Pinpointing the right location

Mehdi M. Laichoubi and Sylvain Decombe, SKIPPER NDT, France, discuss the use of magnetic technology to locate and map buried steel pipelines.

Buried pipelines are the most secure and efficient mean to transport vital resources for our communities. A precise mapping of such infrastructures is a critical input to Geographic Information Systems (GIS) used to ensure the safety and integrity of these networks. The safety impact of such an information is twofold: prevent any threat due to third party excavations, and monitor any ground movement on

unstable slopes (landslides) that could affect the pipeline structure.

According to the 2019 Common Ground Alliance report[1], which promotes effective underground infrastructure damages prevention, incidents are on the rise and reached an all-time high. In 2019 a total of 532 000 excavation-related damages to underground facilities were recorded in the US alone, representing a 4.5% increase compared to the 2018 estimate. The human, environmental and financial costs of these incidents are significant. In the US, over a 10 year period, third-party damage on gas networks caused 363 fatalities, 1392 injuries and US$800 billion in financial losses.

Damages to buried pipeline due to third party intervention are a global concern. In Belgium, an excavator's impact on a buried gas pipeline resulted in an explosion two weeks later, with a high number of casualties, 24 dead and 132 seriously injured.

Addressing the challenge of third-party damages to buried infrastructures is a pressing issue for operators and regulators. Some countries have started to enforce stringent legal requirements. In France, a government decree[2] mandates operators to map critical pipelines, at a precision of at least 40 cm laterally (X,Y) and vertically (Z).

SKIPPER NDT has developed a buried pipeline positioning technology using magnetic mapping. This solution, which combines magnetometry and topography measurements, provides significant competitive advantages compared to existing tools in terms of:

- Data accuracy: proprietary algorithms automatically process the acquired data, minimising human error and measurement bias.
- Continuous measurement: data is acquired continuously along the right-of-way. It ensures that no area of interest is missed thanks to a high-resolution magnetic view of the pipeline and its underground environment. This is especially useful in the case of pipeline intersections.
- Operator safety and field accessibility: the versatility of our equipment and detection methods allows UAV-based inspections on previously inaccessible locations while ensuring the field operator safety.

Figure 1. UAV with SKIPPER NDT's embedded technology.

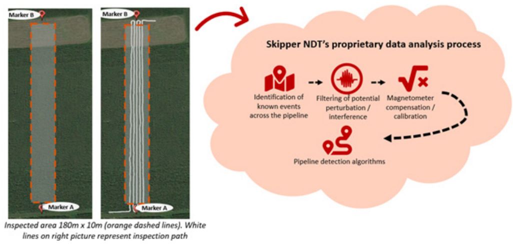

Figure 2. Description of the inspection protocol and data analysis process.

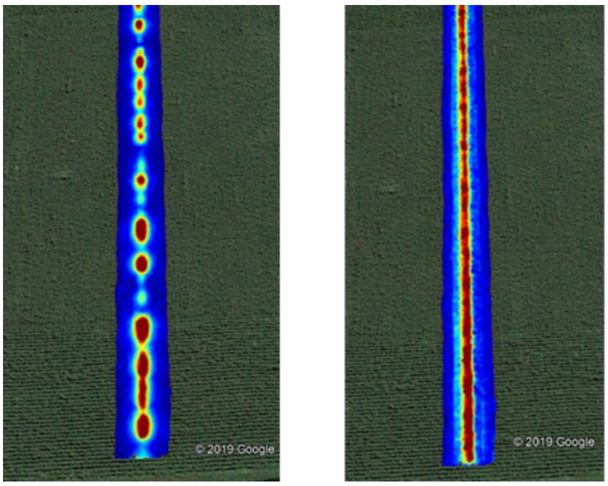

Figure 3. Resulting magnetic maps of the previous inspected area. The two maps rely on the same dataset but treated with different algorithms.

Table 1: Summary of the inspection parameters for each of the two inspections

	First Inspection	Second Inspection
Pipe's Nominal Diameter (DN)	DN 200/8 in.	DN 150/6 in.
Dimensions of the inspected area	387*33 ft	482*33 ft
Duration of the inspection using the Field Machine	13 min.	14 min.
Duration of the inspection using the UAV	6 min.	7 min.

Moreover, the technology is contactless and does not require any modification of the pipeline's operating conditions. The processed results of the network's location (latitude, longitude, and altitude/depth of cover) are provided in various formats to be compliant with the client's GIS system.

The equipment and methods involved in the SKIPPER NDT georeferencing technology will now be detailed, and its efficiency illustrated through a real case study.

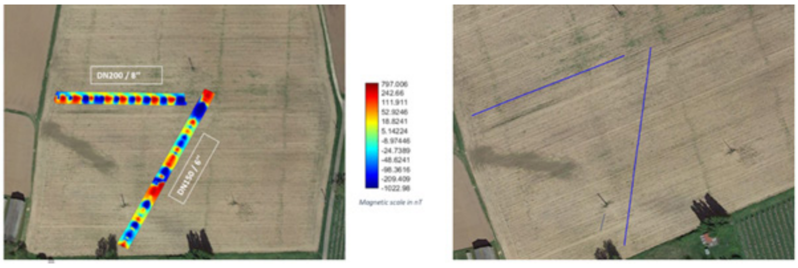

Figure 4. **Magnetic maps of each inspected areas with its corresponding colorbar (in nanotesla) on the left. Estimated XY position of the corresponding pipeline in blue line.**

Equipment and methods

Data acquisition tools: tailor-made, patented, high-precision equipment

In terms of hardware, the SKIPPER NDT team has patented a ground-based mobile equipment that can be pulled by an operator or towed by a vehicle. SKIPPER NDT has also released a UAV-based solution for its magnetic inspections. Both tools embark for the most part the same equipment:

- Five triaxial fluxgate magnetometers.
- GNSS with a centimetric precision.
- Inertial Measurement Unit (IMU).
- Ground distance sensors (Lidar, Infrared and Ultrasonic sensors). This is UAV specific.
- Proprietary electronic card for data integration.

In order to record the most granular level of magnetic field and avoid any interferences, a tailor-made electronic system was developed in collaboration with prime research centres. It allows the combination of high resolution magnetic measurements (nanotesla-level) with centimetric-level spatial resolution on a UAV agnostic embedded material.

Field machine 6 in./482 ft	
Acquisition time	14 min.
Average precision	2.4 in.
Standard deviation	1.7 in.
90th percentile	4.7 in.

Drone 6 in./482 ft	
Acquisition time	6 min.
Average precision	6.1 in.
Standard deviation	3.8 in.
90th percentile	12.9 in.

Field machine 8 in./387 ft	
Acquisition time	13 min.
Average precision	1.5 in.
Standard deviation	0.7 in.
90th percentile	2.5 in.

Drone 8 in./387 ft	
Acquisition time	5 min.
Average precision	5.2 in.
Standard deviation	4 in.
90th percentile	10.3 in.

Figure 5. **Tables of distance discrepancy between SKIPPER NDT's predicted position of the pipeline and land surveyor's reference. Each table displays the duration of the acquisition (in minutes), the mean error along the line, the standard deviation, and the error for 90% of the given results (in inches).**

SKIPPER NDT data processing: proprietary protocols and algorithms

To reach optimal levels of magnetic field sensitivity, SKIPPER NDT has developed specific acquisition protocols to increase the native resolution of its magnetometers while compensating for signal interferences. Systematic sensors' calibration and level control resulted in a tenfold resolution improvement.

Regarding its algorithms, SKIPPER NDT has implemented ten methods to obtain precise planimetric and altimetric positions according to various configurations of field acquisitions. The result is a robust measurement protocol under various operational conditions and terrain types.

Information gathered through visual inspection on the field and client's data integration allows us to enrich the deliverables and correlate magnetic phenomena on the network.

Inspection protocol: general principles

The inspection's objective is to perform a magnetic map of the pipeline's right-of-way between two points (Marker A and Marker B). Using one of our two available tools described before, the operator will map the area where the pipeline is thought to be located (orange dashed line, Figure 2). This will enable the generation of a magnetic map that will include the pipeline location as well as its surroundings. In some cases, a current injection on the pipeline is required during the inspection. It is injected at the cathodic protection cabinet or at the test point. The current does not exceed 10 amps.

The suit of proprietary algorithms will then interpret the data. The variety of processing options will ensure an optimal result regardless of terrain conditions.

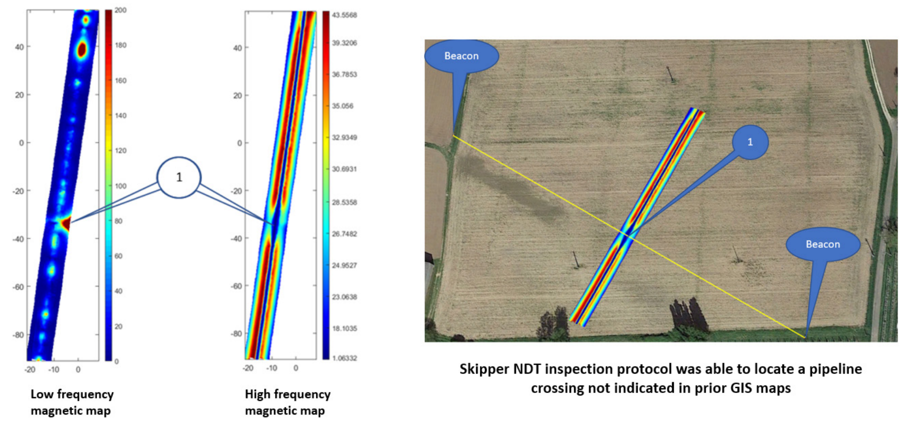

Figure 6. On the left side, high frequency and low frequency magnetic maps showing an anomaly tagged with (1). These anomalies illustrate the presence of a pipeline crossing the inspection area horizontally. On the right side, the position of the anomaly is correlated to the true position of the crossing pipeline.

SKIPPER NDT performances: comparison to the reference line

Results of each of the two detections are compared to the reference position taken by the land surveyor in open ditch.

Figure 5 illustrates SKIPPER NDT's positioning performances compared to the reference line for each tool on each inspected pipeline.

- Field machine results: 5 in. accuracy for 90%, compared to the reference, for both inspections.
- UAV results: 13 in. accuracy for 90%, compared to the reference, for both inspections. The acquisition time is 6 minutes.

Case study: comparison between traditional tools and SKIPPER NDT's technology

In collaboration with Teréga, France's second largest gas network operator, a field trial under real conditions was conducted. Surveyors contracted by Teréga geolocated two pipelines of 6 in. and 8 in. diameter respectively, in an open ditch. The ditches were then backfilled, and SKIPPER NDT was requested to geolocate the pipelines in a blind test. SKIPPER NDT conducted two tests using two different vectors, ground-based mobile equipment as well as a UAV described in the Material and Methods section.

Inspection parameters

The two distinct pipelines were inspected with our protocol and the parameters of each inspection are outlined in Table 1.

Magnetic maps and pipeline positioning

Through data acquired during each inspection using our tools, a high-resolution georeferenced magnetic map of the inspected area is generated. The automatic SKIPPER NDT data analysis process allows us to infer the absolute position of each inspected pipeline (Figure 4).

Additional detections: pipeline's magnetic environment

SKIPPER NDT's does a continuous measurement along the pipeline. As a result, it can precisely map bends and elbows. Furthermore, it can detect metallic objects and structures around the pipeline. Hence, during this pilot test, SKIPPER NDT was able to identify a crossing point with another pipeline which presence was not previously reported (Figure 6).

Conclusion

SKIPPER NDT's localisation solutions are precise and cost-efficient for protecting pipelines from third party damage and for identifying pipeline movement on unstable slopes. The main features include access to the entire pipeline while ensuring high safety standards, precision of measurements, continuity of detection, and quick response to clients.

References

1. Common ground alliance, 2019 report, https://commongroundalliance.com/Resource-Redirects/excavation-related-damages-to-utilities-cost-the-us-approximately-30-billion-in-2019
2. French Standard: NF S70-003-3