

Introduction & Background

Problem Statement & Objective

Problem Statement: Traditional pipeline monitoring methods fail to detect leaks early, leading to safety hazards and costly damage.

Objective: Developing a real-time pipeline health monitoring system capable of early leak detection, accurate localization, and rapid alerting to improve pipeline reliability.

Constraints

Temperature & mechanical changes can cause drift in vibration measurements.

Pipeline test pressure must remain within approved safety limits (≤ 2.0 bar).

Sensor accuracy must not deviate by more than $\pm 10\%$ operationally.

The platform must be developed using open-source tools.

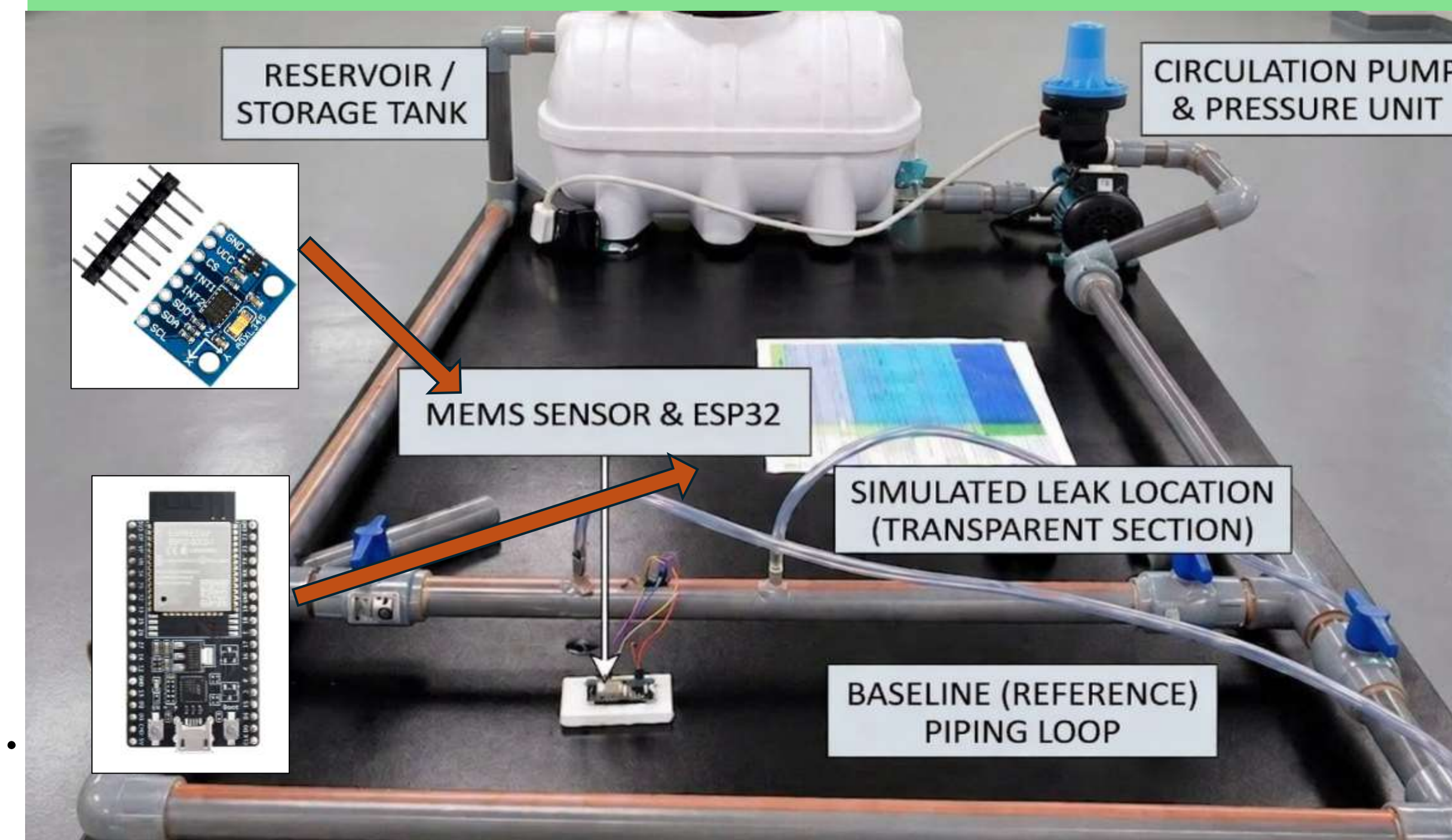
Pipeline flow conditions must remain steady.

Specifications

Dashboard update: every 5 minutes	Structural stress: $\leq 30\%$ of material yield strength
Leak location error: $\leq \pm 5-10$ cm on a 2-3 m pipeline	ROI: < 18 months
SNR: 3-8 dB	MEMS bandwidth ≥ 200 Hz & $\geq 2f_{n,max}$
POD: $\geq 90\%$ at 95% confidence level	Manual inspection cost reduction: 30%
Pressure-drop sensitivity: 0.05 bar	Flow-rate variation: within $\pm 2\%$
Sampling rate: ≥ 200 Hz	System uptime: $\geq 99\%$

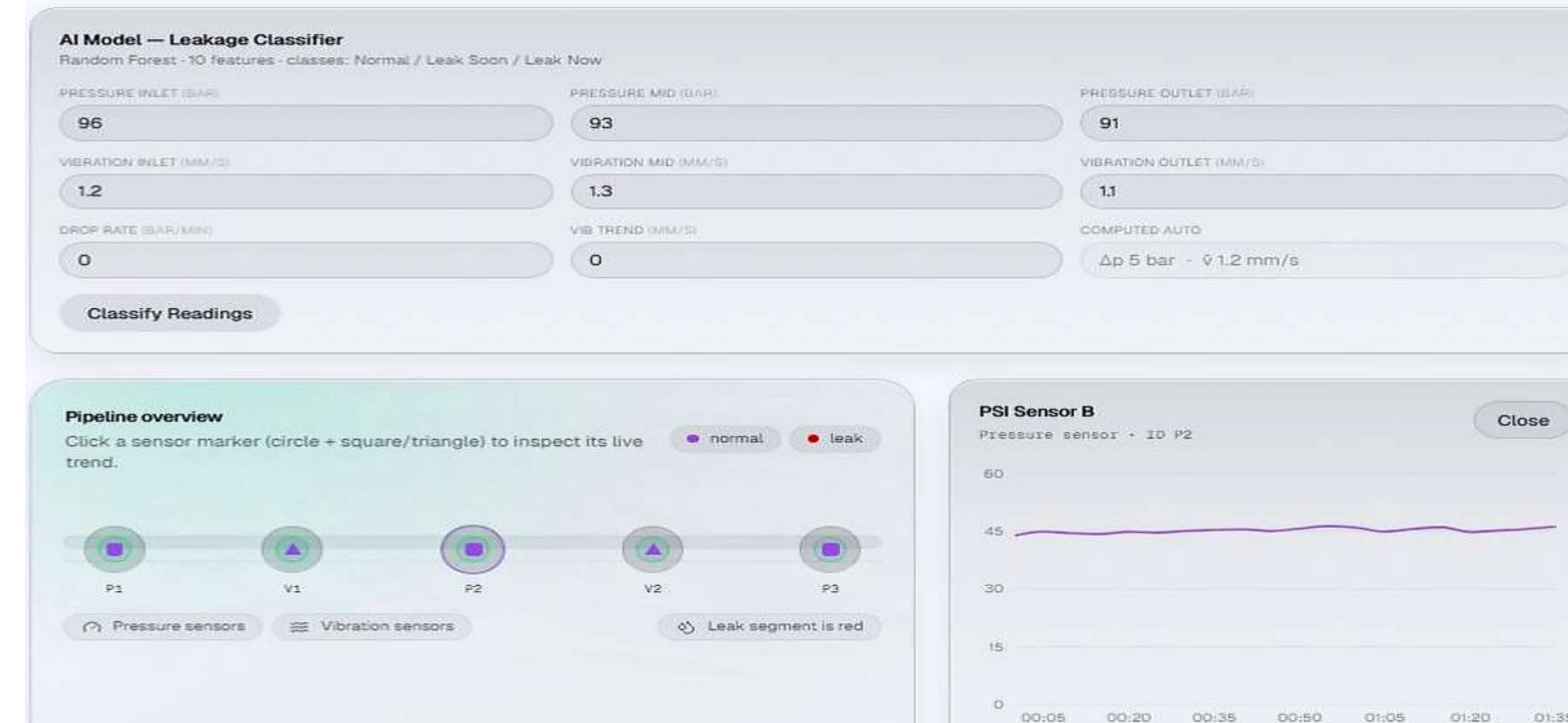
Prototype Design

Final Prototype & Dashboard

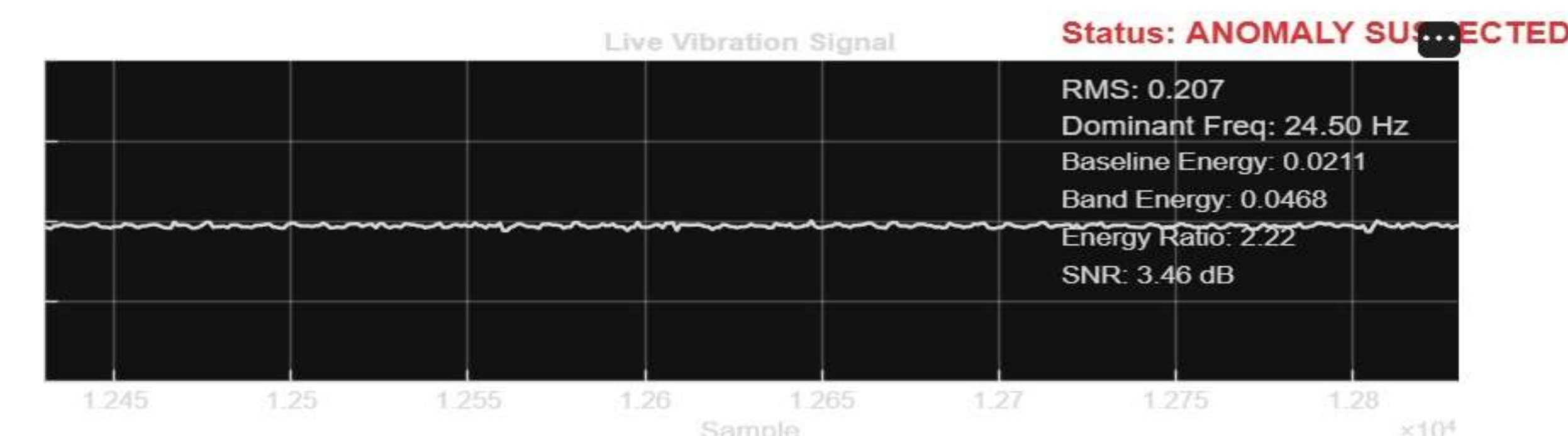
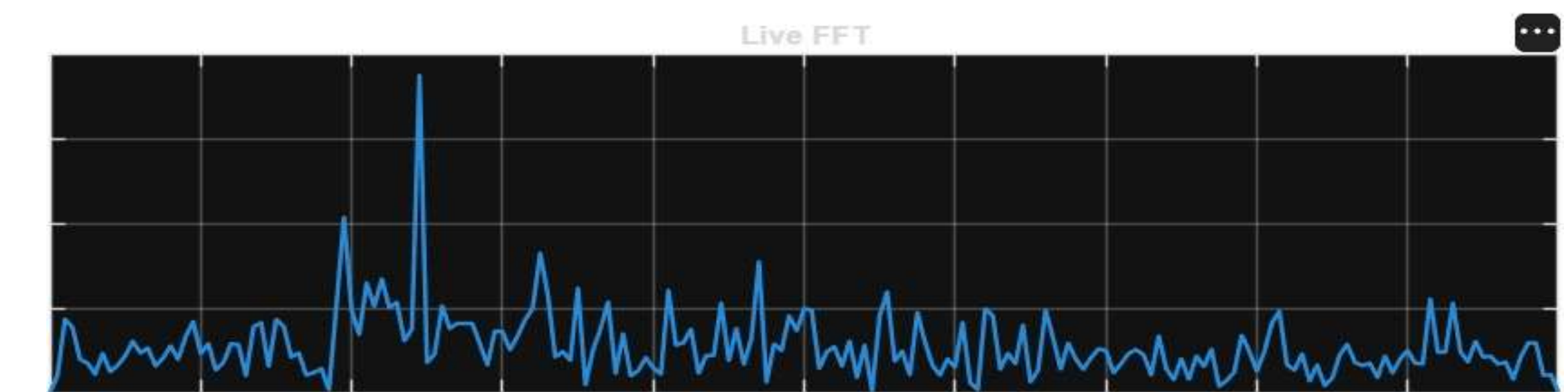
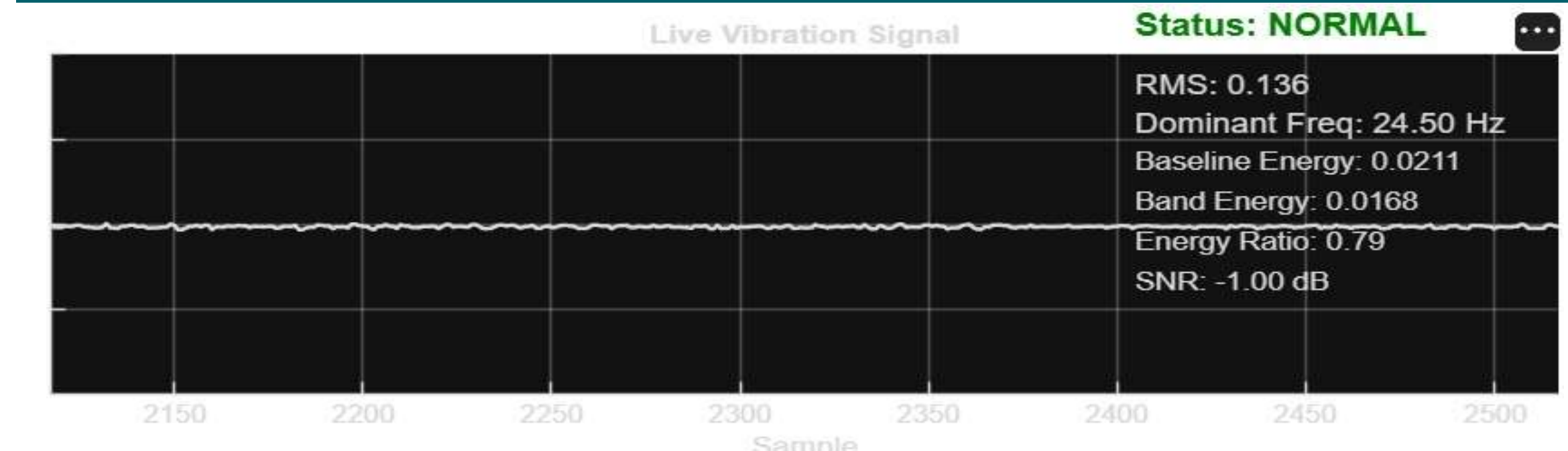


Pipeline Sensor Monitor

Senior project KFUPM term 2S2. Select a marker on the pipeline to inspect a sensor's pressure/vibration trend and highlight leak segments in red. Platform developed by Oukba Bouketir



Testing & Validation



All Constraints and specifications have been successfully met. ✓

Conclusions

The prototype was successfully designed, implemented, and tested to validate the proposed leak detection concept, showing effective leak detection and reliable monitoring under controlled conditions. The integration of MEMS sensing technology with real-time signal processing improved detection sensitivity and supported accurate leak localization, confirming the system's potential as a practical, cost-effective, and efficient solution for smart pipeline monitoring and leak prevention, while future improvements can further enhance accuracy and scalability.