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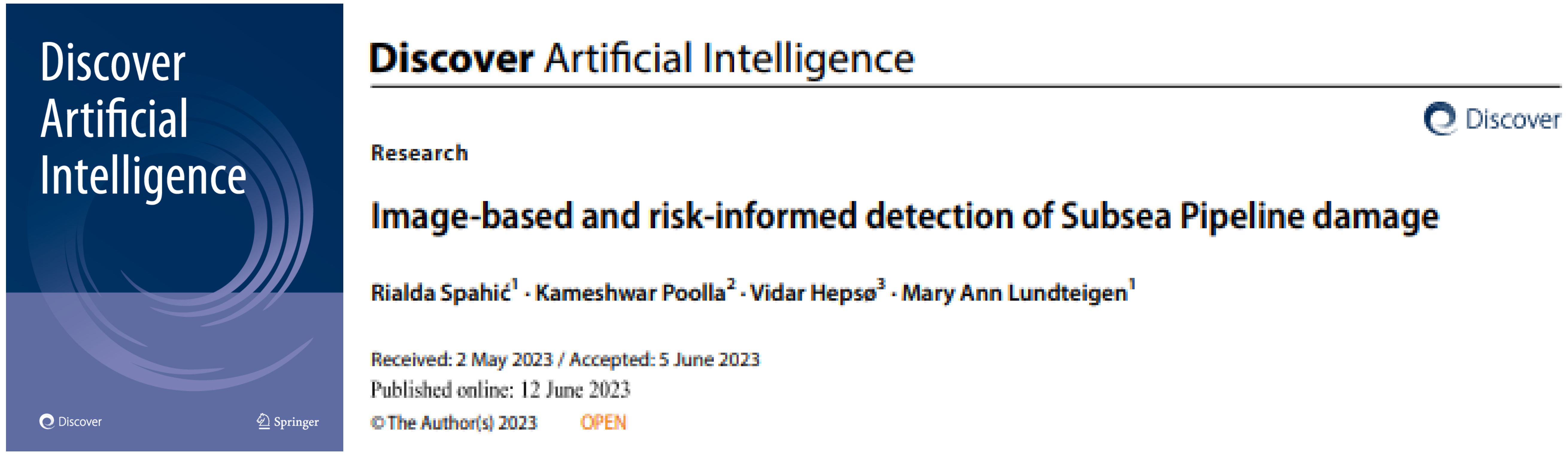
Case:

Risk-informed Artificial Intelligence for Autonomous Subsea Pipelines

with a hint of Responsible AI

Rialda Spahic, PhD

Domain specialist and Task manager of Responsible AI, Equinor



Discover Artificial Intelligence

Discover

Research

Image-based and risk-informed detection of Subsea Pipeline damage

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About me

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Risk-informed Artificial Intelligence for Autonomous Subsea Pipelines

with a hint of Responsible AI

Principles, values, best practices

- Fairness and biases
- Safety, security, resilience, robustness
- Transparency and explainability
- Human oversight (in control, in the loop)

- International standards, legal obligations, governance

AI is an *umbrella term* for a range of technologies and approaches that often attempt to mimic human thought to solve complex tasks.

[Information Commissionar’s Office (ICO) https://ico.org.uk/for-organisations/uk-gdpr-guidance-and-resources/artificial-intelligence/explaining-decisions-made-with-artificial-intelligence/part-1-the-basics-of-explaining-ai/definitions/#:~:text=AI%20is%20an%20umbrella%20term,with%20the%20help%20of%2C%20AI.]

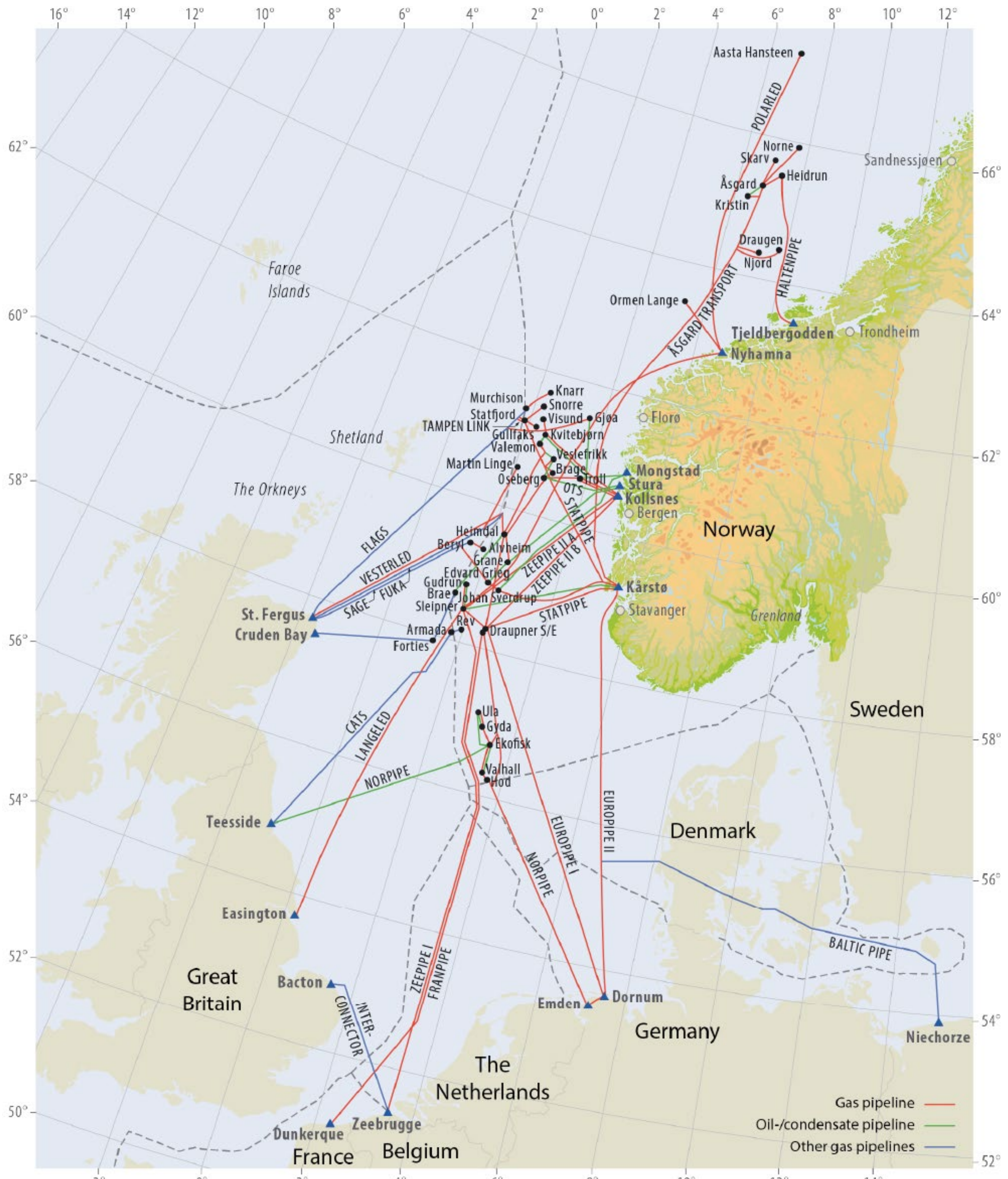
Risk-informed **Artificial Intelligence**
for Autonomous Subsea Pipelines

Risk-informed approach:
ensuring that the decisions between alternatives are taken *with an awareness of the risks* associated with options, and that the attributes of a decision are considered in an integrated manner.

[Ref. Risk-Informed Decision-Making Processes: An overview. Enrico Zio, Nicola Pedroni. Apports De La Recherche. Foundation for an Industrial Safety Culture. 2012]

Risk-informed Artificial Intelligence for Autonomous Subsea Pipelines

Risk-informed Artificial Intelligence for Autonomous **Subsea Pipelines**



Pipelines on Norwegian Continental Shelf, Image property of Norwegian Petroleum Directorate

- Environmental factors impact pipeline integrity, potentially resulting with catastrophic environmental, and financial repercussions.
- Since 1970s, 8,800km of pipelines on the Norwegian Continental Shelf

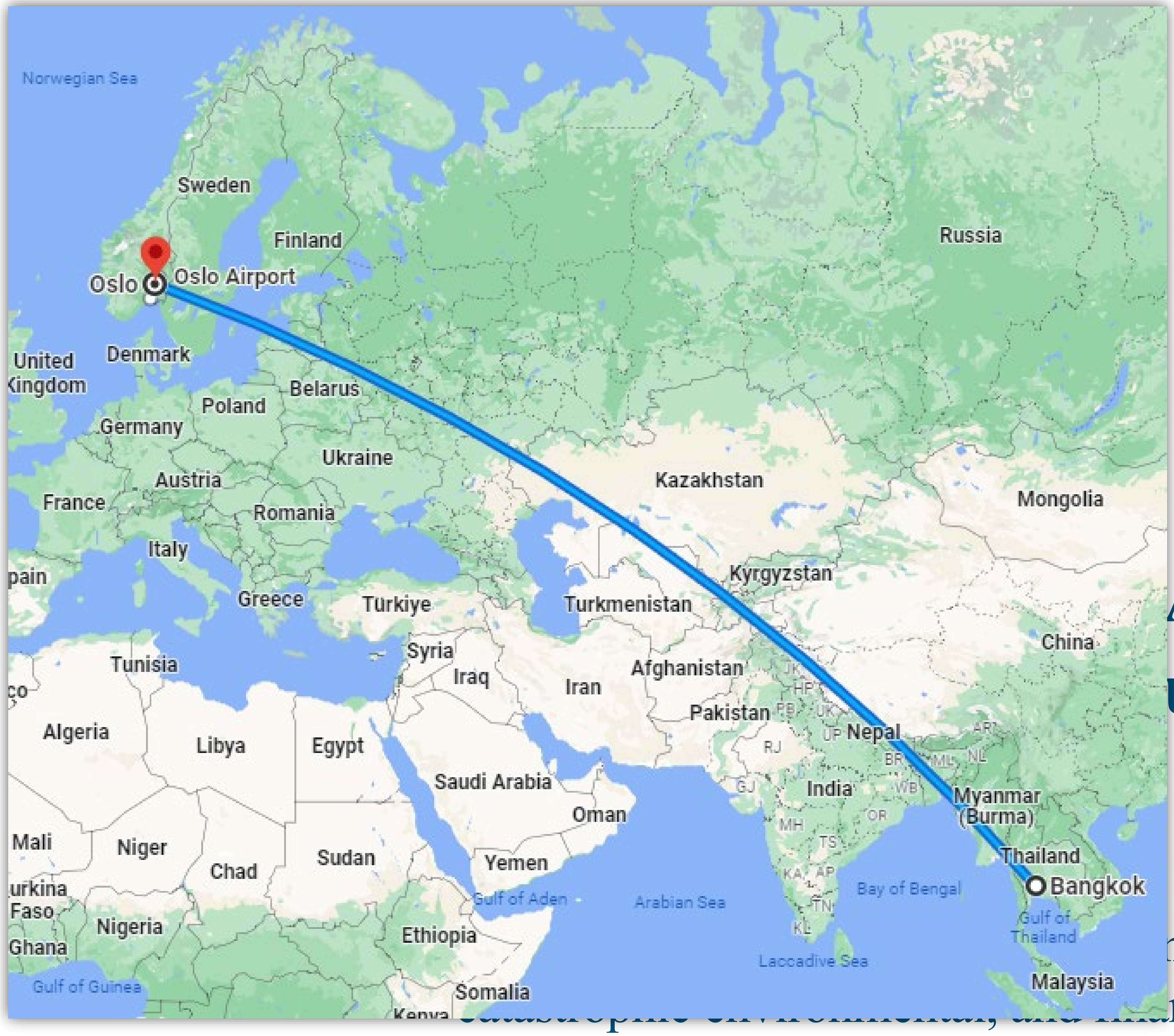
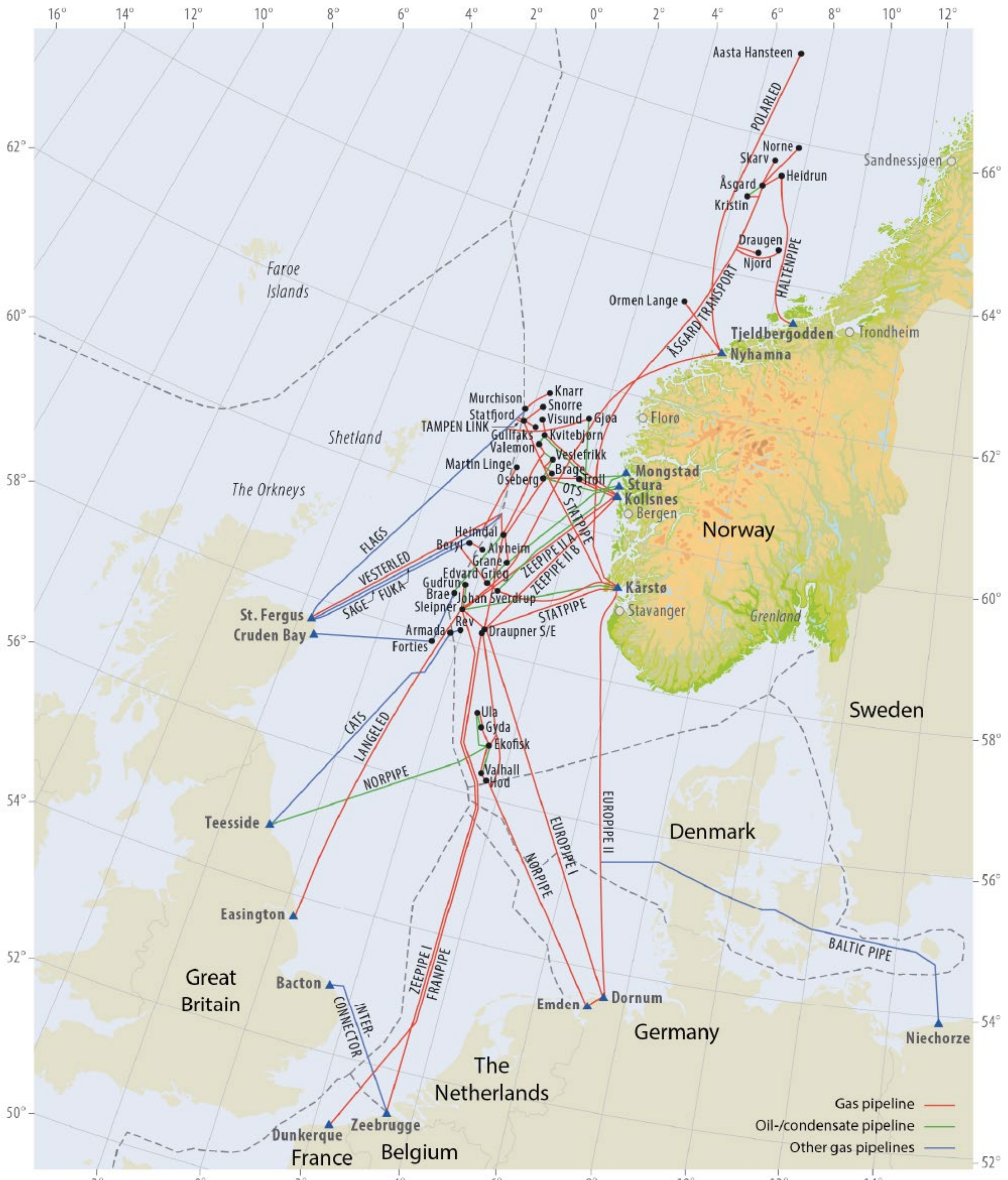


Image: Google Maps

…Artificial Intelligence …us **Subsea Pipelines**



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- Since 1970s, 8,800km of pipelines on the Norwegian Continental Shelf

Risk-informed Artificial Intelligence
for **Autonomous** Subsea Pipelines

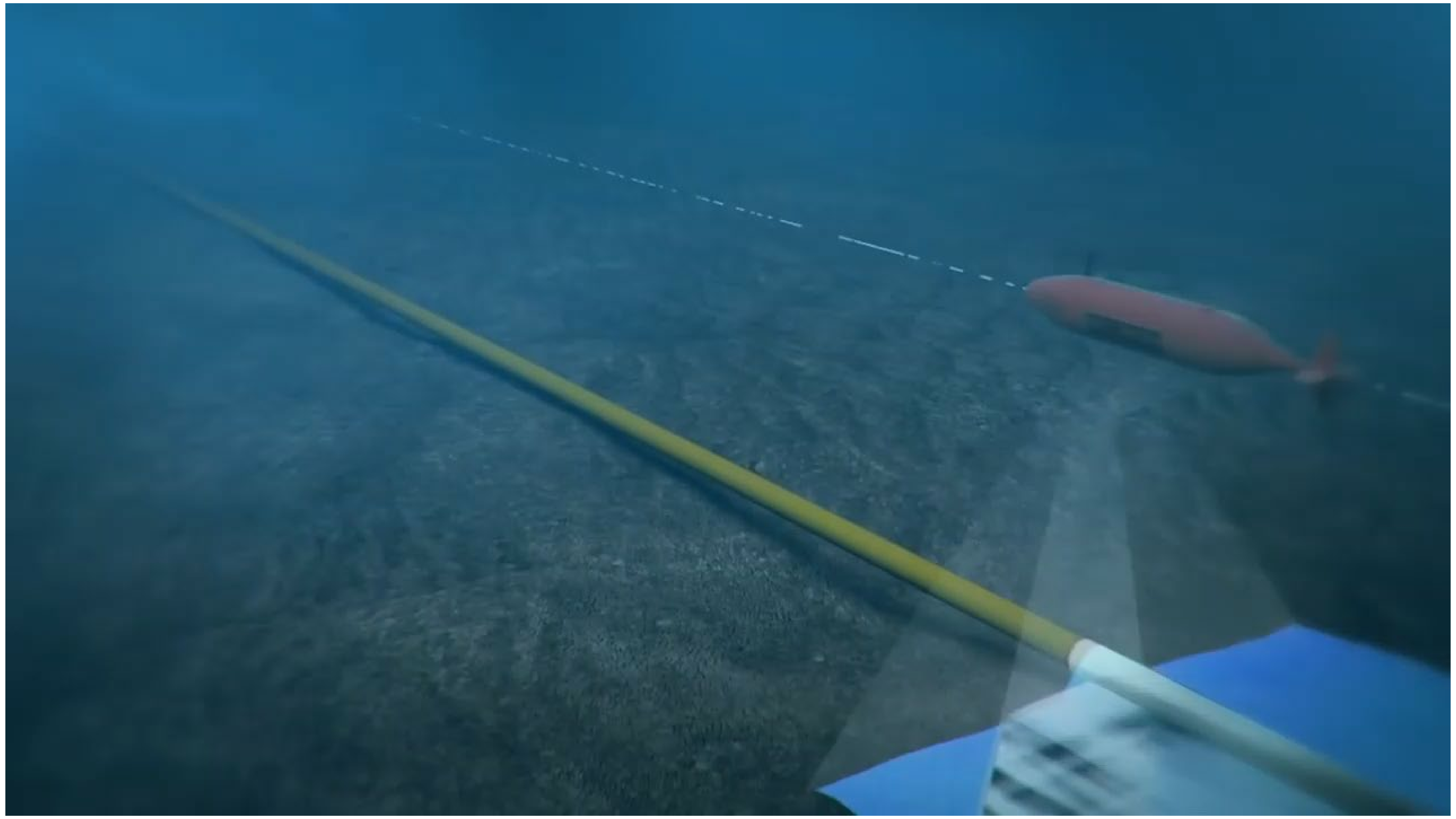
Responsible AI Value
Safety

Remotely Operated Vehicle

Pipeline inspection with a
Remotely Operated Vehicle

Ref.: Underwater pipeline inspection with ROV, Hibbard Inshore https://www.youtube.com/watch?v=-09as6aooWk (Accessed on 08.08.2023)

Underwater Autonomous System



Pipeline inspection with an
Underwater Autonomous System

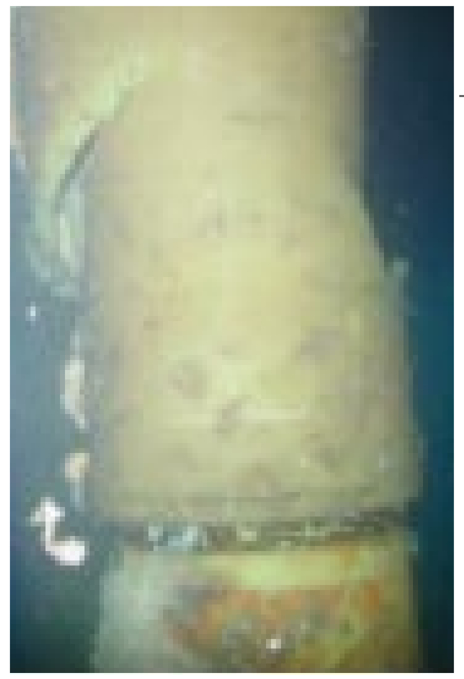
Ref.: How to inspect subsea piplines six times faster, Kongsberg Gruppen https://www.youtube.com/watch?v=7VMTsGYJ7JY (Accessed on 08.08.2023)

Images property of Equinor

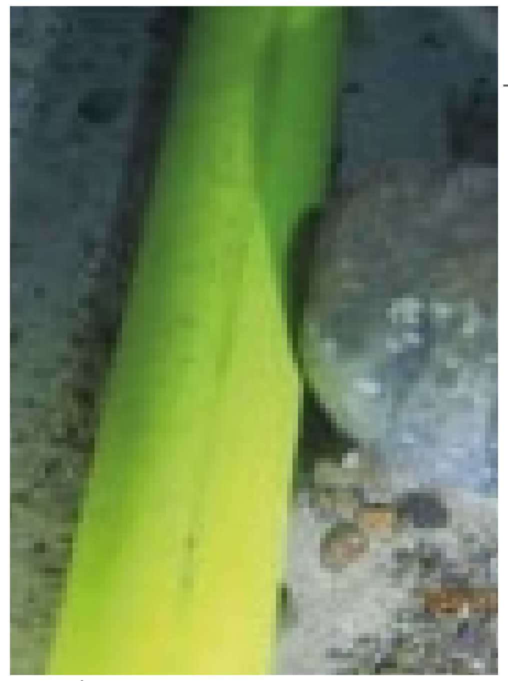
External anomalies as risk factors

Any evidence of **fluid leakage**.

Any external **corrosion** on the exposed metal or outer sheath.



Any external **damage, deformation, and bending** on the pipe surface, anodes or other components.



Objects in the nearby vicinity that can cause damage or obstruct visibility.

Any **debris** blocking the visibility of the pipeline, including litter and other seabed debris, and sediments, is known as fouling.

Ineffective **pipeline support**, including ineffective seabed support.

And **buried pipelines**.

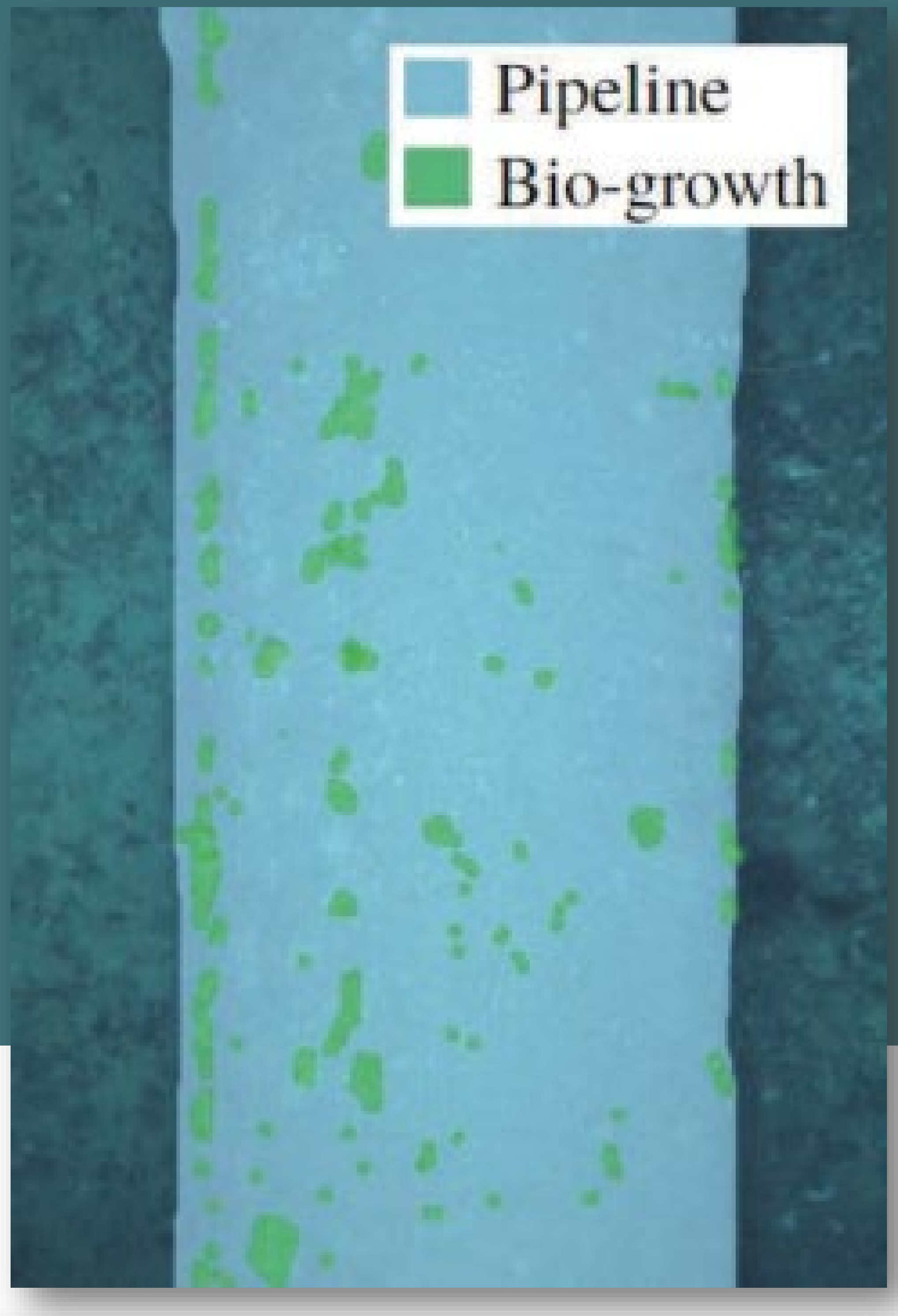
Anomalies as risk factors contributing to pipeline failure

Potential Hazard	Damage Potential			Probability of Occurence		
	Extensive	Moderate	Minor	Most Probable	Expected Occurance	Least Probable
Leakage, explosion						
External Corrosion						
Material Deficiency						
Debris						
Marine Fouling						
Object Dragging (Anchor, boulder)						
Erosion, soil transport and bottom phenomena						

Risk assessment and analysis

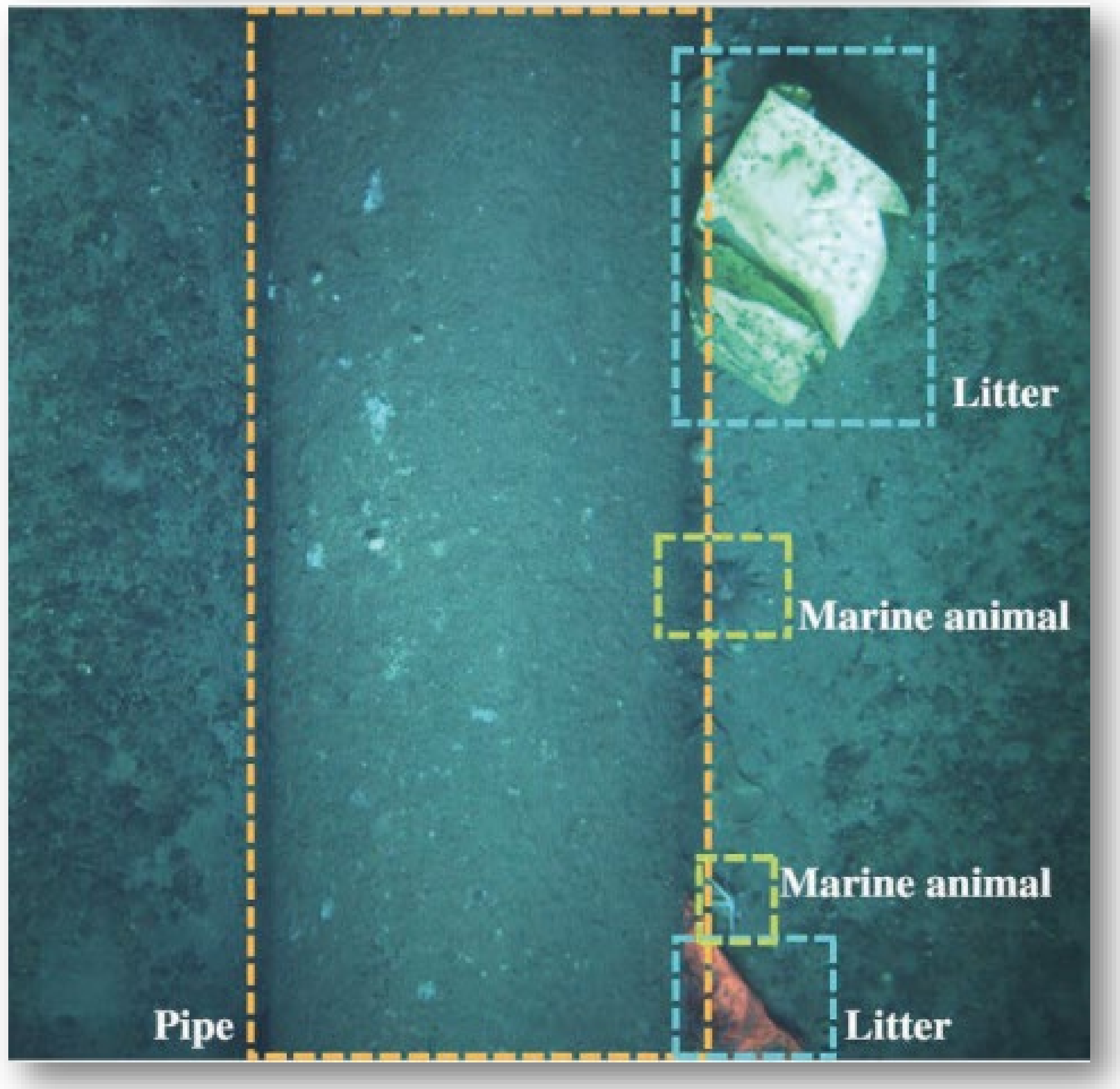
- common and well-established approaches for identifying *what can go wrong* in operations

- offer a list of hazards, as potential sources of harm, the likelihood, sequence of events and consequences of hazards



Dominant AI-based approaches

- ***Computer vision*** methods for analyzing image data.
- ***Machine learning*** methods that learn from large amounts of data to find patterns.
- ***Anomaly detection*** methods that identify and report irregularities, or anomalies, in data patterns.



Images property of Equinor, Stock Images

Train AI models to extract valuable information on hazardous occurrences from massive amounts of data with little evidence of hazards (imbalanced data/bias)

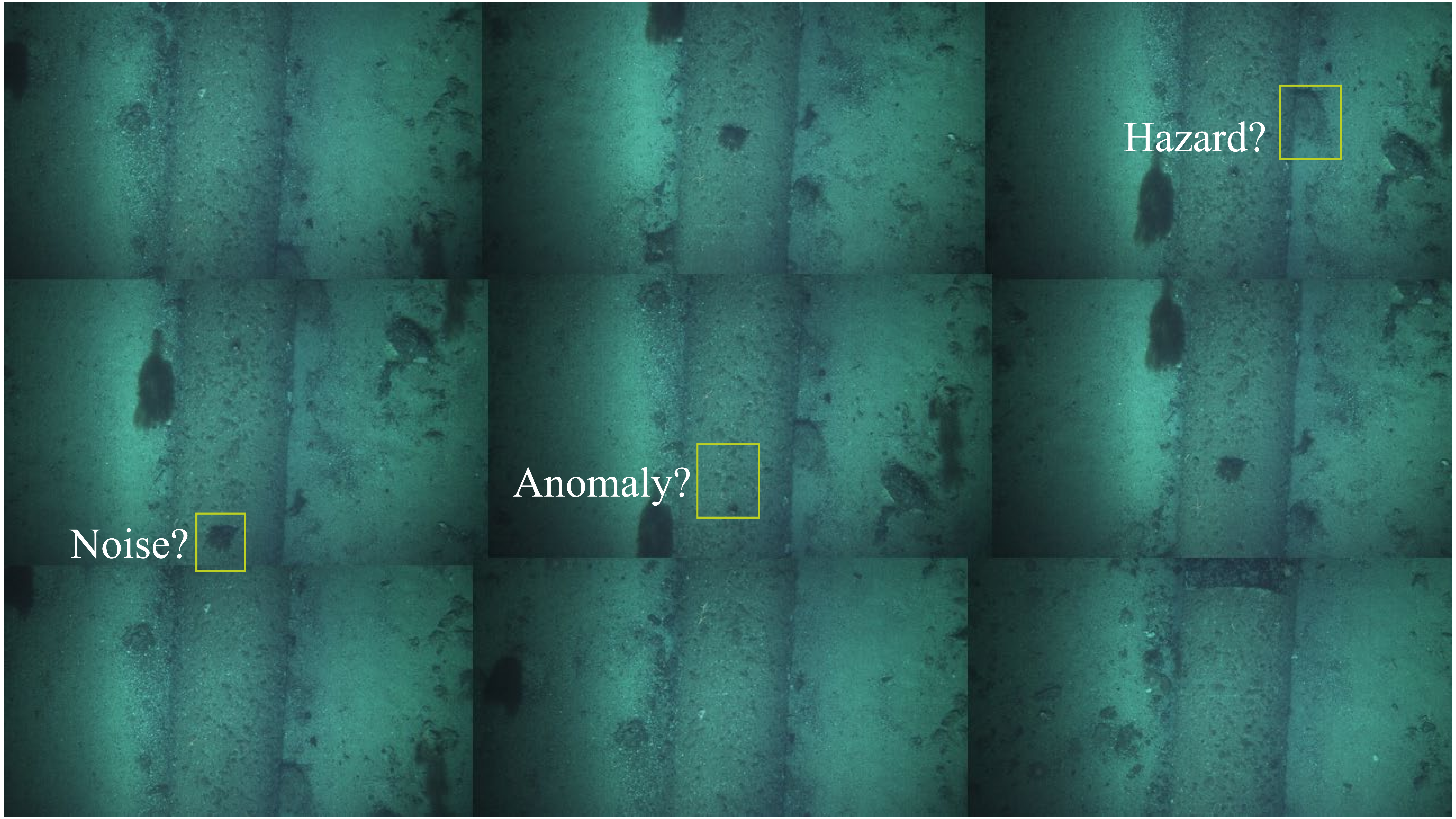


Image (modified)
Original is property of Equinor

Challenges with AI-based approaches

Responsible AI
Bias

Imbalanced (biased) data

Insufficient training data

Responsible AI
Data governance

Image quality

Computer resources

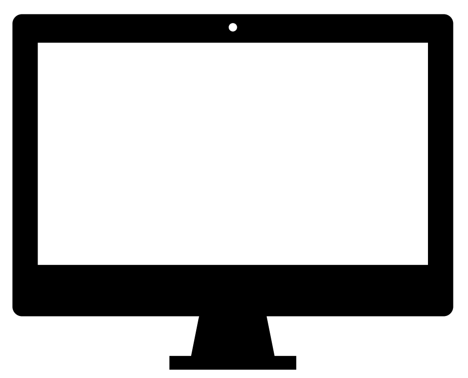
Responsible AI
Sustainability

Explainability, trustworthiness and reliabilty

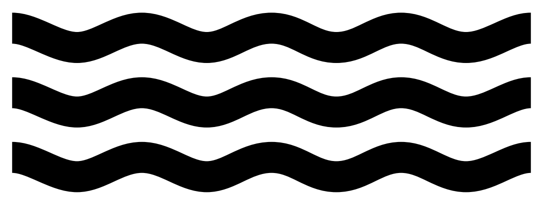
Responsible AI
Explainability and transparency

Some ways to address the *imbalanced data* challenge for anomaly detection:

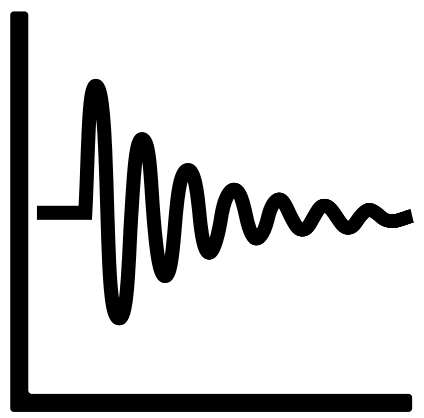
Generate more data



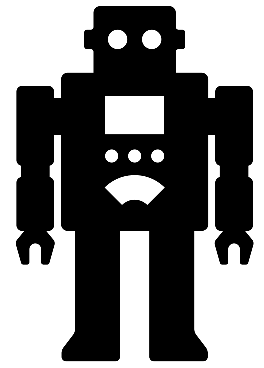
Simulation



Lab

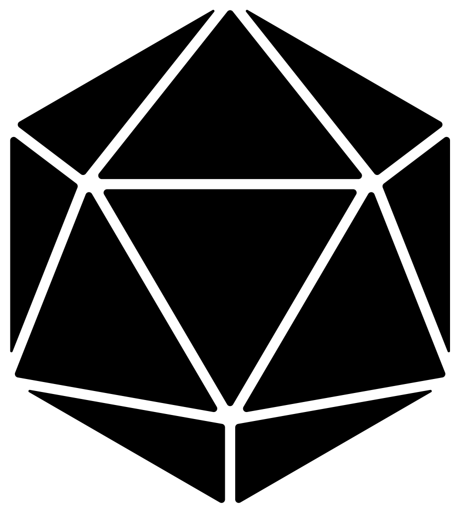


Physics-based extrapolation



Generative AI

Delimit existing data



Set boundaries for normal data

Conditional commands for decision-making (i.e., if-else statements)

Some ways to address the imbalanced data challenge for anomaly detection

Generate more data:

ative AI

Complex

Computationally expensive

Not representative enough

Time consuming

Not trustworthy

Does not provide space for *novelites*

Delimit existing data:

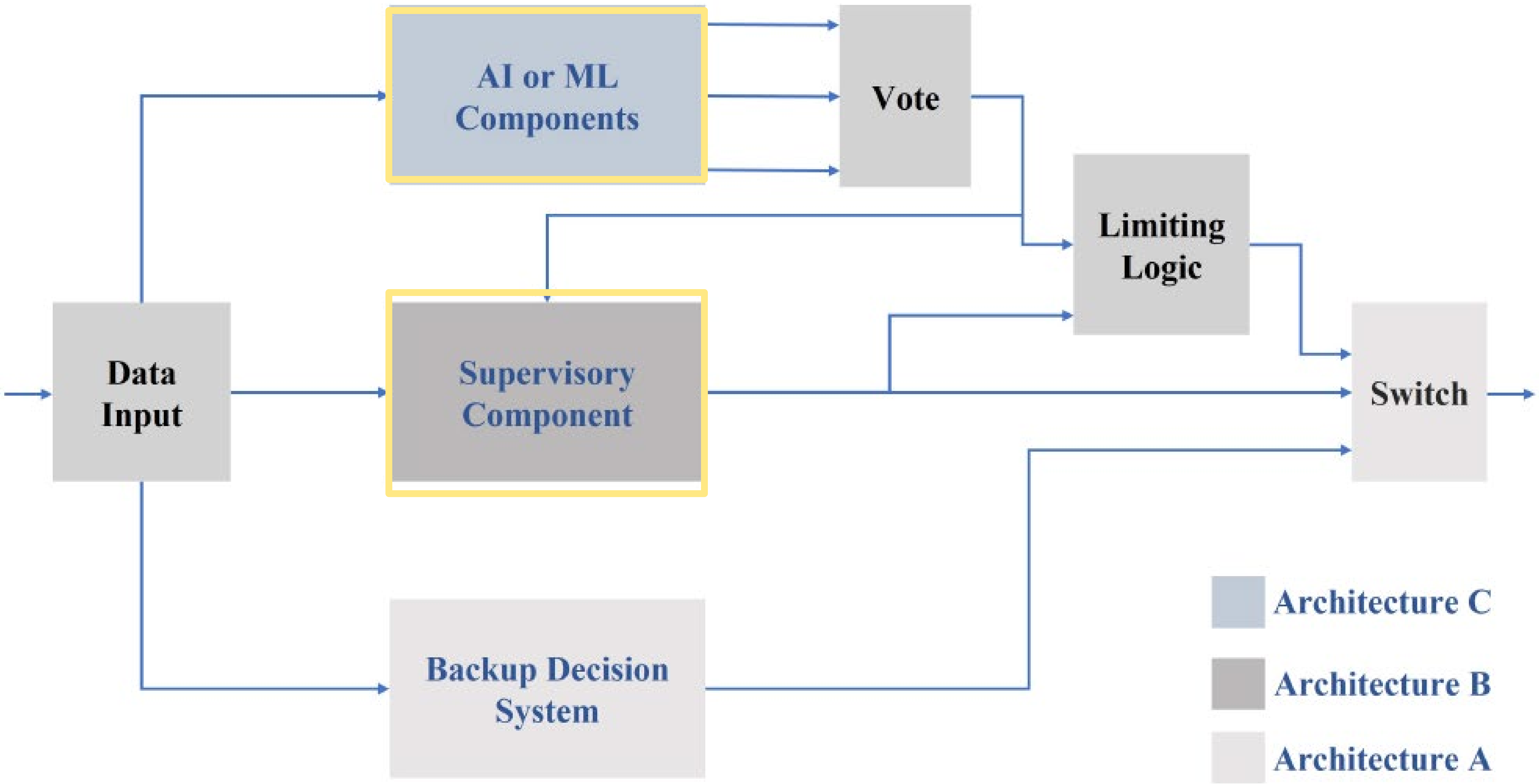
Set boundaries for normal data

Conditional commands for decision-making (i.e., if-else statements)

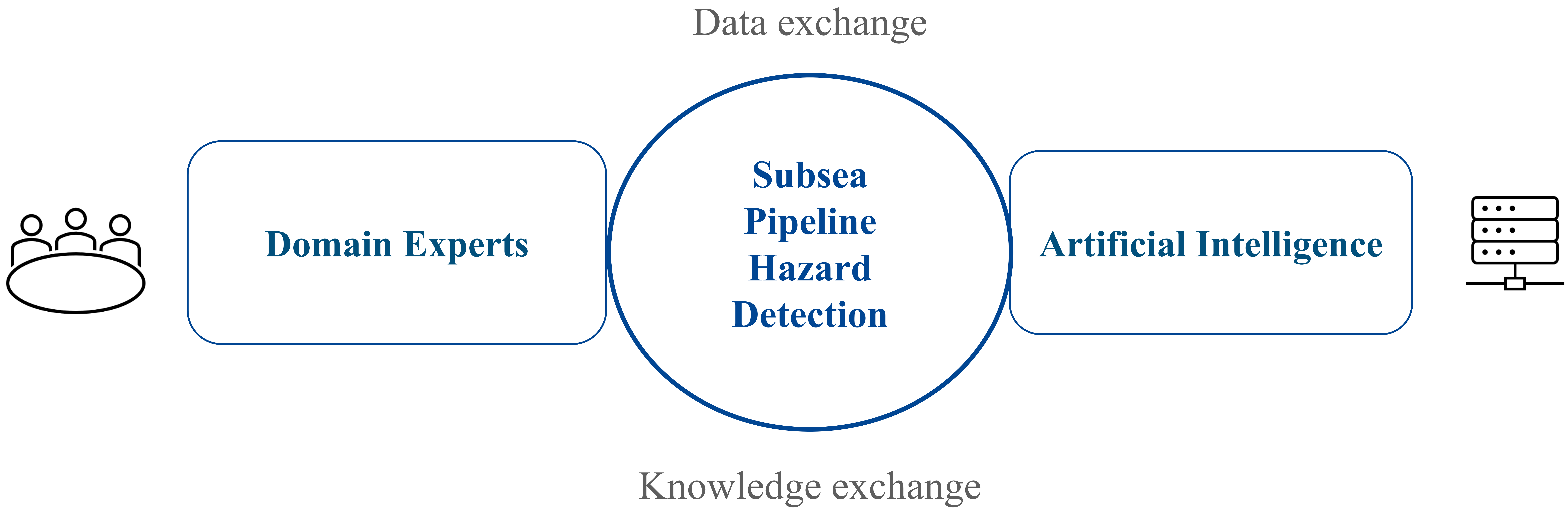
Take inspiration from

ISO/IEC TR 5469:2024

Artificial intelligence — Functional safety and AI systems



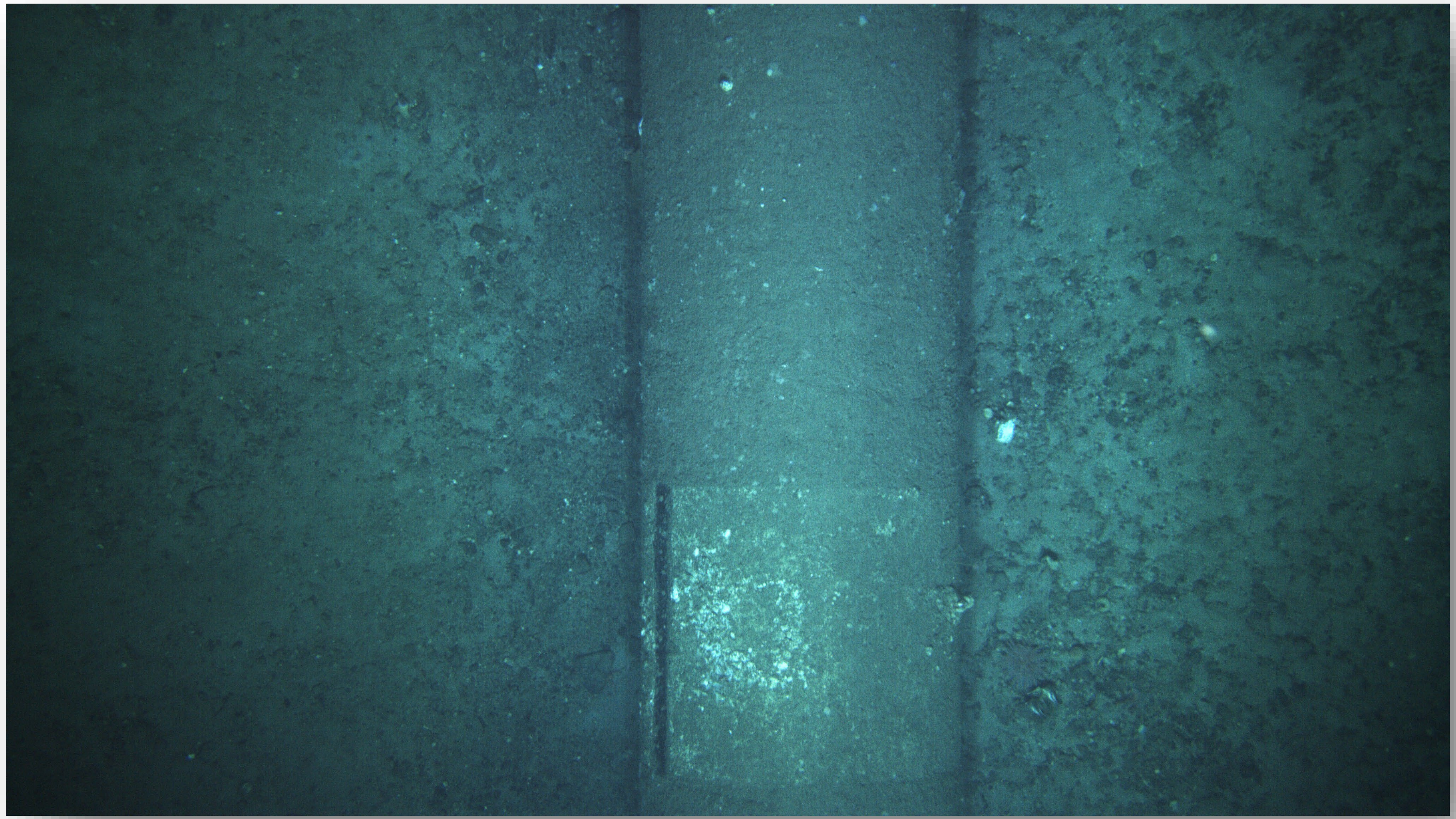
Architectural pattern for systems using AI, Adapted from ISO/IEC TR 5469


Data exchange
Domain Experts
Subsea
Pipeline
Hazard
Detection
Artificial Intelligence
Knowledge exchange

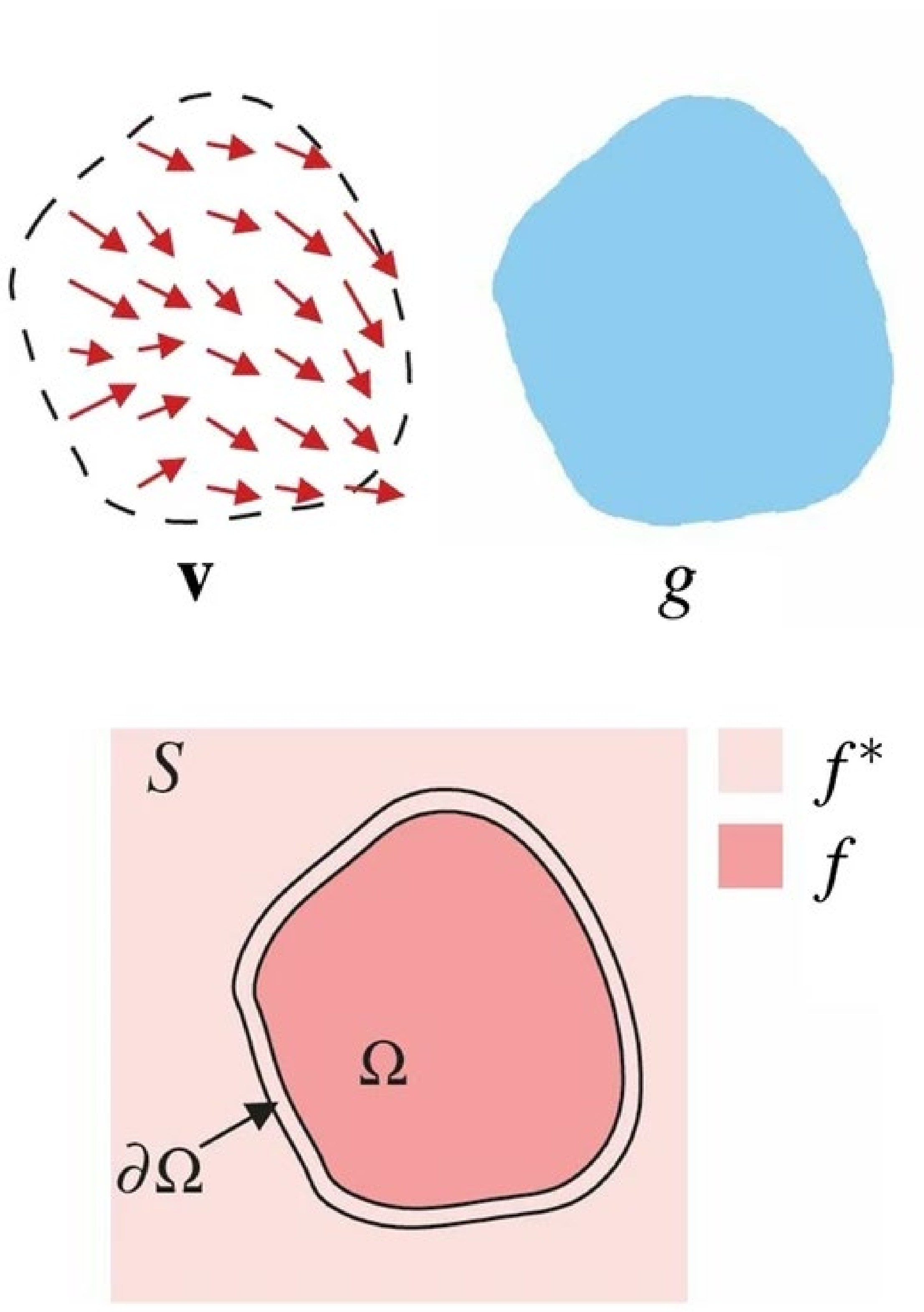
Using real data and identified risks to extend damage evidence on pipelines and improve AI training

- **Low-cost** methodology to address lack of training data
- **Increase** the number of pipeline damage images
- Anomaly detection can **learn** damage pipelines
- **Enhanced** explainability of the approach

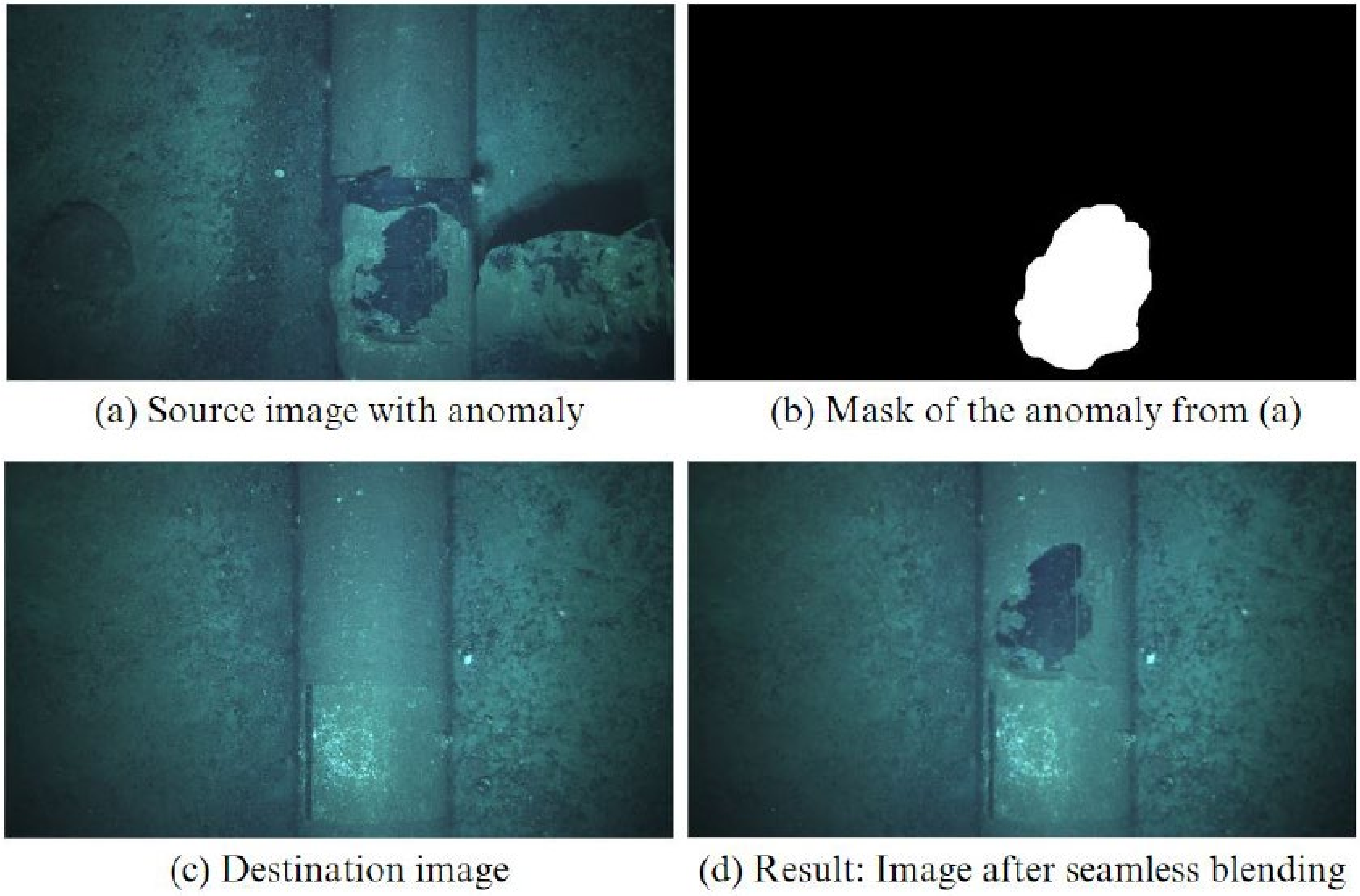
Responsible AI
Sustainability
Sufficient data
Explainability



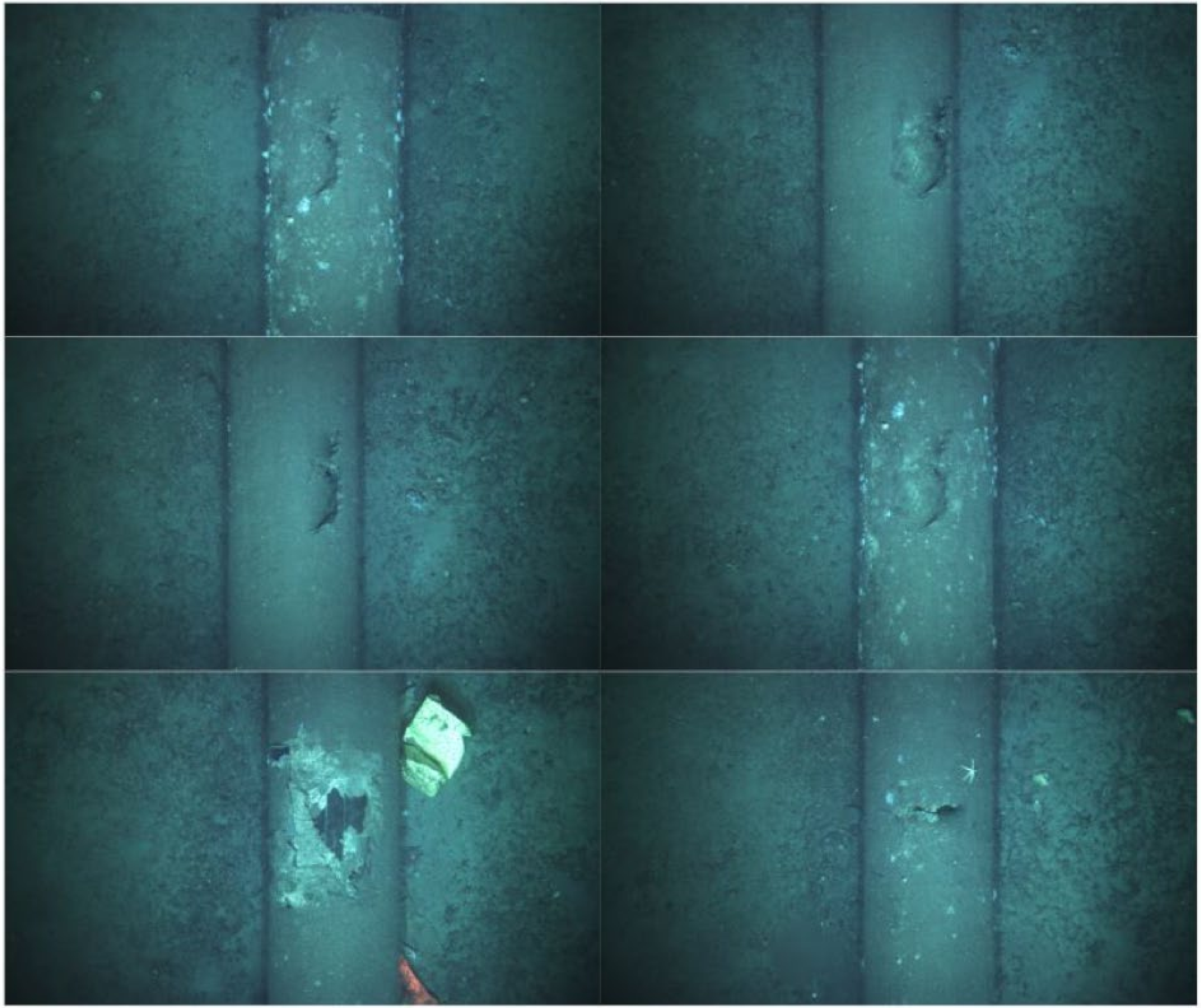
Dataset of 204,000 pipeline images recorded by an underwater autonomous drone (provided by Equinor)



Guided image interpolation



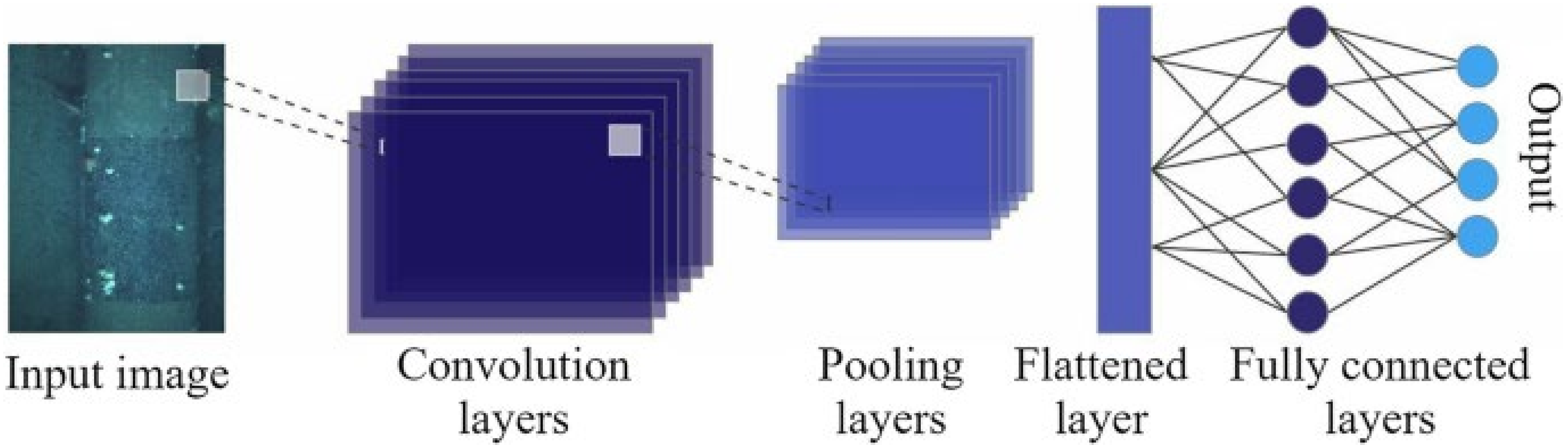
Creating synthetic damage on real images



Synthetic damage on real images

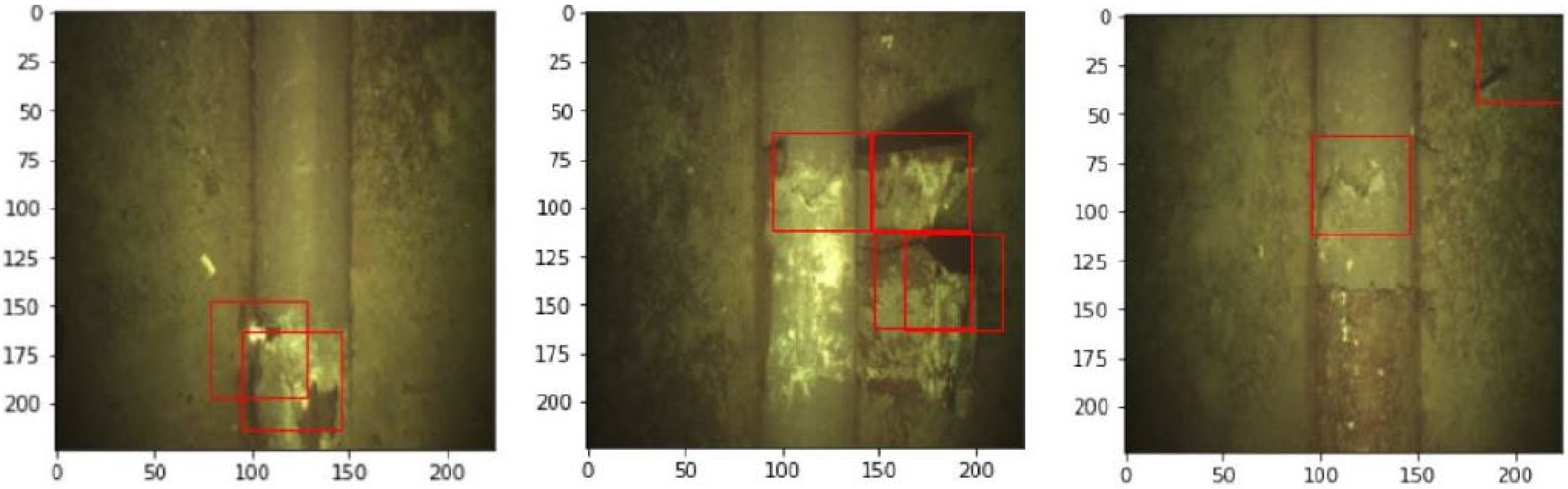
Classification: damage or not?

Convolutional Neural Networks (CNN)



CNN for discovering discriminant data features in images

Inspired by visual cortex processing in the brain that are capable of learning a substantial number of features and extracting patterns

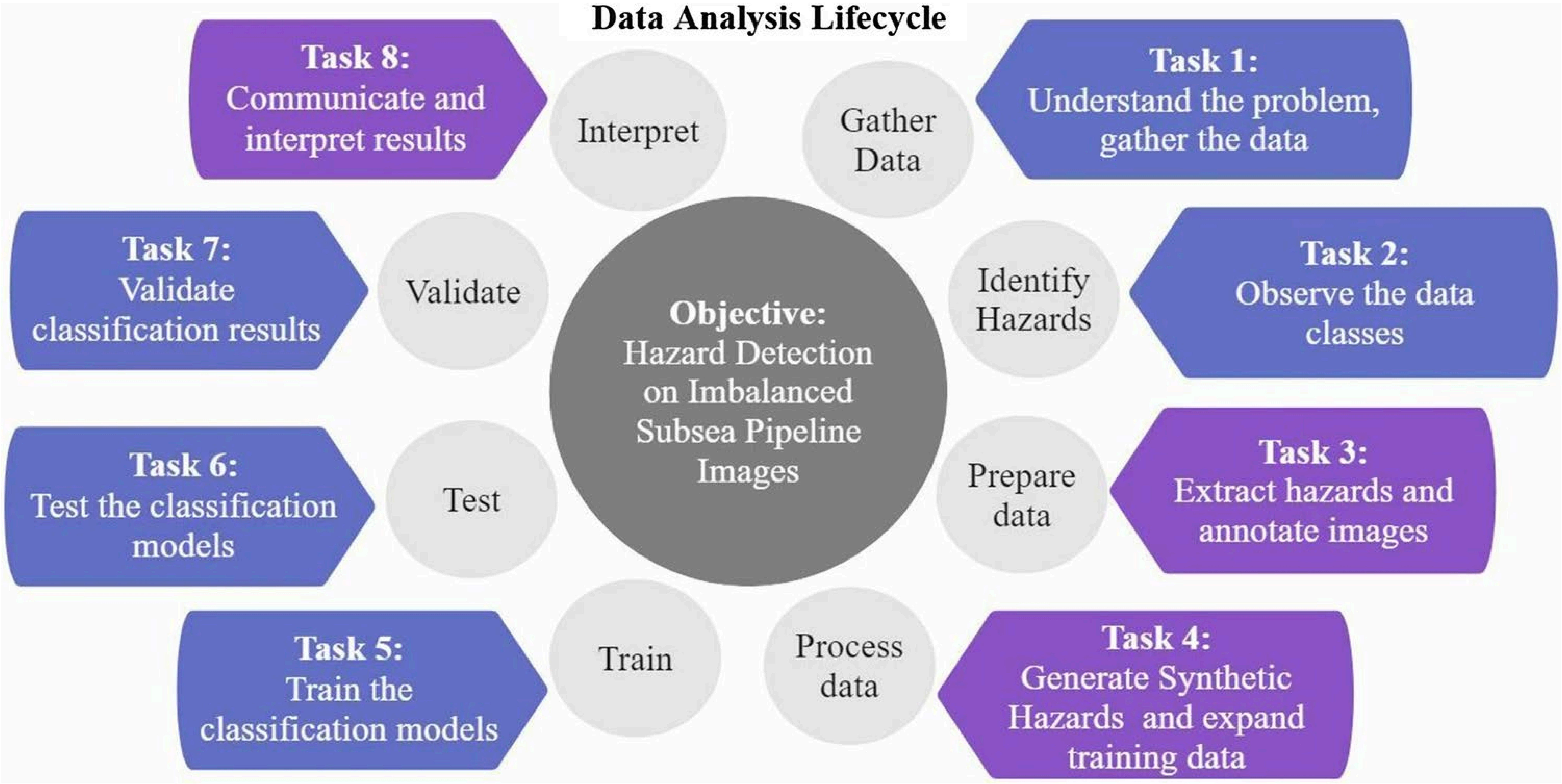


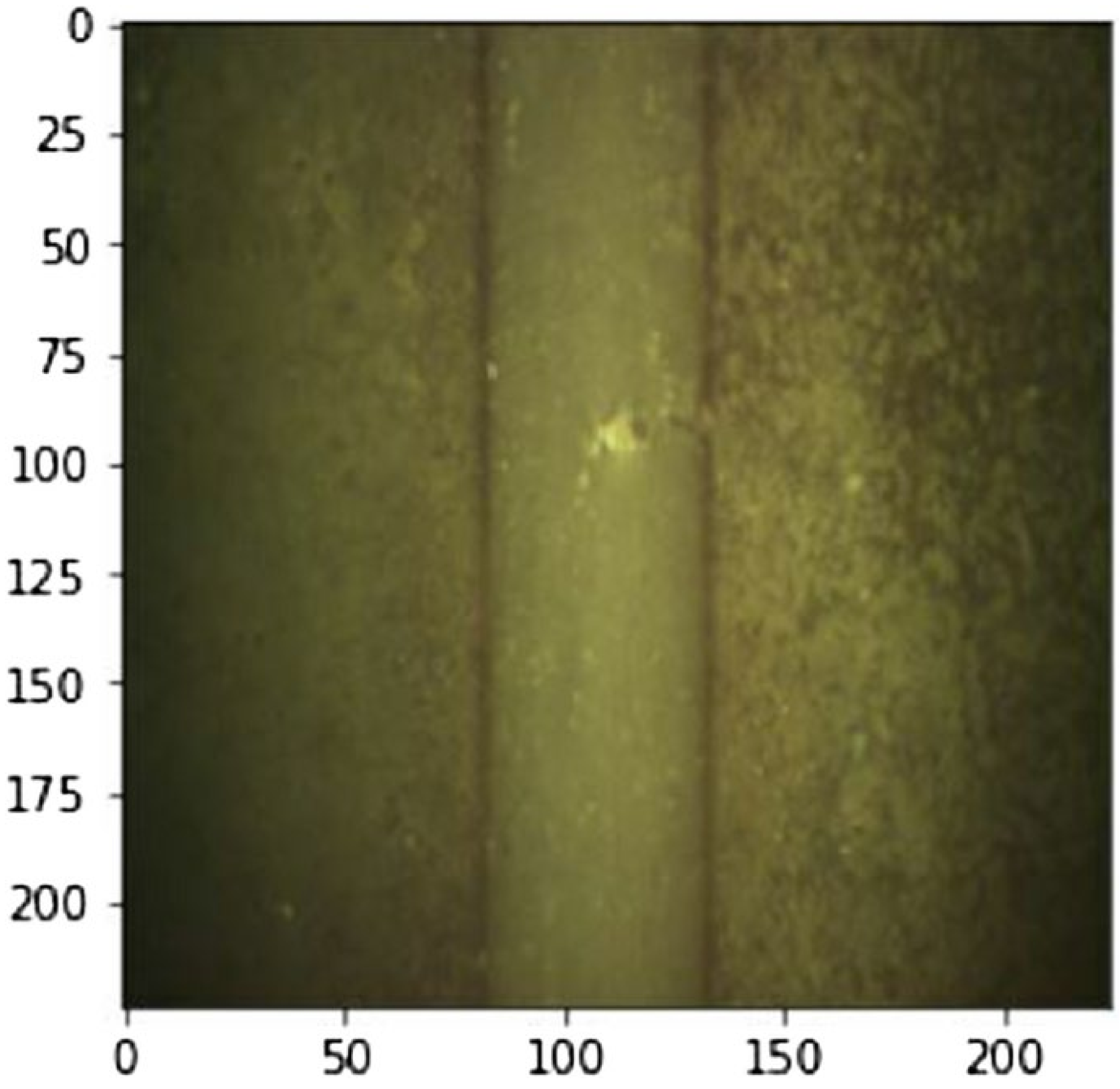
(a) (b) (c)

Addressing Explainability with Localised Anomaly Detection (mechanical damage)

(a) Damage on pipeline
(b) Damage on pipeline + dislocated anode cover on the side of the pipeline
(c) Damage on pipeline + background noise

Methodology





Example of a misclassified image
(classified by CNN as no damage)

Limitations

- Resizing images causes information loss
- Retaining large image size substantially increases time and power needed for classification
- Classification of only one anomaly
- Misclassifying smaller damage
- Efficient image classification algorithms are black boxes

Takeaways

Responsible AI
Sustainability

Create synthetic hazard data with **low cost** improves the training process

Responsible AI
Openness

Open access: **Share** synthetic data instead of sensitive information

Responsible AI
Explainability and traceability

Localize anomalies with distinctive regions on images and **reduce resource waste** by minimizing noise

Responsible AI
Safety

Increased **reliability** of the AI approach by knowledge exchange

Ensuring Reliability of Unmanned Autonomous Systems

Enhancing Safety of Remote Operations

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