



güralp

VERY BROADBAND

**BOREHOLE**

SYSTEMS

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# Flexible design

## To ensure you achieve seismic measurement at depth

Borehole installations offer excellent performance for low-noise detection of weak seismic signals such as from local microseismic events or from regional/ teleseismic earthquakes.

We offer a range of options to assist you in achieving measurement at depth, allowing you to get closer to the seismic event and improve the accuracy of sub-surface velocities and event depths.

Our 'very broadband' borehole (VBB) system can house a weak-motion seismometer, a strong motion accelerometer, or a combination of the two.

If the borehole deviates from the vertical path we recommend our Radian system which can be installed at any angle.

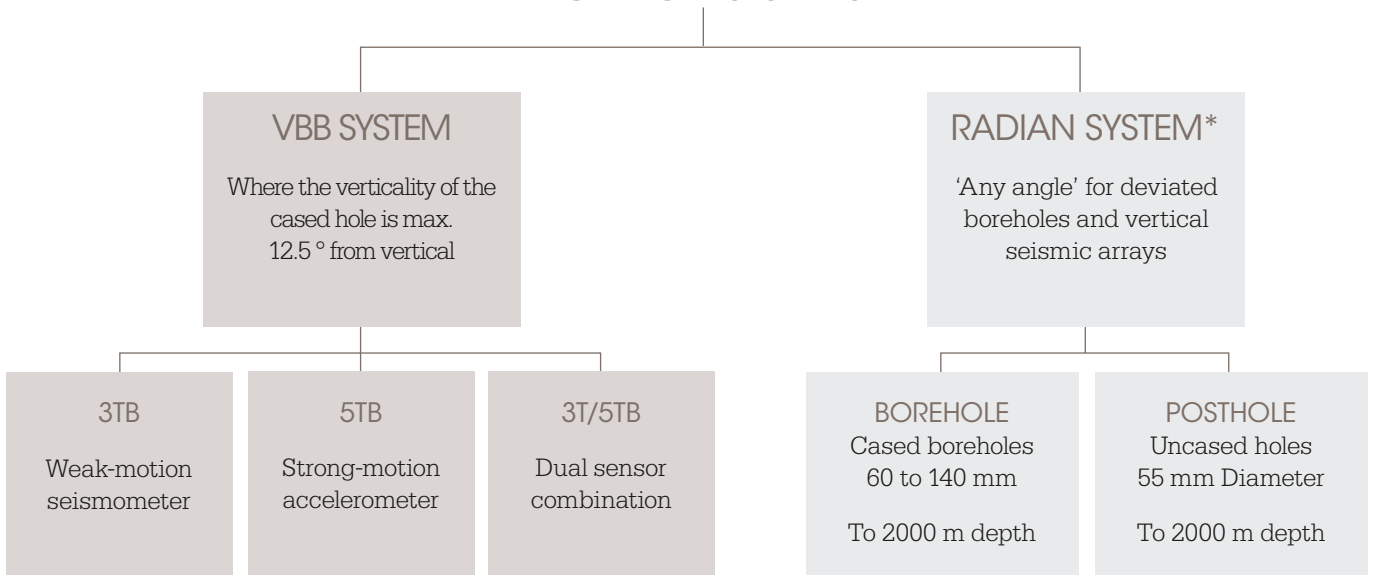
The Radian can also be strung together for vertical seismic profiling (VSP). Please see our separate Radian datasheets for more on this solution.

Through experience, we have learnt that there is a high level of complexity in successfully designing and installing borehole systems. For this reason, we strongly recommend that one of our field engineers is involved in installing Güralp borehole instruments, particularly for a first installation.

If you are considering procuring a borehole instrument we recommend an early discussion with us to explore the full range of available options.



### BOREHOLE SYSTEMS



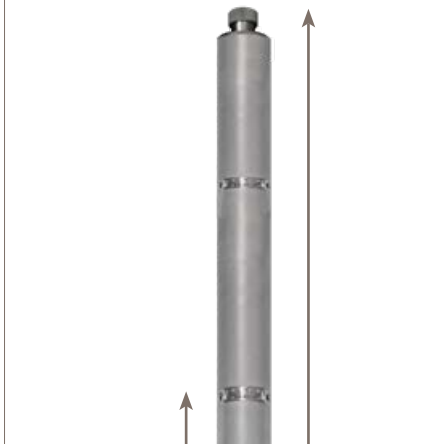


Suitable for a borehole casing diameter of 99 - 203 mm. The depth that can be achieved with the VBB borehole system will depend upon the conditions of the borehole itself e.g. Temperature

\*For details on the Radian systems please see the Radian Borehole datasheet (DAS-RAD-0002) and the Radian Posthole datasheet (DAS-RAD-0001)

# VBB BOREHOLE SENSORS

A modular design that offers a range of installation possibilities. All combinations are supplied with surge protection and a strain relief mechanism to isolate the sensors in the instrument from motions in the cable.

| 5TB   | 3TB   | 3T/5TB   |
|---|---|--|
| <p>The 5T borehole is designed for strong-motion borehole studies. It is fitted with a DC to 100 Hz accelerometer with a full scale output of 2 g as standard (other options are available).</p>  | <p>The 3TB houses our 3T sensor renowned for delivering reliable, high quality performance in long period monitoring applications. Standard response of 120 s - 50 Hz, or 360 s to 50 Hz (other options are available).</p>  | <p>The 3T/5TB combines both sensors in one instrument for simultaneous monitoring of weak seismic signals and near-field, high intensity shaking. It is particularly useful where the shaking has the potential to clip the weak-motion sensor.</p>  |
| <p>THE INSTRUMENTS ARE SHOWN WITH THE OPTIONAL SINGLE JAW HOLE-LOCK - WHICH SECURES THE INSTRUMENT IN THE BOREHOLE AT THE DESIRED DEPTH.</p>  |   |  |

## APPLICATIONS

- > Earthquake Early Warning systems
- > Strong motion seismic hazard modelling
- > Studies of ground amplification / attenuation
- > Structural health monitoring

## APPLICATIONS

- > National observatories
- > Microseismic monitoring
- > Robust velocity subsurface modelling
- > Teleseismic earthquake monitoring
- > Nuclear test ban treaty monitoring

## APPLICATIONS

- > Earthquake Early Warning systems
- > Strong motion monitoring and modelling

# BOREHOLE SYSTEM OVERVIEW

## No two boreholes are the same

Fortunately, the flexibility of the VBB borehole system means instruments can be installed in boreholes with a diameter ranging between 99 mm and 203 mm.

In most cases, an optional single-jaw hole-lock will be used to secure the instrument in the borehole at the required depth. An improved skid design guarantees the stability of the instrument in the casing.

There is also the option, where the conditions are appropriate, to install the instrument using sand backfill. In these instances, the hole-lock module can be eliminated from the design, reducing the length of the system.

As standard, the instruments are supplied with surge protection and a strain relief mechanism that isolates the sensors in the instrument from motions in the cable.

## Deeper deployments with data integrity

For deployments exceeding 100 metres in depth, we recommend the Downhole Minimus digitiser. Digitizing the data at source ensures that the origin can be definitively traced and not subject to attenuation during the travel to the surface; so signals are stronger and more reliable.

The Downhole Minimus, which integrates into the instrument to form a single unit, is an eight channel digitiser. It is connected via fibre optic cable to a surface interface unit which delivers advanced data processing capability and software communications, as well as allowing the user to access waveforms and state-of-health data at the installation location.

## Ancillary equipment

We can provide tripods, winches and other equipment designed specifically for borehole installations. We strongly recommend that one of our field engineers is involved in installing Güralp borehole instruments, particularly for a first installation.

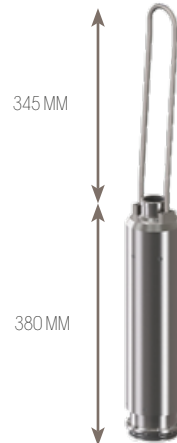
## Design complexities

Due to the level of complexity in designing a successful borehole system, we have created a 'borehole questionnaire' designed to guide you through the key questions that our engineers will need to consider when designing a suitable system for your project.

You can view the questionnaire online here: [www.guralp.com/borehole-questionnaire](http://www.guralp.com/borehole-questionnaire)

### DOWNHOLE MINIMUS

FOR DEPLOYMENTS EXCEEDING 100 METRES, WE RECOMMEND THE INTEGRATION OF A DOWNHOLE MINIMUS DIGITISER MODULE



THE DOWNHOLE MINIMUS CONNECTS TO THE TOP OF THE BOREHOLE INSTRUMENT TO FORM A SINGLE UNIT

A SURFACE INTERFACE UNIT CONNECTS TO THE DOWNHOLE MINIMUS VIA A FIBRE-OPTIC CABLE AND DELIVERS ADVANCED DATA-PROCESSING CAPABILITY AND SOFTWARE COMMUNICATIONS



# 5T Borehole



The 5T Borehole (5TB) accelerometer is designed for capturing strong motion and high intensity shaking.

## KEY FEATURES

Flat acceleration output from DC to 100 Hz (200 Hz option)

In addition to the borehole instrument with single jaw hole-lock, there is a 76 mm diameter option suitable for posthole installation with sand backfill to minimise convection

Waterproof and durable with O-ring seals throughout

Dual output (high and low gain) and optional high/low pass filters

Optional electronic compass module to determine downhole attitude

Remote DC offset zeroing

Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable



5TB WITH SINGLE JAW HOLE-LOCK AND LIFTING BAIL

## APPLICATIONS

- > Earthquake Early Warning systems
- > Strong motion seismic hazard modelling
- > Studies of ground amplification / attenuation
- > Structural health monitoring

## SPECIFICATIONS

| SYSTEM                         |   |
|--------------------------------|---|
| Configuration / Topology       | Triaxial orthogonal (ZNE)   |
| PERFORMANCE                    |   |
| Acceleration output band       | DC to 100 Hz.<br>Options of DC to 200 Hz  |
| Output sensitivity             | 2 g standard, other solutions available   |
| Peak / Full scale output       | Differential: $\pm 20$ V (40 V peak-to-peak)  |
| Sensor Dynamic Range           | 156 dB  |
| Self-noise                     | Below NHNM > 0.08 Hz (12.5 s)   |
| Cross axis rejection           | > 0.001 g/g   |
| Linearity                      | > 77 dB vertical; > 66 dB horizontal  |
| Lowest spurious resonance      | > 400 Hz  |
| Offset zeroing                 | Via remote control  |
| Transfer function              | User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros |
| Calibration controls           | Independent signal & enable lines exposed on sensor connector   |
| POWER                          |   |
| Power voltage range            | 10 - 36 V DC*   |
| Power consumption (at 12 V DC) | 0.4 W   |

\*Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.

| ENVIRONMENTAL   |   |
|---|---|
| Operating temperature   | -20 to +70 °C   |
| PHYSICAL  |   |
| Diameter  | 76 mm (for installation without hole-lock)<br>89 mm (for installation with hole-lock) |
| Inner borehole diameter for installation with hole-locks  | 99 mm to 203 mm   |
| Case height excl. lifting bail  | 240 mm without hole-lock<br>725 mm with hole-lock                                     |
| Enclosure/Materials   | Stainless steel case<br>Gold plated contacts<br>O-ring seals throughout               |
| Borehole install depth  | to 250 m (other options available)  |
| Hole-lock install mechanism   | Spring-loaded single jaw with passive skids or studs (>60 kg force)                   |
| For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003 |   |

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DAS-BHO-0005 Issue J

# 3T Borehole



The 3T Borehole (3TB) offers reliable, high quality performance in long period monitoring applications.

## KEY FEATURES

|   |   |
|---|---|
| Covers the complete seismic spectrum with a single transfer function  | Waterproof and durable with O-ring seals throughout   |
| 120 s to 50 Hz or 360 s to 50 Hz, other bespoke options available on request                                    | Built-in inclinometer option for attitude checking at depth                                   |
| Hybrid velocity-acceleration responses available offering unrivalled dynamic range.                             | Operates with a tilt tolerance of up to 2.5 ° with an option to increase this to 12.5 °       |
| Single-jaw hole lock for inner borehole diameters of 99 to 203 mm, or backfill with sand to minimise convection | Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable |

## APPLICATIONS

- > National observatories
- > Microseismic monitoring
- > Robust velocity subsurface modelling
- > Teleseismic earthquake monitoring
- > Nuclear test ban treaty monitoring



3TB WITH SINGLE JAW HOLE-LOCK

## SPECIFICATIONS

| SYSTEM                    |   |
|---------------------------|---|
| Configuration / Topology  | Triaxial orthogonal (ZNE)   |
| PERFORMANCE               |   |
| Velocity output band      | 3T-120: 120s (0.0083 Hz) to 50 Hz<br>3T-360: 360 s (0.0028 Hz) to 50 Hz<br><br>Contact Güralp to discuss other frequency response options   |
| Output sensitivity        | 1500 V/ms <sup>-1</sup> (2 x 750 V/ms <sup>-1</sup> ) differential standard output (full-scale clip level of 13 mm/s)<br><br>Contact Güralp to discuss alternative high sensitivity (high gain) options |
| Peak / Full scale output  | Differential: ±20 V (40 V peak-to-peak)<br><br>Single-ended (e.g. mass positions): ±10 V (20 V peak-to-peak)  |
| Sensor Dynamic Range      | 167 dB at 1 Hz (Full octave width across 1 Hz)  |
| Self-noise                | 3T-120: Below NLNM 166 s (0.006 Hz) to 10 Hz<br>3T-360: Below NLNM 200 s (0.005 Hz) to 10 Hz  |
| Cross axis rejection      | 65 dB   |
| Linearity                 | > 111 dB  |
| Lowest spurious resonance | > 140 Hz  |
| Transfer function         | User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros |
| Calibration controls      | Independent signal & enable lines exposed on sensor connector   |
| Operational tilt          | Up to 2.5 ° (option to increase this to 12.5 °)   |

| MASS / MONITORING CONTROL   |   |
|---|---|
| Locking   | Remote auto mass lock/unlock  |
| Mass centre   | Remote automatic mass centreing   |
| POWER   |   |
| Power voltage range   | 11– 30 V DC* (24 V DC recommended)  |
| Power consumption (at 12 V DC)  | 1.1 W   |
| <i>*Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.</i>       |   |
| ENVIRONMENTAL   |   |
| Operating temperature   | -20 to +75 °C   |
| PHYSICAL  |   |
| Instrument diameter   | 89 mm   |
| Inner borehole diameter   | 99 mm to 203 mm   |
| Case height (exc. lifting bail)   | 795 mm without hole-lock<br>1280 mm with single jaw hole-lock             |
| Enclosure/Materials   | Stainless steel casing<br>Gold plated contacts<br>O-ring seals throughout |
| Communication / Connectors  | 100 bar/10 MPa waterproof connector                                       |
| Hole-lock install mechanism   | Spring-loaded single jaw with passive skirts or studs (>60 kg force)      |
| For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003 |   |

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DAS-BHO-0001 Issue Q

# 3T/5T Borehole



The 3T/5T Borehole (3T/5TB) seismometer offers exceptional dynamic range achieved with this dual sensor 3T/5T instrument, designed specifically for borehole applications.

## KEY FEATURES

|   |  |
|---|--|
| Total realised dynamic range of over 200 dB with exceptionally low noise floor                                  | Built-in inclinometer option for attitude checking at depth  |
| Single-jaw hole lock for inner borehole diameters of 99 to 203 mm, or backfill with sand to minimise convection | Hole-lock units with cable pass-through available, allowing installation in boreholes already containing an instrument |
| Operates with a tilt tolerance of up to 2.5 ° with an option to increase this to 12.5 °                         | Strain relief mechanism fully isolates the sensors from any motions in the load-bearing cable                          |
| Waterproof and durable with O-ring seals throughout   |  |

## APPLICATIONS

- > Earthquake Early Warning systems
- > Strong motion monitoring and modelling

## SPECIFICATIONS

| SYSTEM                        |  |
|-------------------------------|--|
| Configuration / Topology      | Two sensors, each with triaxial, orthogonal (ZNE) components   |
| PERFORMANCE                   |  |
| Velocity output band (3T)     | 120s (0.0083 Hz) to 50 Hz or 360 s (0.0028 Hz) to 50 Hz<br>Contact Güralp to discuss other frequency response options  |
| Acceleration output band (5T) | DC to 100 Hz.<br>Option of DC to 200 Hz  |
| Output sensitivity            | 3T sensor: 1500 V/ms <sup>-1</sup> (2 x 750 V/ms <sup>-1</sup> ) differential standard output (full-scale clip level of 13 mm/s) 2 g standard, other options available<br>5T sensor:<br>Contact Güralp to discuss alternative high sensitivity (high gain) options |
| Peak / Full scale output      | Differential: ±20 V (40 V peak-to-peak)<br>Single-ended (e.g. mass positions): ±10 V (20 V peak-to-peak)   |
| Sensor Dynamic Range          | 3T sensor: 167 dB at 1 Hz (Full octave width across 1 Hz)<br>5T sensor: > 156 dB   |
| Self-noise                    | 3T-120 sensor: Below NLNM 166 s (0.006 Hz) to 10 Hz<br>3T-360 Sensor: Below NLNM 200 s (0.005 Hz) to 10 Hz<br>5T sensor: Below NHHM > 0.08 Hz (12.5 s)   |
| Cross axis rejection          | 3T sensor: 65 dB<br>5T sensor: > 0.001 g/g   |
| Linearity                     | 3T sensor: > 111 dB<br>5T sensor: > 77 dB vertical; > 66 dB horizontal   |
| Lowest spurious resonance     | 3T sensor: > 140 Hz<br>5T sensor: > 400 Hz   |
| Offset zeroing (5T)           | Via remote control   |
| Transfer function             | User manual is available to download from the website. Each sensor is provided with full calibration details including measured sensitivity, measured frequency response and instrument poles and zeros  |

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3T/5TB WITH SINGLE JAW HOLE-LOCK

| Calibration controls  | Remote calibration on both 3T and 5T sensors                            |
|---|---|
| Operational tilt  | Up to 2.5 ° (option to increase this to 12.5 °)                         |
| MASS / MONITORING CONTROL   |   |
| Locking (3T)  | Remote auto mass lock/unlock  |
| Mass centre (3T)  | Remote automatic mass centring  |
| POWER   |   |
| Power voltage range   | 11– 30 V DC* (24 V DC recommended)                                      |
| Power consumption (at 12 V DC)  | 2.0 W   |
| <i>*Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.</i>       |   |
| ENVIRONMENTAL   |   |
| Operating temperature   | -20 to +70 °C   |
| PHYSICAL  |   |
| Instrument diameter   | 89 mm   |
| Inner borehole diameter   | 99 mm to 203 mm   |
| Case height (exc. lifting bail)   | 1075 mm without hole-lock<br>1560 mm with single-jaw hole lock          |
| Enclosure/Materials   | Stainless steel case<br>Gold plated contacts<br>O-ring seals throughout |
| Communication / Connectors  | 100 bar/10 MPa waterproof connector                                     |
| Hole-lock install mechanism   | Spring-loaded single jaw with passive skids or studs (>60 kg force)     |
| For deployments exceeding 100 metres in depth, we recommend the integrated Downhole Minimus digitiser. For more information see the Borehole brochure or datasheet DAS-MIN-0003 |   |

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DAS-BHO-0006 Issue J

# Downhole Minimus



A downhole digitiser that converts the data at source for stronger and more reliable signals. Suitable for all borehole applications and strongly recommended for installations exceeding 100 metres depth.



DOWNHOLE MINIMUS

## SPECIFICATIONS

| SENSOR INPUTS                   |   |
|---------------------------------|---|
| Primary digitisation channels   | Eight at 24 bits<br>Differential input: 40 V peak-to-peak ( $\pm 20$ V).<br>Also compatible with single-ended inputs: 20 V peak-to-peak ( $\pm 10$ V)   |
| Secondary channels              | Six analogue channels for sensor mass positions,<br>two internal calibration channels   |
| Internal environmental channels | Humidity<br>Temperature<br>Supply voltage<br>MEMS accelerometer (three component)<br>Magnetometer (three component)   |
| Input impedance                 | 50 k $\Omega$   |
| PERFORMANCE                     |   |
| ADC converter type              | Delta-sigma   |
| ADC conversion delay            | 6 $\mu$ s   |
| Output format                   | 32-bit  |
| Dynamic Range                   | >142 dB at 100 samples per second   |
| Gain drift                      | 3 ppm / $^{\circ}$ C  |
| Common-mode rejection           | >110 dB   |
| DATA PROCESSING                 |   |
| Output rates available          | 1 sample per hour up to 5000 samples per second for primary channels, user-selectable<br><br>Multiple independent data streams at different sample rates for all channels (transmission and recording)<br><br>Up to 500 samples per second for environmental channels |
| Decimation filters              | $\pm 2, \pm 3, \pm 4, \pm 5$ decimation (Causal / Acausal)  |
| Out-of-band rejection           | >194 dB   |
| Data transmission mode          | Continuous and trigger modes  |
| Triggered data                  | Retrievable using event table in digitiser's web page. User selectable pre and post event time.   |
| Trigger modes                   | STA/LTA, Threshold  |
| Output streams                  | Direct output of PGA, PGV and PGD without external software   |
| Selectable gain                 | Unity, $\times 2, \times 4, \times 8, \times 12, \times 64$   |
| TIMING AND CALIBRATION          |   |
| Timing source precision         | Accuracy when GNSS locked $\pm 50$ ns. Typical drift when unsynchronised (without GNSS) <1 ms per day   |
| Timing source at the surface    | Stratum 1: GNSS (GPS and GLONASS, BeiDou optional), PTP (Precision Time Protocol)   |
| Calibration signal generator    | Triangle, Step or Broadband noise with adjustable amplitude.  |

| OPERATION AND POWER USAGE    |   |
|------------------------------|---|
| Operating temperature        | -20 to +60 $^{\circ}$ C                 |
| Relative humidity range      | zero to 100 %                           |
| Power supply                 | 9 - 36 V DC*<br>Or mains 90 - 250 V AC  |
| Power consumption at 12 V DC | Dependent upon installations parameters |

\*Power voltage for operation of this unit only. Connection to additional instrumentation or use of longer cables may result in a higher input voltage requirement.

| SOFTWARE                             |  |
|--------------------------------------|--|
| Operating system                     | Windows, Linux and macOS compatible                                    |
| Communication technologies supported | Ethernet (10/100/1000BASE-T)<br><br>Optional Power over Ethernet (PoE) |

| USER INTERFACE            |   |
|---------------------------|---|
| Configuration and control | (Ethernet) Güralp Discovery - free download, web browser interface. |

| DATA COMMUNICATION     |  |
|------------------------|--|
| Data recording formats | miniSEED (metadata stored in dataless SEED format) |

|   |   |
|---|---|
| Data streaming protocols (via Ethernet) | GCF (Scream!), GDI-link <sup>1</sup> and SEEDlink <sup>1</sup> (metadata sent in RESP, StationXML and dataless SEED file formats) |
|---|---|

|                    |                                    |
|--------------------|------------------------------------|
| Memory and storage | Dual redundant 64 GB microSD cards |
|--------------------|------------------------------------|

|     |        |
|-----|--------|
| RAM | 256 MB |
|-----|--------|

## PHYSICAL CHARACTERISTICS

|             |   |
|-------------|---|
| Casing type | Environmentally sealed, hard anodised aluminium |
|-------------|---|

|                      |                          |
|----------------------|--------------------------|
| Environmental sensor | Humidity and temperature |
|----------------------|--------------------------|

|            |   |
|------------|---|
| Dimensions | Diameter 89 mm<br>Height without lifting bail 350 mm<br>Height with lifting bail 725 mm |
|------------|---|

|                |   |
|----------------|---|
| Connector type | MIL-DTL-26482 Series 1:<br>2 $\times$ Ethernet Power<br>Ethernet - 8P8C (RJ45)<br>Power - 10 pin<br>GNSS - 10 pin (GPS) |
|----------------|---|

|   |  |
|---|--|
| Global navigation satellite system (GNSS) | Compact, encapsulated, waterproof, precision timing GPS/GLONASS (BeiDou optional) receiver |
|---|--|

|                            |   |
|----------------------------|---|
| Communication / Connectors | 100 bar/10 MPa waterproof connector up to 1000 metres |
|----------------------------|---|

|                                   |  |
|-----------------------------------|--|
| Surface Interface Unit dimensions | 512* mm $\times$ 376 mm $\times$ 432 mm<br>*Allow additional 350 mm for cable connectors |
|-----------------------------------|--|

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DAS-MIN-0003 Issue B