This product should be installed and operated only by qualified personnel. Its misuse is potentially dangerous. The Company makes no warranty as to the information furnished in this manual and assumes no liability for damages resulting from the installation or use of this product. The information herein is subject to change without notification.
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1- INTRODUCTION

Introduction

The GEOSTRING system consists of a vertically installed casing and a string of GEOSTRING in-place inclinometer MEMS sensors. The casing provides access for the subsurface measurements and moves with the surrounding ground. The casing is installed in a borehole that passes through a suspected zone of movement into stable ground below. The GEOSTRING sensors are installed in the casing and measure inclination from vertical. As ground movement occurs, the casing moves with it, changing the inclination of the sensors inside the casing.

The inclination measurements are then processed to provide displacement readings in millimeters or inches. In most applications, the sensors are connected to a data acquisition system and data processing is completed by a computer program.

System Components

Casing
- 70mm (2.75 in) ABS Inclinometer Casing, or
- 38mm (1.5 in) Schedule 40 PVC Pipe
<table>
<thead>
<tr>
<th>Description</th>
<th>Length (m)</th>
<th>Length (ft)</th>
<th>Inclinometer Casing System 70 mm (2.75 in)</th>
<th>Schedule 40 PVC Pipe System 38 mm (1.5 in)</th>
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<tr>
<td><strong>GEOSTRING Standard Segment</strong></td>
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<td><strong>GEOSTRING Custom Segments</strong></td>
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<td><strong>GEOSTRING Dummy Segments</strong></td>
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<td><strong>GEOSTRING Required Accessories</strong></td>
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<td>Suspension Kit, GEOSTRING</td>
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<td>Jumper Cable, GEOSTRING to Logger</td>
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<td><strong>GEOSTRING Replacement Accessories</strong></td>
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<tr>
<td>Replacement Centralizer</td>
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<td>GEOSTRING Clevis Pin with Head</td>
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</tbody>
</table>
Advantages

**Real Time Monitoring:**
The GEOSTRING system is ideal for continuous, unattended monitoring and can deliver readings in near-real time.

**Convenient Shipping and Transport:**
GEOSTRING systems have joints capable of bending to 90°, allowing for a compact shipping option. Five segments, each 3.048 meters (10 feet) long, can be shipped in a carton measuring approximately 64 x 64 x 64 cm (26 x 26 x 26 in) and which weighs less than 22 kilograms (50 pounds). This allows for the system to be shipped via common overnight carrier as well as fit in most standard vehicles.

![Figure 1: GEOSTRING segment folded for transport](image)

**Flexible Configurations:**
GEOSTRING systems have standard segment length of 3.048 m (10 ft) but can be custom ordered in lengths of 0.609, 1.219, 1.828 & 2.438 meters (2, 4, 6 & 8 feet) in order to instrument the precise length required. The GEOSTRING system can also be installed with sensorless nodes at the top of the system, allowing the designer to economize by only monitoring the zone of interest and bypassing the upper layers.

**Durable & Redeployable Components:**
Nodes, cables, connectors and gage rods are exceptionally durable, making it practical to remove the systems at the end of the project and redeploy them on other projects.

**Data Reduction:**
The GEOSTRING system outputs the displacement as engineering units, requiring less computing power and a lighter load on your data acquisition system. The nodes are preloaded with the calibration information, allowing the segments to be installed in any order.
2- INSTALLATION

Preparation
Verify that all system components have been received and are ready for installation.

Suspension Kit: One suspension kit is used for each string.

![Figure 2: GEOSTRING suspension kit for PVC pipe](image)

GEOSTRING segments or strings

Standard Configuration: Each standard GEOSTRING segment is either 3 m or 10 ft in length and has a male connector at the upper end and a female connector at the lower end. The segment consists of 5 nodes and each node has a 0.6 m or 2 ft gage length. The upper end can also be identified by its lack of joint on the node. The lower end has a universal joint, as can be seen in the images below.

Custom Configuration: GEOSTRING systems can be ordered with custom length string for long-term monitoring projects. The custom system has one male connector at the upper end and no female connectors. Please note that custom length systems cannot be reconfigured once they are manufactured and therefore are not eligible to be returned for credit.
**GEOSTRING Jumper Cable:** One jumper cable is used for each string. The jumper cable has a female connector on one end and exposed inner conductor wires on the other for connection to the data logger.

**GEOSTRING Bottom Plug:** One bottom plug is used for each standard configuration string. The bottom plug has a male connector on one end and is used to protect the last node from water ingress via the connector.
Installation

Attach the Bottom Plug to the female connector on the first segment to be placed in the casing.

Insert the bottom end of the first segment into the casing.

If inclinometer casing is being used, verify that the centralizer standoffs are placed in the grooves orthogonal to the direction of movement. The X-axis direction is marked on the sensor and should point towards the direction of anticipated movement.

If PVC pipe is being used, roughly align the X-axis direction marking on the sensor with the direction of anticipated movement. Adjustments may be made once the entire string has been installed.

Continue to lower the segment into the casing until four nodes have been inserted. Fold the fifth node over the top edge of the casing. For deeper installations, a clamp (e.g. vise grips) may be attached to the upper node to protect it from accidentally dropping into the casing.

While lowering the nodes, the signal cable should be placed in the notch of the centralizer to avoid pinching it between the segment and the casing.

Connect the signal cables of the installed segment and the next segment to be installed. Note - it does not matter in which order the segments are installed, as the data logger will query the sensors and number them at start-up.

Remove the pin from the universal joint of the installed segment and insert the top node’s gage rod, pinning it in place. Verify that the alignment of the sensors is the same for both segments.

Lower the nodes into the casing, repeating the above steps until all but one segment has been installed in the casing.

Attach the suspension kit to the top of the last segment.

Connect the last segment to the installed segments, as per above.

Lower the last segment into the casing, aligning the suspension kit so that it is firmly seated on the top of the casing. The male connector should extend out of the casing.

Attach the jumper cable to the male connector and to the data logger.
### 3- DATA REDUCTION/DATA FORMAT

#### Data Format

1. The Campbell Data Logger outputs a *.dat file. This file contains the readings in a comma-separated format, which can be imported into a spreadsheet program, such as Microsoft Excel™.

2. Once imported, the data will appear as below:

![Data Format Table]

3. The columns consist of the following:

   a. TIMESTAMP - date and time the reading was taken.
   b. RECORD - consecutive reading that was taken since last data logger reboot.
   c. Batt_volt - voltage of data logger battery at time of reading.
   d. PTemp - temperature measured at the data logger.
   e. $X_{(n)}$ - X-axis tilt reading, in mm/m
   f. $Y_{(n)}$ - Y-axis tilt reading, in mm/m
   g. Volt(n) - voltage input to the sensor, in V
   h. Temp(n) - temperature measured by sensor node, in °C

   where $n = $ sensor node location (1 is the top sensor, 2 is second from the top, etc.)
Calculations

Calculating Tilt in mm/m

It is not necessary to calculate tilt, as the GEOSTRING system outputs the tilt in mm/m natively. The sign of the result indicates the direction of the tilt. The X+ direction of the sensor node is marked on every node.

Calculating Tilt in Degrees

$Tilt(degrees) = \arcsin\left(\frac{Tilt_{mm/m}}{1000}\right)$

Calculating Deviation

To calculate deviation over the gauge length of the sensor node, use one of the formulas below:

$Deviation_{mm} = Tilt_{mm/m} \times 0.6m$

or

$Deviation_{in} = Tilt_{mm/m} \times \left(\frac{24 \text{ in}}{1000 \text{ in}}\right)$

Calculating Displacement

Displacement (movement) is the change in deviation:

$Displacement = Deviation_{current} - Deviation_{initial}$
4- CONNECTION TO DATA LOGGERS

Overview

These instructions provide information needed for reading the GEOSTRING system with the Campbell Scientific CR300, CR800, CR1000, CR1000X or CR6 data loggers. Please note that the diagrams presented on the following page are examples and do not cover every potential connection type. A wiring diagram will be provided with each data logger system that is purchased.

Limitations

The last sensor node in the chain must receive 8 volts. This limits the number of sensor nodes that can be connected based on the distance of the chain from the data logger.

<table>
<thead>
<tr>
<th>Number of Nodes</th>
<th>Jumper Length, m (12V supply)</th>
<th>Jumper Length, m (24V supply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>320</td>
<td>-</td>
</tr>
<tr>
<td>25</td>
<td>122</td>
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<td>150</td>
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<tr>
<td>200</td>
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