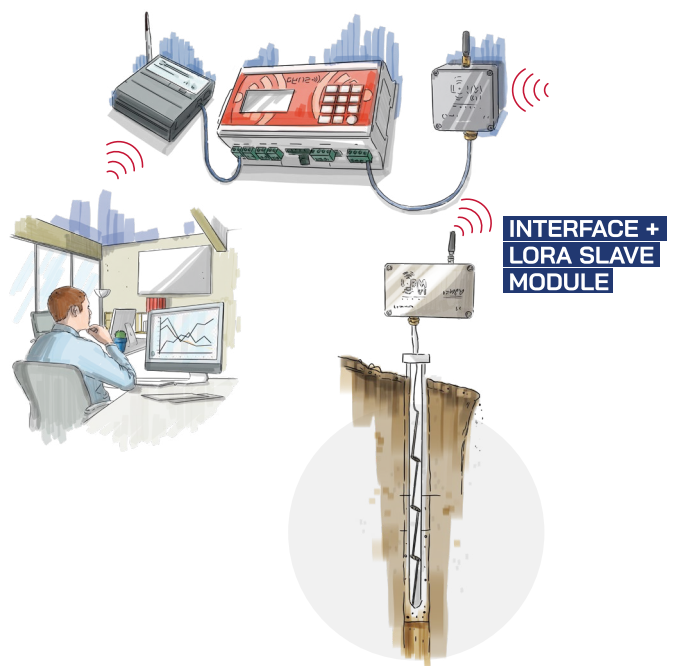


— LoRa Wireless Connection

Communication can also be established via LoRa radio link, physically decoupling the inclinometer chain from the datalogger and simplifying installation where cable runs are impractical.

This setup makes VERTEBRA easily integrable into various monitoring architectures, keeping the measurement function separate from data acquisition, transmission, and management functions.

The modular architecture thus allows the same inclinometer chain to be used across different acquisition systems according to specific site requirements.



Freedom in Data Management



The architecture of VERTEBRA has been designed to **keep the measurement acquisition function independent** from subsequent data processing and visualization.

The recommended platform for data management, archiving, processing, and visualization named **Geo-Atlas** is a dedicated web platform for monitoring systems featuring time-series management, threshold alerts, alarm notifications, and dynamic visual representations.

However, using Geo-Atlas is optional: data acquired by the VERTEBRA system can be exported and made available for processing, management, and visualization using **third-party or client-owned software platforms**.

This approach guarantees full separation between the physical measurement system and the management software platform, granting clients complete flexibility in selecting their supervision and analysis ecosystem.





via Artigianato, 5/A
43022 Montechiarugolo (PR) - Italia

t. +39 0521 394595

e. info@earthsystem.it

