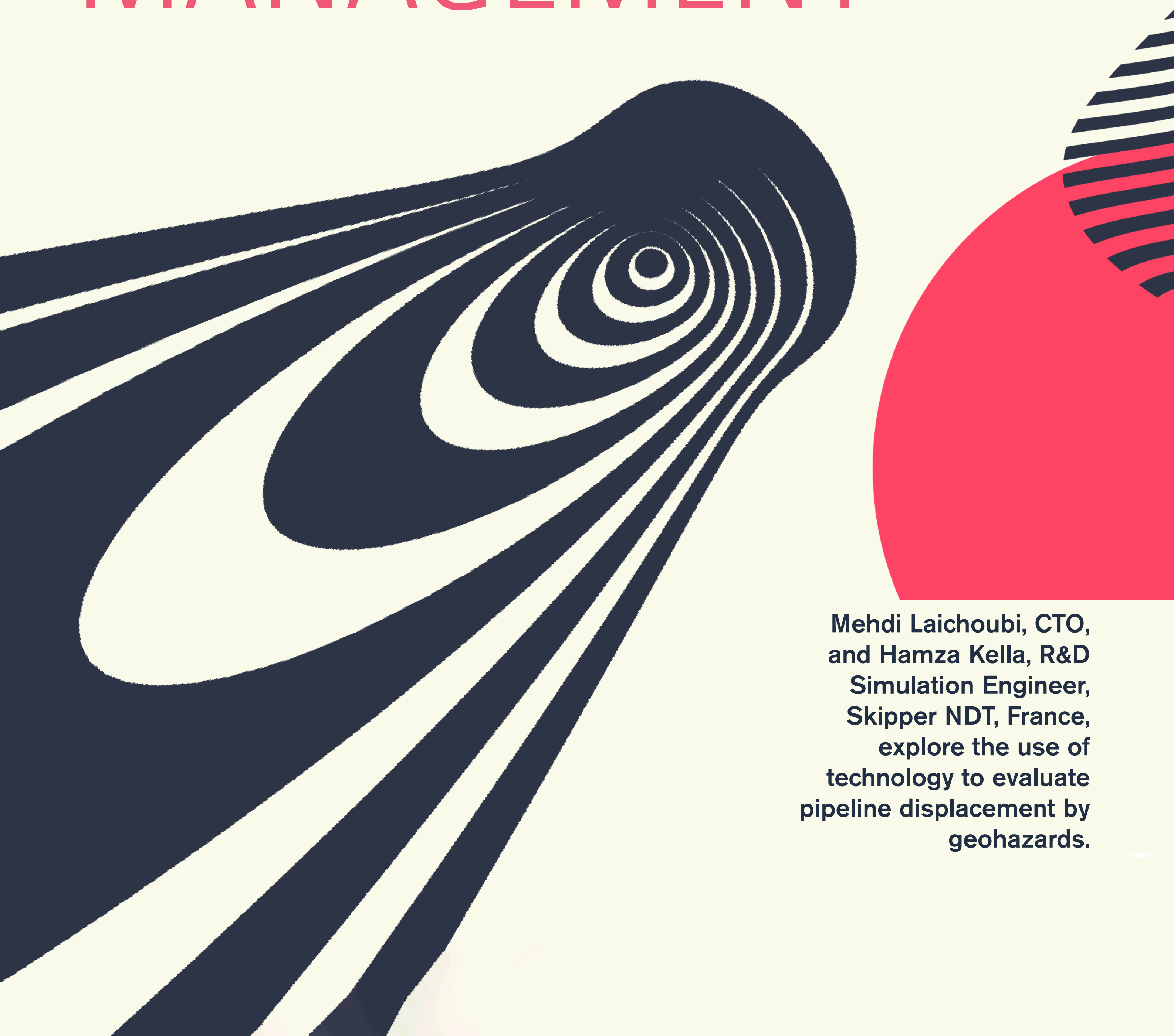
DISRUPTING GEOHAZARD MANAGEMENT



Mehdi Laichoubi, CTO, and Hamza Kella, R&D Simulation Engineer, Skipper NDT, France, explore the use of technology to evaluate pipeline displacement by geohazards.

Natural disasters such as earthquakes, flooding, and hurricanes have a devasting impact on communities. They destroy not only above-ground infrastructure, but also buried infrastructure such as pipelines. After hurricane Ida struck the coastline of Louisiana in 2021, oil spills of several miles long were seen in the Gulf of Mexico. Extreme climatic events are forecast to intensify in frequency and intensity due to the effect of global warming. This threat is taken seriously by governing authorities and specific legislation was promulgated to ensure swift action is taken to protect local communities. The new PHMSA Mega rule Part 2, which went into effect in 2020, requires operators to inspect pipelines within 72 hours of an extreme weather event.

Although pipeline operators cannot control the weather, they can assess the mechanical integrity of their buried pipeline networks. Current methods are either indirect, correlating surface measurements and potential pipeline mechanical strain, or direct, with actual pipeline measurement through the launch of an inline inspection (ILI) tool fitted with an inertial measurement unit (IMU). One indirect method is rapid to deploy, but relies on secondary data and statistical models to obtain information about the pipeline. Another method, based on ILI, is direct but entails significant logistical constraints making it difficult to be deployed within a short time frame.

The Skipper NDT technology could help bridge this gap by providing an assessment of the pipeline mechanical strain based on direct data acquired from the ground surface. By leveraging the latest developments in the field of hardware and software, Skipper NDT is able to rapidly and remotely deploy its technology based on the physical principles of magnetism. The objective is to create a high-precision digital twin of the buried structure from which bending strain calculations are performed. The geospatial accuracy of the technology was confirmed in PRCI project PL-1-05, where data provided by Skipper NDT were compared to open ditch measurements on a 24 in. dia. pipeline. The result showed a 5 in. average accuracy with a high degree of reproducibility. This dataset is then used to deploy proprietary data computation to assess the bending strain of the pipeline.

Figure 1. **The Skipper NDT Embedded System mounted on an off-the-shelf UAS (DJI M300).**

Figure 2. **Inspected area (red outline) and the trajectory of the drone (green).**

The hardware

Reliable and repeatable data acquisition is the building block upon which the Skipper NDT technology relies. The main objective is to provide the highest data quality while ensuring the field operator's safety at all times. By leveraging the latest developments in the field of hardware and software, Skipper NDT uses an unmanned aerial system (UAS) vector to carry the equipment required for capturing the necessary geospatial and magnetic metadata. The system was made as compact as possible to be compatible with a large array of drone vectors. The payload weighs a total of 1.6 kg (3.5 lb) with a span of 160 cm (62 in.), and includes the following elements (Figure 1):

- Four three-component fluxgate magnetometers.
- Real-time global navigation satellite system (GNSS) receiver with centimetric-level precision.
- Tactical-grade IMU.
- Telemetric sensors that measure the distance between the magnetometers and the ground (or canopy).
- Proprietary electronic card responsible for data acquisition, digitalisation, and synchronisation are the system's core components.

Using this system, large areas can be rapidly scanned regardless of the complexity of access to the site or the soil type/condition.

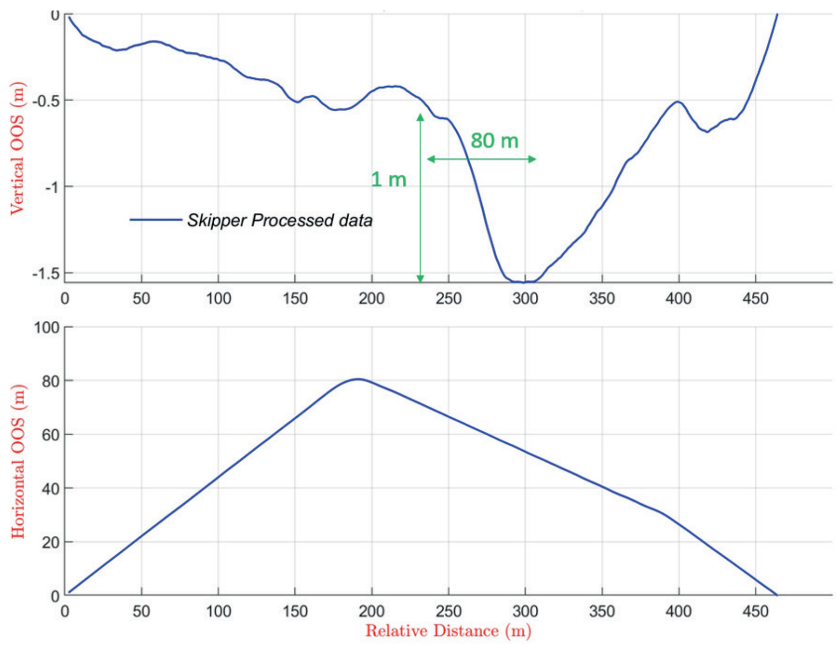


Figure 3. **Vertical (top) and horizontal (bottom) OOS profiles.**

General procedure

To ensure data reliability and repeatability, Skipper NDT has created an automated multi-step procedure for deriving the buried pipeline position (horizontal, vertical, and depth of cover). From this metadata, out-of-straightness (OOS) is quantified.

The first step is to perform the actual field data acquisition. Simple and fully automated, this requires the drone pilot to create, using the dedicated software, a flight plan over the area of interest (Figure 2). The drone will then autonomously scan the area and acquire the data without any manual intervention. Data quality does not depend on the drone pilot's skills, and difficult-to-access areas can be efficiently surveyed while ensuring the field operator's safety.

The second step entails data post-processing. Here again, the process is automated and relies on patented algorithms to perform a number of operations, including magnetic data calibration to erase any potential interference and the production of magnetic maps, which will be the basis for determining the pipeline location.

The third step will see Skipper NDT deploy its proprietary magnetic inversion algorithms to pinpoint the exact lateral, horizontal, and depth of cover position of the buried pipeline. Using this data, Skipper NDT has a specific set of algorithms to determine the vertical and horizontal bending strain of the structure to highlight potential zones of abnormal strain which could threaten the safety of the buried pipeline.

Finally, the operator will receive both an inspection report with a data file adapted to the format of its geographic information system (GIS) for ease of integration into the integrity management programme for the pipeline.

Case study

A major energy gas distribution operator mandated the services of Skipper NDT to inspect a 450 mm (18 in.) dia. buried pipeline in an area that exhibited signs of ground displacement. The drone was deployed to collect the magnetic data. The average magnetic map dimension was approximately 450 m (1476 ft) by six profiles. The drone flew at an average height of 2 m (6.5 ft) AGL, with an average flying speed of 6.5 km/hr (4 mph). The acquisition time for the inspection was 30 minutes in total. In Figures 3 - 5, the pipeline geometry profiles are presented over a length of about 450 m (1476 ft).

OOS profiles are used to visually capture subtle alterations in the pipeline centreline. These profiles measure the horizontal and vertical deviations from various possible sources which could be the as-built plans provided by the operator, a previous Skipper NDT survey, or a straight-line assumption. OOS profiles are especially valuable for detecting pipeline direction change due to ground movements.

As shown in the vertical OOS profile in Figure 3, the landslide-induced pipeline displacement has generated a vertical OOS of about 1 m (3 ft) over 80 m (262 ft) with a peak vertical OOS at a relative distance of about 300 m (984 ft). In addition, the horizontal OOS data (Figure 3) clearly indicates the presence of two horizontal bends (32˚ and 5˚) at 200 m (656 ft) and 400 m (1312 ft), which are well-illustrated

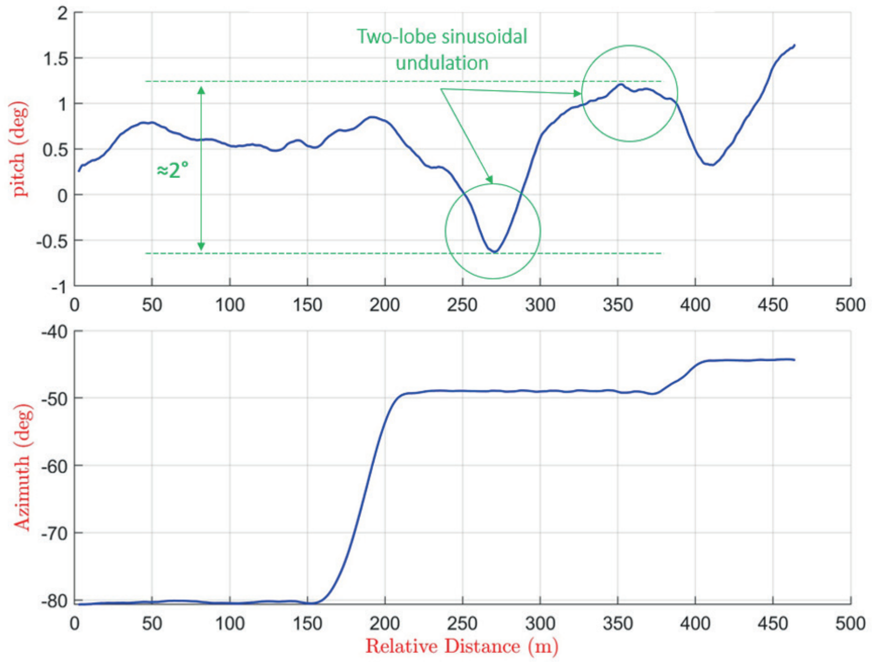


Figure 4. **Pitch and azimuth profiles along the inspected line.**

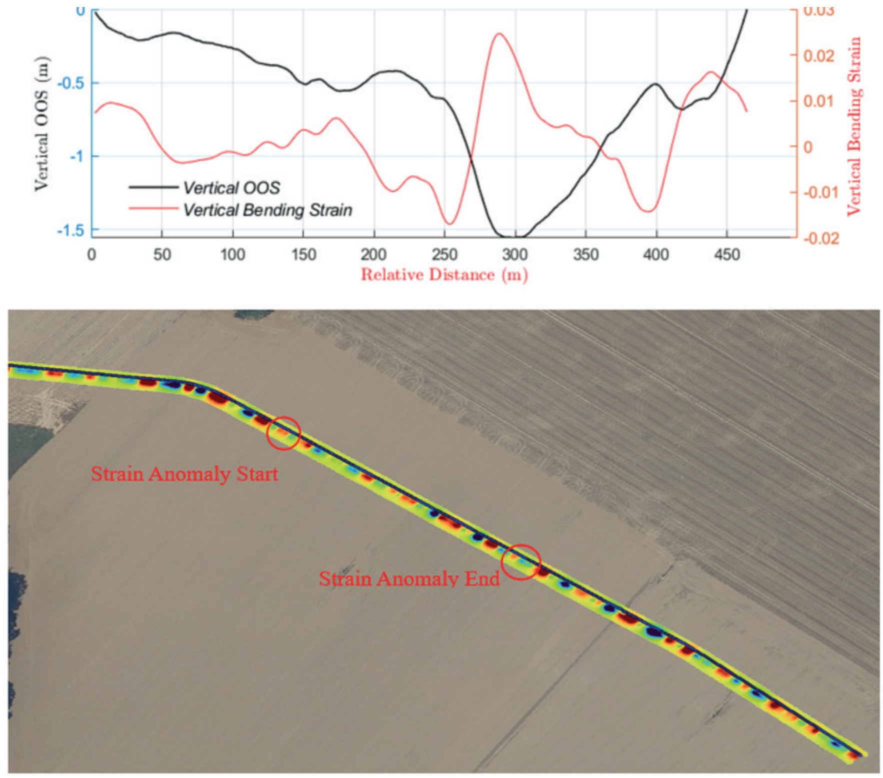


Figure 5. **Bending strain plots (top) showing vertical anomaly and magnetic map variation (bottom).**

by the stair-stepped pattern in the azimuth profile in Figure 4 and are known to the operator. The vertical geometry is characterised by a clear, two-lobe sinusoidal undulation in the pitch profile in Figure 4 extending over the distance range from about 260 - 380 m (787 - 1246 ft), with a total pitch swing of 2˚.

The vertical bending strain profile, shown in Figure 5 exhibits a distinct and characteristic W-shape with a negative peak value of -0.017% and -0.014% at a relative distance of about 255 m and 390 m (836 ft and 1279 ft), respectively, and a positive peak value of 0.024% at a relative distance of about 285 m (935 ft) near the middle of the landslide. Moreover, Figure 5 shows a reduction of the magnetic field along the anomaly and helps us to better interpret the results. This indication, obtained without any interference with the normal operating conditions of the pipeline, made it possible for the operator to take the required corrective actions at the precise location affected by the ground movement.

Summary

In summary, the advantages of the Skipper NDT technology for bending strain assessment in case of a geohazard event can be summarised as follows.

Bending strain analysis derived from reliable primary data

- The magnetic data acquired using the Skipper NDT technology is based on the pipeline itself. No models are used to derive this primary information, just as in ILI.
- Primary data input was proven to be reliable and repeatable as shown by the PRCI audit (PL-1-05), showing an average positioning accuracy of 5 in. and a precision of 3 in. Bending strain estimates were also confirmed through field trials.

Easy deployment for compliance with PHMSA requirements

- Data is acquired using a drone vector to rapidly collect the data regardless of terrain conditions.
- Pipelines can continue to operate as the necessary data is collected from the ground surface with no interference with the flow inside the pipeline.

Enhanced field operator safety

- The field operator is safe as all data is acquired using a drone, ensuring that a safety distance is respected at the site of a geohazard event.

The Skipper NDT technology is positioned as complementary to other technologies, to remove any doubts concerning pipeline mechanical integrity in case of geohazard events. The speed of execution and the data accuracy provided without impacting pipeline operating conditions make it a valuable complement to alternatives such as ILI tool.