ANNUAL SEMINAR

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How AI can revolutionize the data analysis process of crack detection

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Trapil a pipeline operator and a service provider

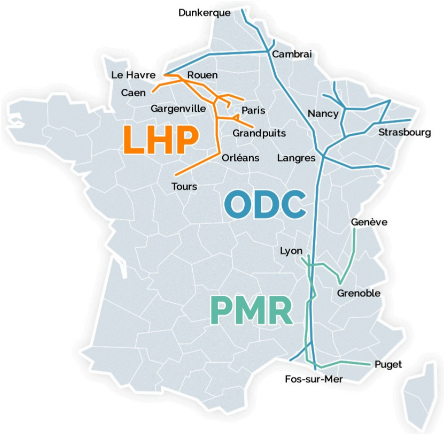
Context and Challenges

Innovative Solutions: ILI Tool Development and AI Integration for Enhanced Analysis

Quantifiable Benefits of AI-Enhanced Data Analysis

Conclusion

Trapil as a pipeline operator …

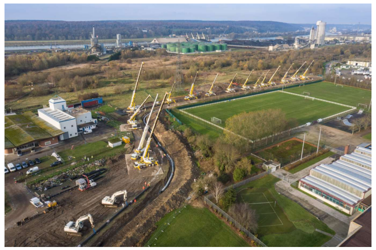


TRAPIL's core business is refined petroleum products transportation in the safetiest conditions.

Created in 1950, TRAPIL
« Société des Transports Pétroliers par Pipelines » operates 3 multi-product pipelines :

- The Le Havre/Paris (LHP), which it owns
- The NATO pipelines in France (ODC)
- The Pipeline Méditerranée/Rhône (PMR)

… and as a service provider

QUALITY & METERING	ENGINEERING & PIPELINE CONSTRUCTION	INSPECTION & INTEGRITY
		

Dual vision
(operator and inspection)

Inline Inspection Activities in Trapil: A story of over 45 years

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MFL ILI tools
Metal loss and crack

1978


ALD ILI Tools
Leak Detection

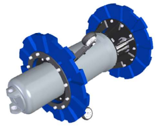
1985


XTraSonic UT ILI Tools
Dent, metal loss detection

2003


XTraSonic-Neo UT ILI Tools
Axial Crack, Dent, metal loss detection

2018


Inertial Measurement Unit
Mapping XYZ

2020


T3 UT ILI Tools
Illegal taps detection

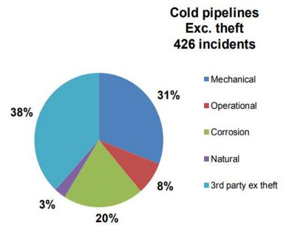
2021


XTraSonic-Neo UT ILI Tools
axial **and girth** Crack, Dent, metal loss detection

2023


XTraSonic-Neo UT ILI Tools
axial / **girth** Crack, Dent, metal loss detection **in 3 diameters**

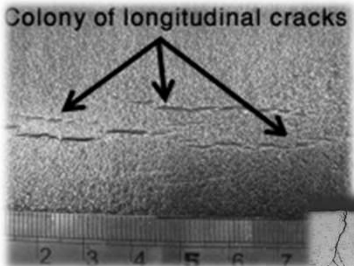
2025

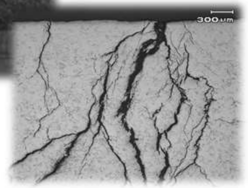


Concawe

Distribution of major spillage causes for cold pipelines

Over 45 year's ILI experience





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The Challenge – Look at Pipeline Anomalies

The Risk: Pipeline Anomalies

- Crack field (depth ≥ 1 mm)
- Crack like (depht ≥ 1 mm)
- SCC (depht ≥ 1 mm)

The challenge:

- Strict delivery window of inspection report (<3 months)
- High data volume from UT inspections
- Ensuring the safety of people and property by detection reliability

Code Name: Key Metrics

POD – Probability of Detection
→ Measures how many real defects are correctly detected (like **recall**).
POI – Probability of Identification
→ Measures how well detected defects are correctly classified (**classification accuracy**).
CF – Coefficient of False Alarm
→ Ratio of false positives to true positives — evaluates **noise level** in predictions.

Our Mission: Build a powerful Artificial Intelligent

- Detect and identify critical & non-critical anomalies
- Handle both UT data types effectively
- Meet strict performance standards:

Metrics	Critical anomalies	All anomalies
POD	100%	95%
POI	90%	
CF	< 0.1	
Processing time	< 24 h for 50 km	

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AI Solution Development Workflow

Understanding the context

Identification of objectives, experts and data

Data understanding and preparation:
getting to know the data, identify risks, mitigate if possible

Data collection

Data exploration

Data preparation

Modelling and evaluation : building the solution on prepared data

Model design

Model training and testing

Validation using chosen metrics

Creating a Usable Dataset

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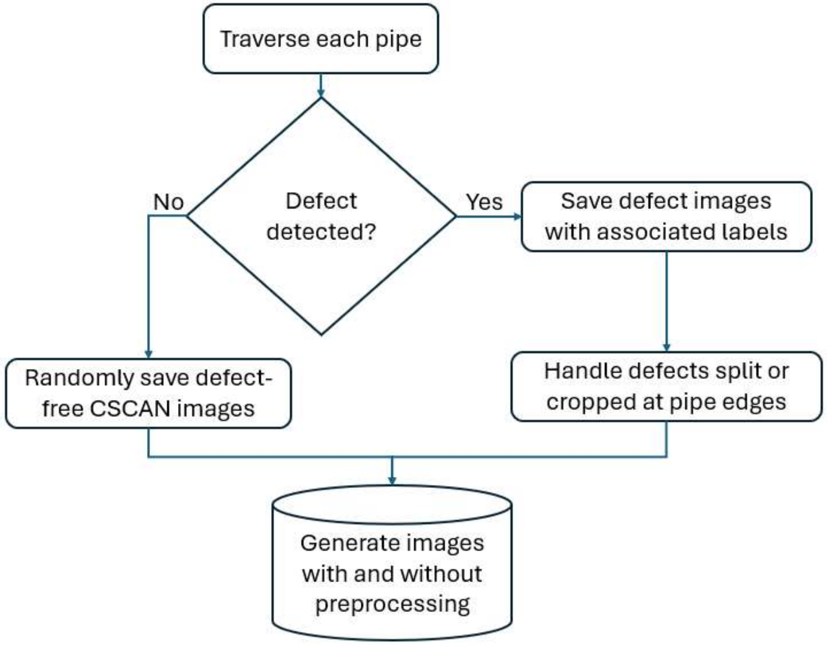
Full pipeline NDE data

- Contains portions **with and without defects**
- Data consistency : **evaluation of new data should be consistent with training data**
  Every major change in the detection chain can impact performance and require a new model optimization using an updated training dataset.

Ground truth annotations

- Ideally based on **excavation feedback**
- Includes:
  precise bounding box coordinates
  defect types (e.g., crack like, crack field)
- **Homogeneity is important: a labelling protocol should exist and be enforced**
  risk: more complex model training and reduced performance in production

Workflow for Dataset Creation



The task set is one of AI model **supervised learning**

From the NDE measurement of pipes :

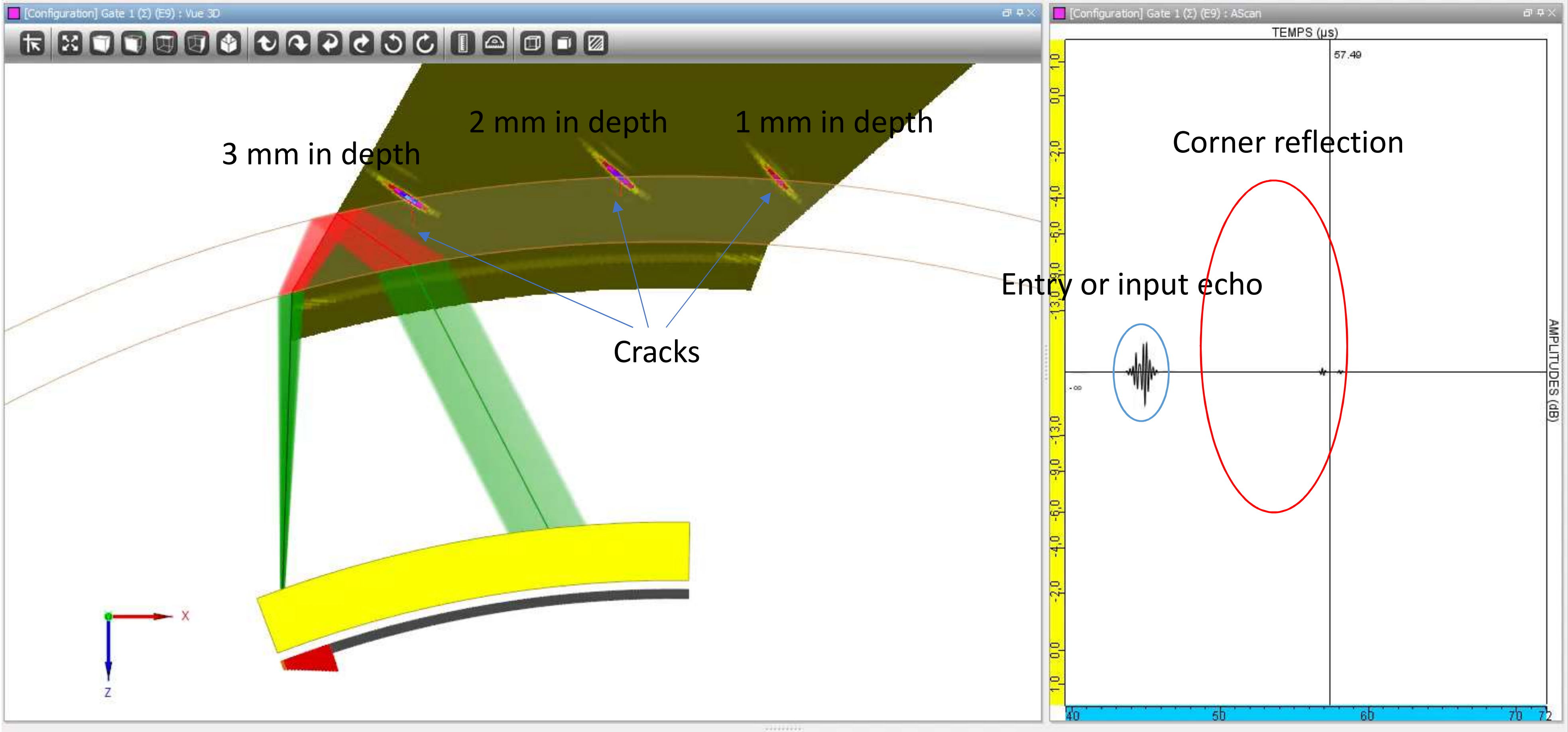
- **Compute image-like maps of anomalous ultrasound echoes** which enables to pinpoint defects giving their positions on the pipe and their level of criticality
- **Identify defects with accurate labelling** (position & type), save related pseudo-images (matrices)
- To enable efficient defect type prediction by an AI model, a **balanced selection of all possible defect types** is necessary
- **Also randomly select defect-free matrices** from various sections of the pipe to ensure diverse representation.

A **large quantity of data with a good labeling quality** is required to train a deep learning model.

To accelerate and secure data collection : **"Direct Model"**

- **Automatic filtering of measurement noise** on generated maps
- **First estimator of crack-type anomalies** bounding boxes.

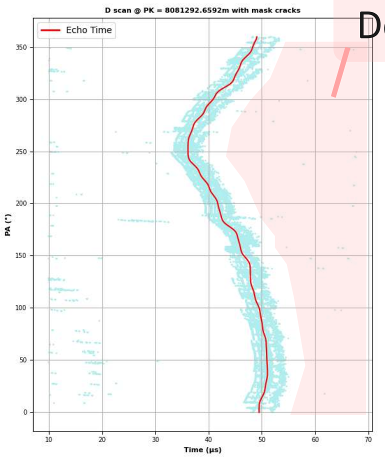
A brief introduction on vocabulary

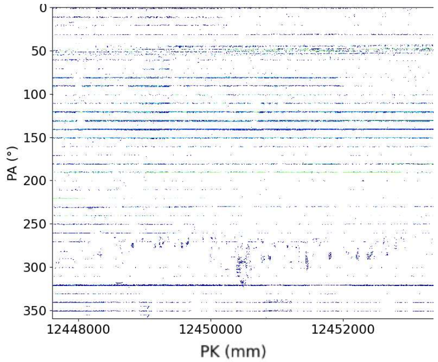


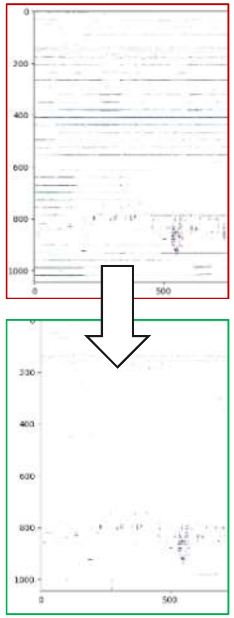
Direct Model

Without enough homogeneous data suitable for a deep learning approach, **we used proven techniques from signal processing, computer vision, and classical statistics.**

Defect search zone

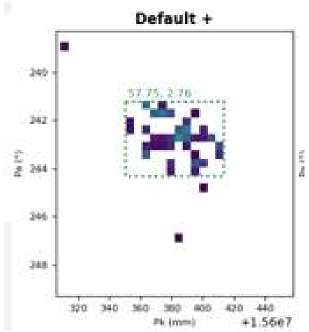






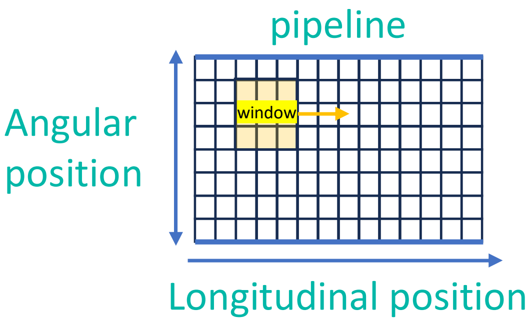
Machine Learning Annotation filter :

- Trained on **field-validated ground truth annotations**
- Selection of **relevant features** (size, total energy…) to tag as defect or filter out



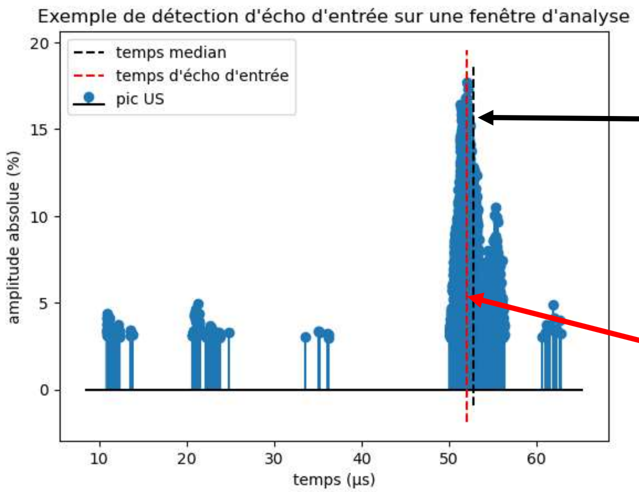
Robust Entry Echo Detection → CSCAN map computation → Noise filtering → Rule-based annotation workflow + annotation filtering ML model

The Model's Core: Robust Entry Echo Detection



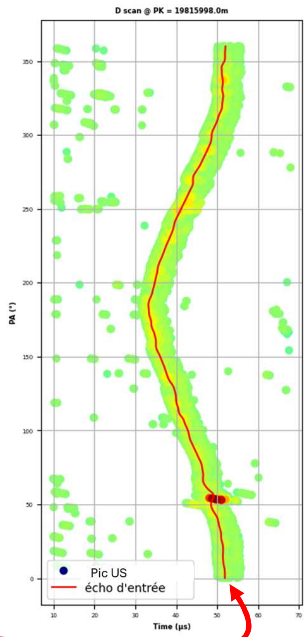
At each sampled coordinate, we have the **time-of-flight data of back-propagated ultrasonic pulse**.

At each coordinate, **the most prominent back-propagated US peaks are identified**. The strongest, called the **entry echo**, is expected to **mark the position of the inner pipeline surface**.



We define a **sliding window** over the full measurement grid:

- For each window position, we compute the **median time of flight** of all the most prominent US peaks.
  This median time is **a robust first estimate of the entry echo**, little sensitive to noise and outliers.
- A **most precise estimate** is obtained by searching for a local peak amplitude maximum close enough to the first estimate.



Evaluation and validation in comparison with traditional analysis

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Detection performance of the solution
using a selection of 129 real crack signals **observed in the field.**

Probability Of Detection (POD)	**95%**
CF (False Alarm rate)	**2.2**

A **second test on signals analysed without available field feedback** was carried out, the table below shows the results obtained.

	pipeline # 1 20" x 45 km	Pipeline # 2 20" x 80 km	Pipeline # 3 12" x 110 km
# cracks reported	31	487	15
POD	91%	93%	100%
CF	3	8	2.2

High false alarm rate may be explained by the limitation of the direct model and the ML annotation filter due to the limited access to field-validated annotations.

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Quantifiable Benefits of AI-Enhanced Data Analysis in ILI Tools

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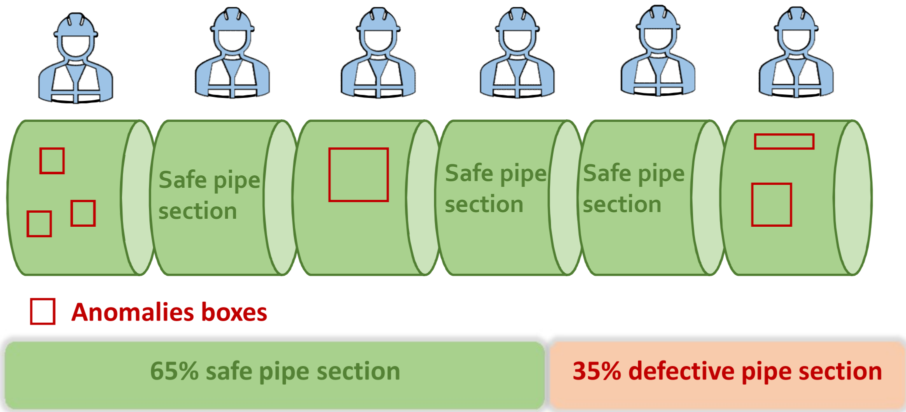
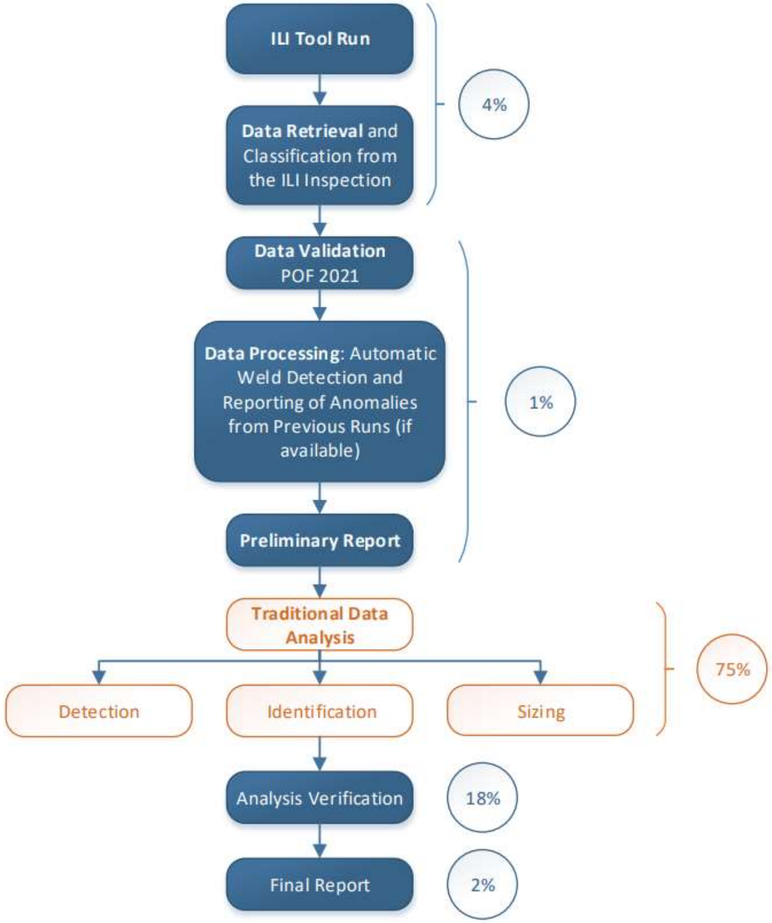
Context and challenges

- Final Report deadline (POF 2021)
- New regulations increase workload
- Traditional ILI analysis is time-consuming (~ 75% of total workflow)

Goal : Reduce data analysis time while maintaining reliability and compliance





Quantifiable Benefits of AI-Enhanced Data Analysis in ILI Tools

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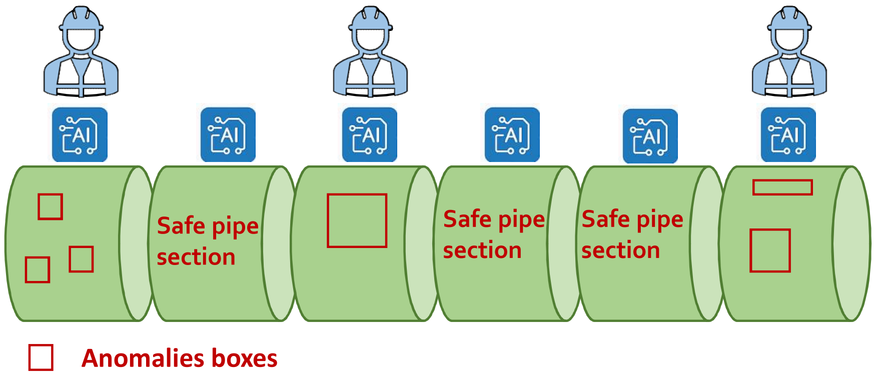
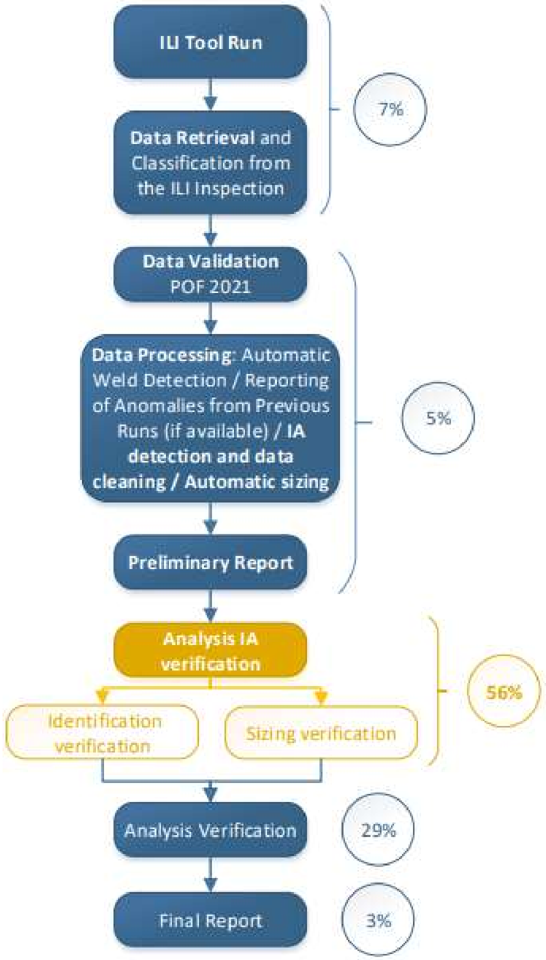
The AI Enhanced workflow

- **Detection phase is now AI-driven**
- Analysts focus on **identification and sizing**
- Analysis **time reduced** from 75% to 56%
- Improves capacity to meet **report deadlines** while **maintaining high levels of accuracy**

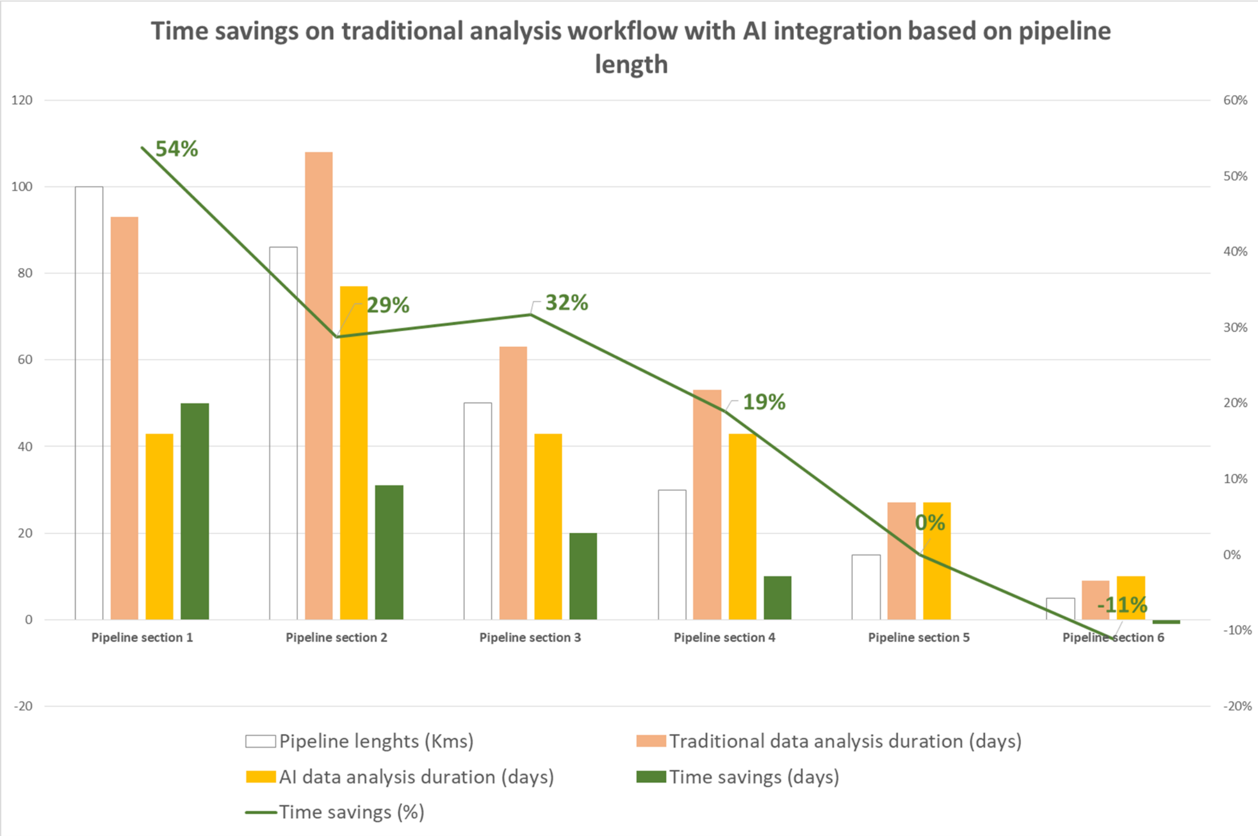




Quantifiable Benefits of AI-Enhanced Data Analysis in ILI Tools

Key results : Time savings

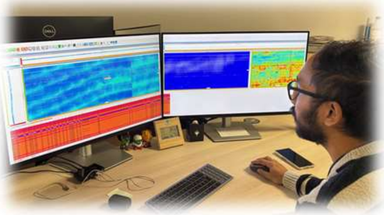
- **Time savings up to 54%** for long pipelines
- **Less gain for short pipelines** mostly due to **false positives** and number of safe pipe section
- **Uniform and consistent defect detection**



Quantifiable Benefits of AI-Enhanced Data Analysis in ILI Tools

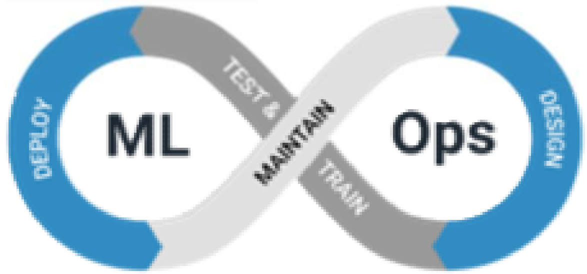
Conclusion : Key Benefits of AI Integration

- **Economic benefit** : up to 54% time saved
- **Enhancing Human expertise** : Analysts focus on defective area verification
- **Supporting company growth**



Perspectives : Sustaining the AI Transformation

- **MLops integration**: for continuous model improvement and fast deployment



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