# GEOHAZARDS ARE A POTENTIAL **THREAT TO PIPELINES**

## GENERAL INTRODUCTION ON THE NATURE OF THE THREAT

Geohazards can seriously compromise pipeline operational safety and come in various forms, such as landslides, geological faults, liquefaction, and sinkholes. The environment in which geohazards occur can impact the severity of consequences; for example, consequences of pipeline failure can be much higher at water crossing locations than at locations entirely on land. For a pipeline crossing a river, heavy rain and flood conditions can create scouring of the riverbed, exposing the pipeline to further damage.

An effective geohazard threat management plan is essential to mitigate pipeline damage and reduce failure probability. A key element of effective geohazard threat management consists of monitoring change in curvature along a pipeline to estimate mechanical deformation. An accurate, frequent and efficient method of monitoring is critical to ensuring the ongoing safe operation of pipelines in areas of high geohazard risk.

FEMA, the Federal Emergency Management Agency, produced a National Risk Index (Figure 1), a Landslide Risk Index score and rating representing a community's risk occurrence. As shown on the map, a large majority of the United States is affected. The same holds true for Canada and other parts of the world with varied topography leading to earthquakes and/or unstable slopes.

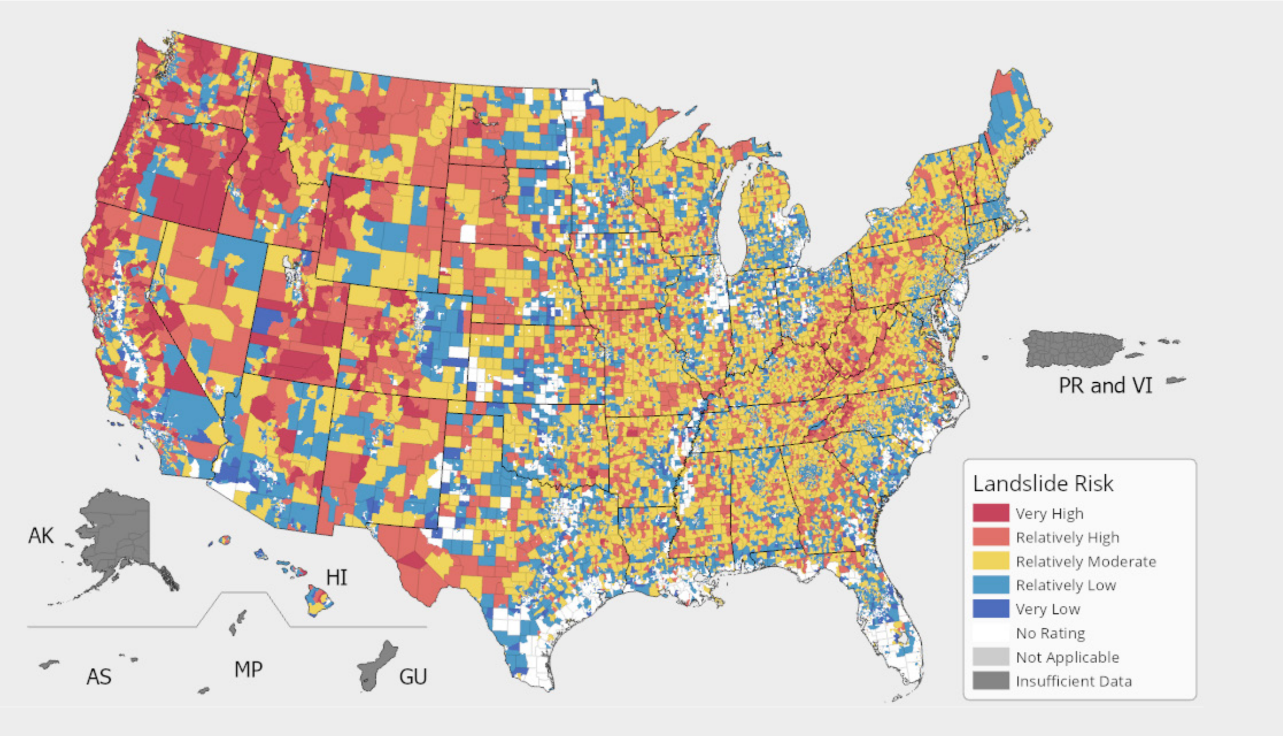



*Figure 1 : USA landslide risk index score and rating : community's relative risk for landslide when compared to the rest of the United States*

Climate change is acerbating landslide risk with changing weather patterns resulting in heavier than normal rainfall and increased temperatures causing soil saturation and flooding or soil erosion. These environmental developments adversely impact the stability of soil surrounding or supporting nearby pipelines.

## Regulations are becoming more stringent

### PHMSA MEGA RULE

PHMSA has addressed geohazard issues with a number of initiatives. It issued Advisory Bulletins in 2015, 2016, and 2019 to communicate the potential for damage to pipeline facilities caused by severe flooding, river scour, river channel migration, and earth movement. PHMSA amended its Mega Rule (Part 2) to require that operators commence inspection of their potentially affected facilities within 72 hours after the operator determines the affected area can be safely accessed.

# SKIPPER NDT'S ARGOS SENSOR SYSTEM IS A GREAT COMPLEMENT TO **EXISTING TECHNOLOGIES**

Skipper NDT's innovation,[1] illustrated in Figure 2, can be used to assess the mechanical integrity of the pipeline without interfering with operations.

*Figure 2 : Embedded System, mounted on an off-shelf UAS (DJI M300)*

To demonstrate the Skipper NDT technology effectiveness, a comparison was done between ILI and Skipper NDT's Argos sensor data sets under the stewardship of the energy major, Enbridge. The objective was to confirm the successful application of Skipper NDT geospatial positioning data to assess bending strain.

Two criteria were used to select the site for the trial:

- The presence of a small cold bend, in order to simulate curvature changes resulting from permanent ground displacement and to test the lower detection limit of the Skipper NDT technology.
- Comparison data. The selected site should have recent ILI / IMU survey data so that the results of the two different technologies could be compared.

Ultimately, a 500-meter/1,640 foot-length, 24-inch diameter pipeline was selected that had a 2.5° horizontal cold bend. Figure 3 illustrates the inspected area where the red rectangle corresponds to the limits of the inspection area. The white lines correspond to the trajectory followed by the drone during this mission.

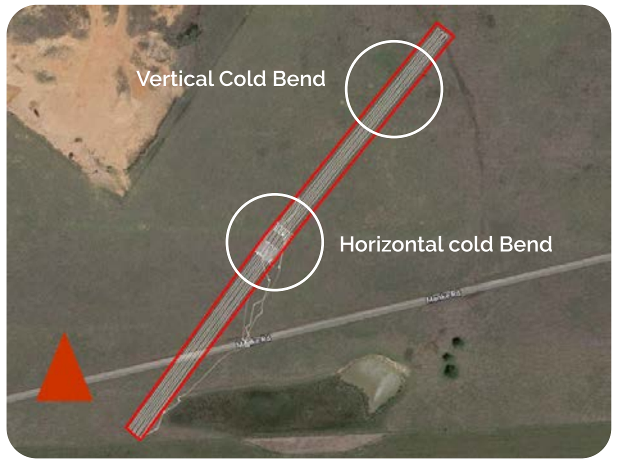



*Figure 3 : Inspection area*

During this inspection, Skipper NDT's drone-based equipment (Argos) was deployed above the pipeline to collect magnetic data. The parameters of the mission were the following:

- Area covered: the magnetic map dimension was 590-by-5 meters/1'935-by-16 feet, by 7 profiles.
- Flight height and speed: average height of 2 meters / 6.5 feet, with an average flying speed of 6.5 km / 4 miles per hour.
- Acquisition time: 45 minutes for the entire area.

The acquired magnetic data underwent two proprietary processes to improve its quality:

- Magnetic data calibration: This proprietary process improves the resolution of the field data 25 times by factoring in the local magnetic field intensity.
- Magnetic data filtering: A proprietary process to compensate for the field acquisition vector movements which might impact data quality. Skipper NDT is also able to filter other electro-magnetic interference, such as the presence of electrical lines, electrified rail, etc.

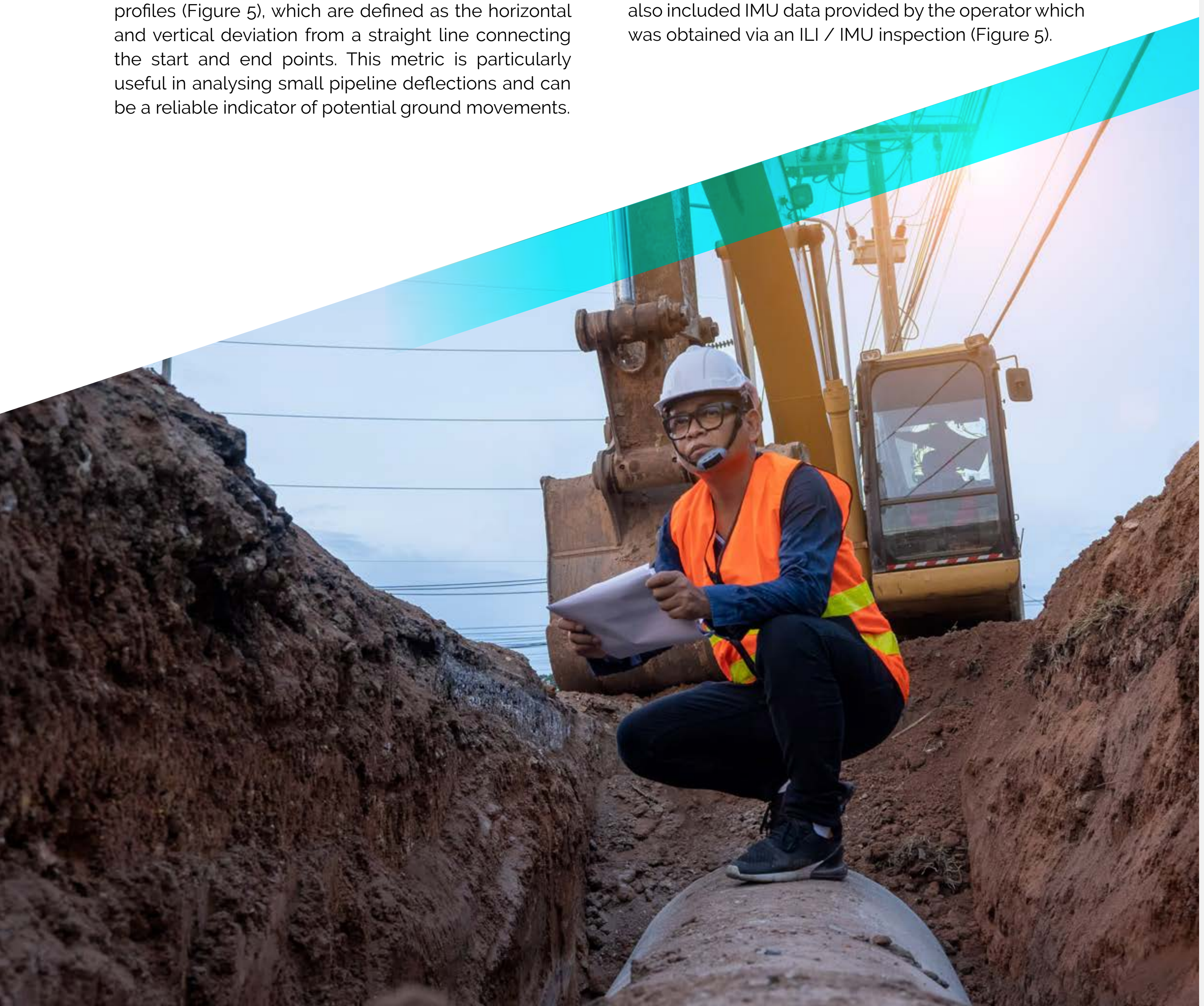
[1] 2.2 kg / 4.4 lbs. and a 160-cm/5,2 feet wide embedded system that can be easily mounted on any UAS. Relying on two primary sensors: magnetometers and GNSS for the acquisition of magnetic data.

After these preliminary steps, the magnetic data is processed using the Skipper NDT patented algorithms to create high resolution magnetic maps as shown in Figure 4.

*Figure 4 : Total magnetic field overlay image of the inspected area (high frequency map)*

To visualize subtle changes in the centreline of the pipeline, Skipper NDT utilizes out-of-straightness (OOS) profiles (Figure 5), which are defined as the horizontal and vertical deviation from a straight line connecting the start and end points. This metric is particularly useful in analysing small pipeline deflections and can be a reliable indicator of potential ground movements.

To provide a comparative analysis of the OOS profiles generated by our drone-based tool, Skipper NDT has also included IMU data provided by the operator which was obtained via an ILI / IMU inspection (Figure 5).



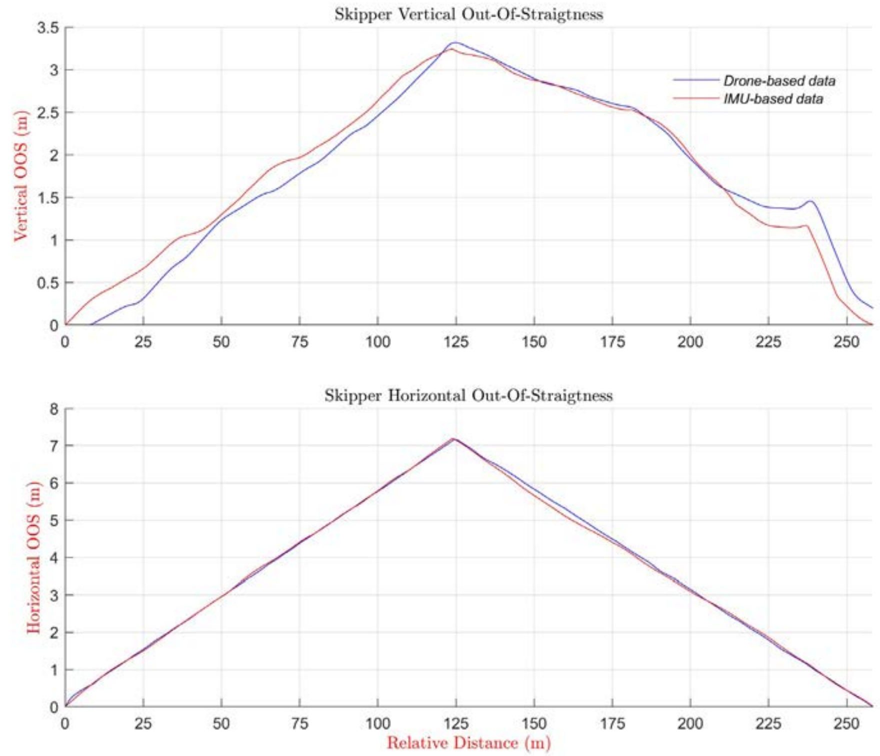



*Figure 5 : Comparison of OOS profiles from drone/IMU-based tools*

Before developing bending strain profiles, it is necessary to evaluate the orientation profile deviation along the pipeline. One way to do this is by analysing the azimuth/pitch orientation profiles (Figure 6). The azimuth/pitch profiles capture the directional trend of the pipeline, which can be readily compared to those provided by the ILI / IMU survey data.

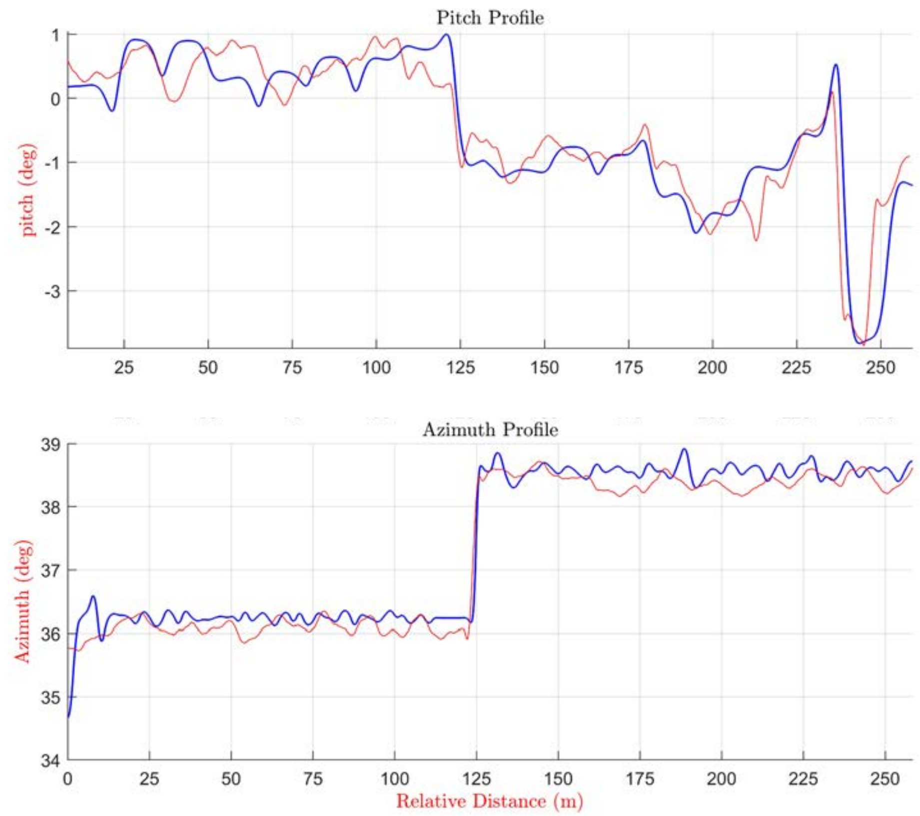



*Figure 6 : Comparison of pitch and azimuth profiles from drone/IMU based tools*

There is good agreement (a difference of less than 0.6°) between the two datasets, indicating that Skipper NDT drone-based technology was used to accurately quantify the orientation change. Furthermore, the comparison revealed a 2.5° change in the pipeline orientation, which was well-quantified using our technology. Once the location data were confirmed, Skipper NDT developed the protocol for assessing the vertical/horizontal out-of-straightness using a methodology aligned with previous research work *[2]*.

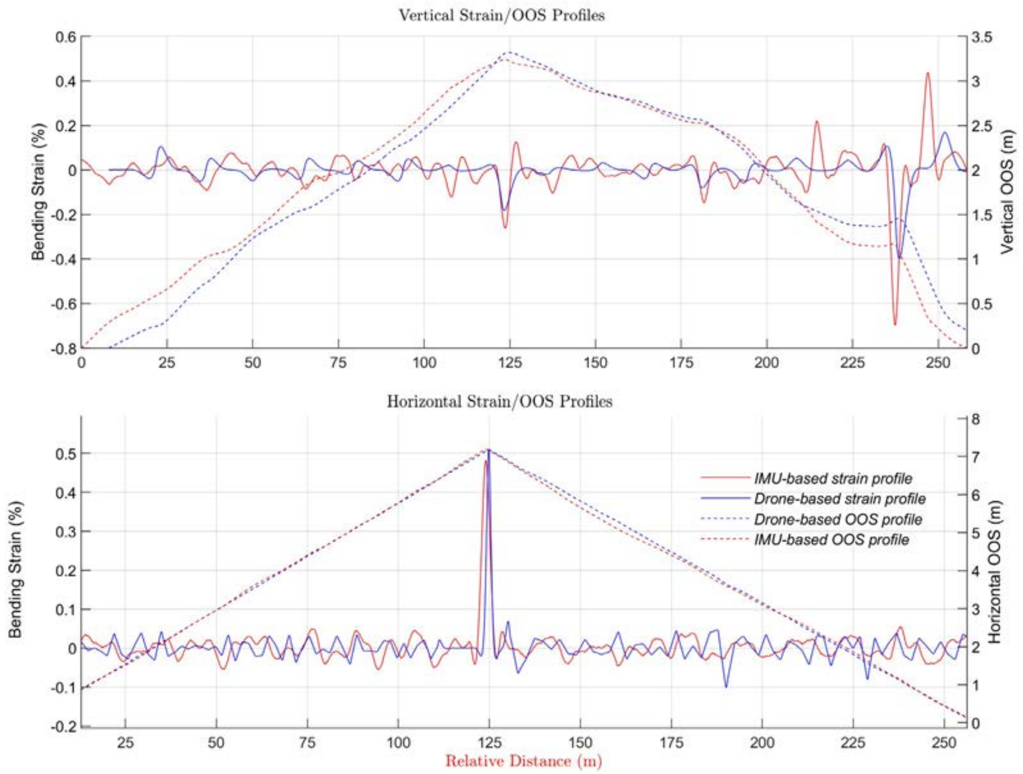



*Figure 7 : : Comparison of bending strain and OOS profiles from drone/IMU based tools showing cold bend locations*

In Figure 7, the blue curve obtained from the drone-based approach was compared with the results (red curve) of an ILI / IMU inspection to evaluate the changes in orientation and bending strain. Regarding the vertical out-of-straightness (top), a sudden curvature change is observed, corresponding to vertical cold bend near the end of the surveyed pipeline section. This change aligns with a well-identified strain peak using both technologies. With respect to the horizontal view (bottom), the cold bend located at 125 m/410 feet is distinctively identified. The comparison revealed agreement within 0.05% between the two data sets, thereby instilling confidence in the accuracy and relevance of the Skipper NDT technology when identifying and quantifying geohazard threats on pipelines.

# CONCLUSION

The results presented above indicate that Skipper NDT's Argos system, based on our proprietary contactless drone-based magnetic technology, enables a preliminary curvature-based analysis to identify potential areas of concern in geohazard areas. This technology can significantly contribute to operator's pipeline integrity programs in case of geohazard events in several ways:

- **Speed**. Data acquisition and processing can be done in 24h if needed. In High Consequence Areas (HCAs), the process of identifying pipeline potential safety hazards can be completed rapidly. This enables integrity departments to take necessary remedial actions, comply with regulatory requirements, and respond quickly to specific events.
- **Data quality with no operational impact.** Skipper NDT is able to perform a direct assessment of the pipeline with light logistical requirements and without interfering with the pipelines in-service operation.
- **Access to remote / dangerous site**. Through the use of its drone vector, the Skipper NDT technology can be rapidly deployed in difficult-to-reach areas.
- **Field operator safety**. Finally, one of the major advantages of using a drone-based tool is that it operates without the need for human intervention on the field, thereby improving personnel safety.

Skipper NDT's Argos technology has various field applications to support pipeline integrity management departments, such as depth of cover assessment, pipeline geospatial positioning under river crossings, and identification of buried assets, as illustrated in Figure 8..


*Figure 8 : Remote services proposals*

SKIPPER NDT

# REFERENCES


*[1]* USA Landslide Risk Index score and rating map : *https://hazards.fema.gov/nri/landslide*

*[2]* Hart, J.D., Zulfiqar, N., and McClarty, E., "*Recommended Procedures for Evaluation and Synthesis of Pipelines Subject to Multiple IMU Tool Surveys* ", IPC2020-9235, Proceedings of the 13th International Pipeline Conference, Calgary, Alberta, Canada, September 28-October 2, 2020.