White Paper

THE REAL-WORLD DATA ADVANTAGE

How KartaSoft's **Physics-Informed Artificial Intelligence** Predict Failures and Optimize Maintenance

Authors:

Dr. Ian Oppermann
Chair, Global Advisory Board, KartaSoft

David Cleminson
Chief Technology Officer & Global Head of Critical Infrastructure and Defence, KartaSoft

kartasoft
Lead with Insights

Table of Contents

03 Executive Summary

04 Gold-Standard Data is Rare and May Be Something You Can't Afford

05 Physics-Informed AI: Built for Real-World Complexity

06 From Data Lakes to Actionable Intelligence

07 Building Trust Through Transparency & Impact for Operators

08 Contact Information

Executive Summary

Operators in energy and utility companies face a critical challenge: aging infrastructure, rising ESG pressures, and unpredictable failures, all while drowning in messy, incomplete data. Traditional AI models demand gold-standard data, but waiting for perfection costs millions.

This paper introduces a rigorous physics-informed AI (PIAI) model, a breakthrough approach that combines engineering principles with machine learning to deliver predictive insights, even when data is far from perfect. Learn how leading operators are using this technology to optimize maintenance strategies, reduce downtime, and meet strategic business goals.

Defensible

Apply machine learning from a perspective of underlying physical model insights.

Bias-free

Real-world validation under blind conditions.

Financial Impacts

Optimizing operations and reshaping capital planning strategies.

Gold-Standard Data is Rare and May Be Something You Can't Afford

For decades, predictive analytics assumed pristine data was the key to success. In reality:

- Pipeline and asset data is fragmented, noisy, and inconsistent.
- Algorithms trained on perfect lab data fail in real-world conditions.
- Waiting for perfect data delays transformation and inflates costs.

Existing models fall short:

1. Pure physics-driven approach:

Conventional mechanistic models, based on the physical laws of natural sciences, have long been used in infrastructure industries like the energy and utility sectors to approximate the performance or behaviour of assets and processes.

They have their place in 'human-sized' data problems when the theory is an accurate characterisation or predictor of behaviour, but struggle where there is uncertainty:

Complex environments
Multiple potential mechanisms in play

Uncommon conditions
Difficult to predict rare failures or behaviours

Unclear causal relationships
What is really driving change or failure?

Noisy, incomplete data
Inability to calibrate models

2. Pure data-driven approach:

Data-driven tools like Machine Learning (ML) can leverage very large datasets to solve problems without a 'theory first' approach.

However, a purely data-driven model can be 'blind' - it doesn't 'understand' what it is trying to predict, and is:

- Heavily depends on the quality and quantity of training data
- Computationally intense, time-consuming and expensive to train
- Challenging to generalize results to new, unseen scenarios and achieve actionable predictions due to biased/incomplete datasets

Physics-Informed AI: Built for Real-World Complexity

Never let perfect get in the way of good. Your competitive edge lies in leveraging what you have - today.

The new science of PIAI is the 'Goldilocks' part of the 'Mechanistic-to-Machine Learning' spectrum and goes directly to contemporary challenges and needs of infrastructure-heavy essential service providers, their customers, and regulators.

Unlike traditional "black-box" machine learning models that learn relationships solely from input-output data, or slow and computationally intensive physics models, PI-AI models are constrained by the governing physical laws of the system they represent. This fusion of data-driven learning with physics-based constraints offers a robust framework for solving complex problems governed by differential equations.

Applying ML from a perspective of underlying physical model insights

Faster, cheaper and uses less data, while improving quality & utility of insights

Better at finding weak signals in noisy data and/or complex systems

This hybrid physics & data approach:

Filters out noise and anomalies.

Detects weak signals buried in messy datasets.

Predicts failures 3–6 months ahead of leading indicators.

Why It Matters:

When you manage large-scale, complex assets, early failure prediction means fewer emergency interventions, optimized maintenance budgets, and safer, more reliable operations.

From Data Lakes to Actionable Intelligence

Data lakes promise flexibility but often create inefficiencies:

Storage might be cheap, but curation and lifecycle management are costly.

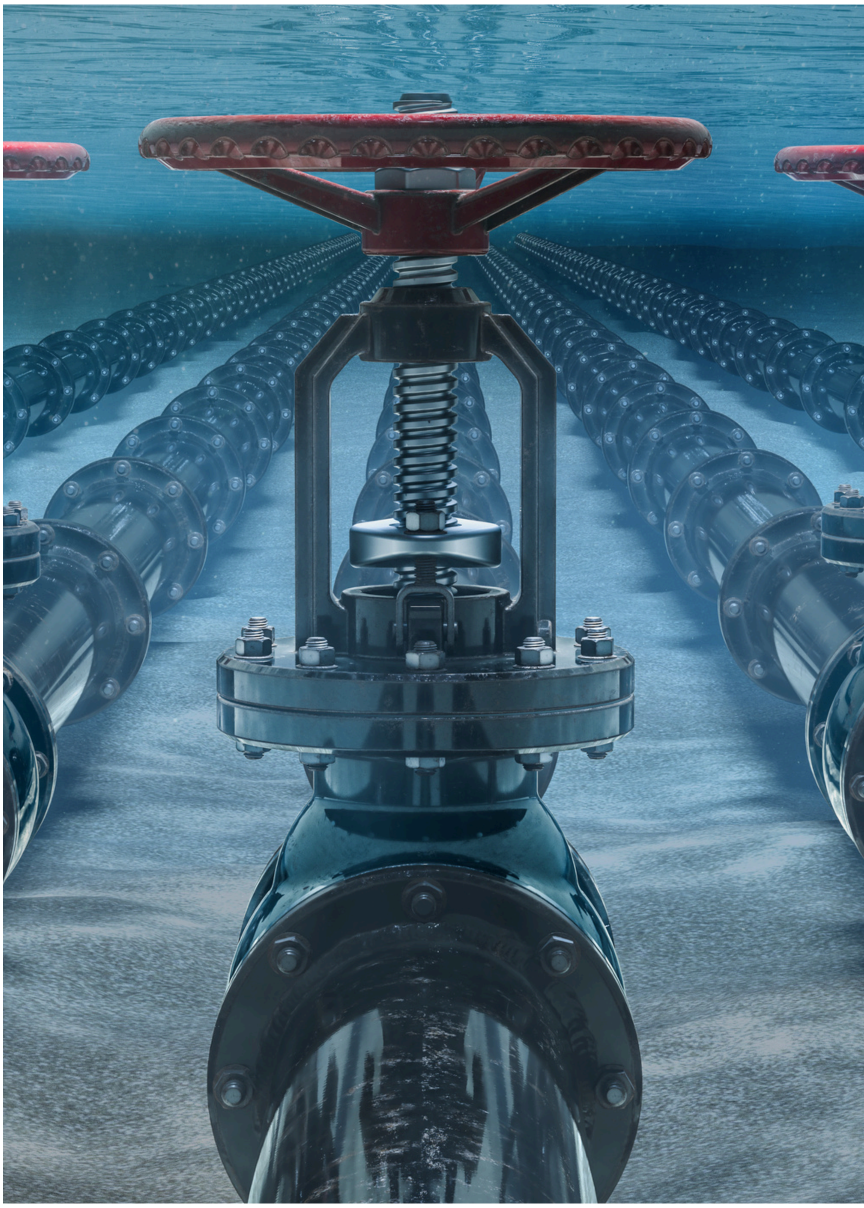
Systems generate more data than they consume, complicating lineage.

KartaSoft solves this by:

Ingesting format-agnostic data.

Prioritizing fit-for-purpose datasets.

Delivering insights without exhaustive data cleansing.



Building Trust Through Transparency

Trust isn't built on perfect data. It's built on:

Explainability

Clear frameworks for how predictions are generated.

Validation

Blind testing against historical data.

Continuous Learning

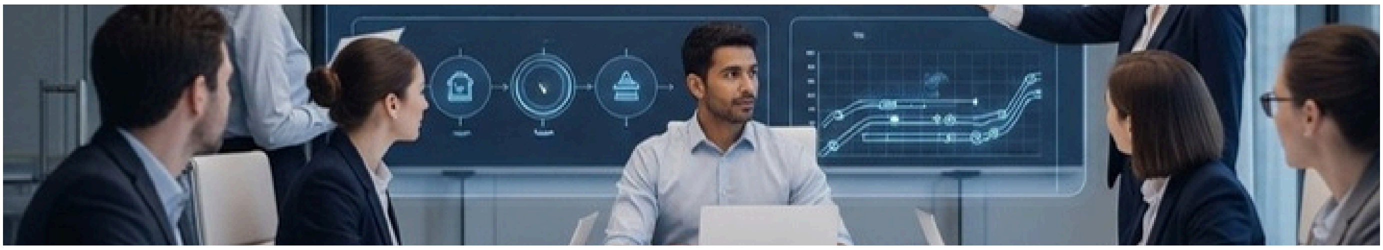
Models that adapt as assets age and environments shift.

KartaSoft's approach includes:

3–4 years of historical data for training.

Blind test sets for performance benchmarking.

Transparent reporting on prediction accuracy.



Impact for Operators

Physics-informed AI enables:

Reliability-Centered Maintenance

Replace reactive schedules with predictive and prescriptive strategies.

Capital Efficiency

Optimize capital planning and reallocation strategies across asset portfolio.

ESG Compliance

Monitor and improve sustainability metrics without costly sensor deployments.

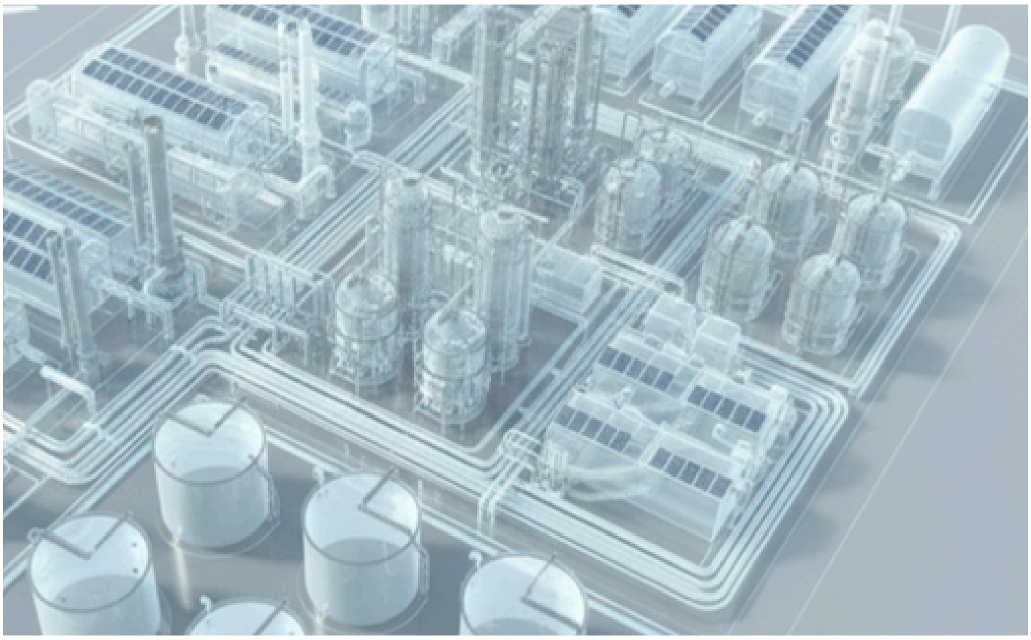
Example: For a gas pipeline spanning 147,000 miles, predictive insights allow targeted maintenance, avoiding blind inspections and minimizing downtime.

Conclusion

Gold-standard data is rare, and waiting for it is costly.

Physics-informed AI offers a practical, proven path to predictive and prescriptive intelligence, operational resilience, and ESG compliance.

Asset managers who embrace this approach today will lead the industry tomorrow.



Watch Energy Equation EP1: **Forecasting Intelligence from Imperfect Data** for expert insights.

Watch now

Contact KartaSoft and speak about your infrastructure intelligence.

Email

info@kartasoft.com

Website

www.kartasoft.com