

- **Problem Statement ID** – 26025
- **Problem Statement Title-** Development of an AI-enabled Low Cost Real Time Mine Subsidence Monitoring, Prediction and Early Warning System for Underground Coal Mines in India
- **Theme-** Smart Automation
- **PS Category-** Hardware
- **Team ID-** 26RBU143
- **Team Name** - ZeroIQ's



Prototype: collisioni.tech



AI-Enabled Wireless Surface Mesh Network for Real-Time Mine Subsidence Early Warning

Self-Healing LoRa Mesh – AI-Enabled Real-Time Subsidence Monitoring for Underground Coal Mines

- Solar-powered ESP32 nodes with tilt, vibration, strain & crack sensors span the mine surface.
- Self-healing LoRa mesh – routes re-form around any failed node, no single point of failure.
- Edge-to-cloud pipeline: LoRa → gateway → MQTT → InfluxDB/PostGIS → live GIS dashboard.
- AI engine scores deformation trend to rate subsidence severity before physical failure.
- Automated SMS, email & app alerts reach mine safety officers, DGMS and CMPDI directly.

How It Addresses the Problem:

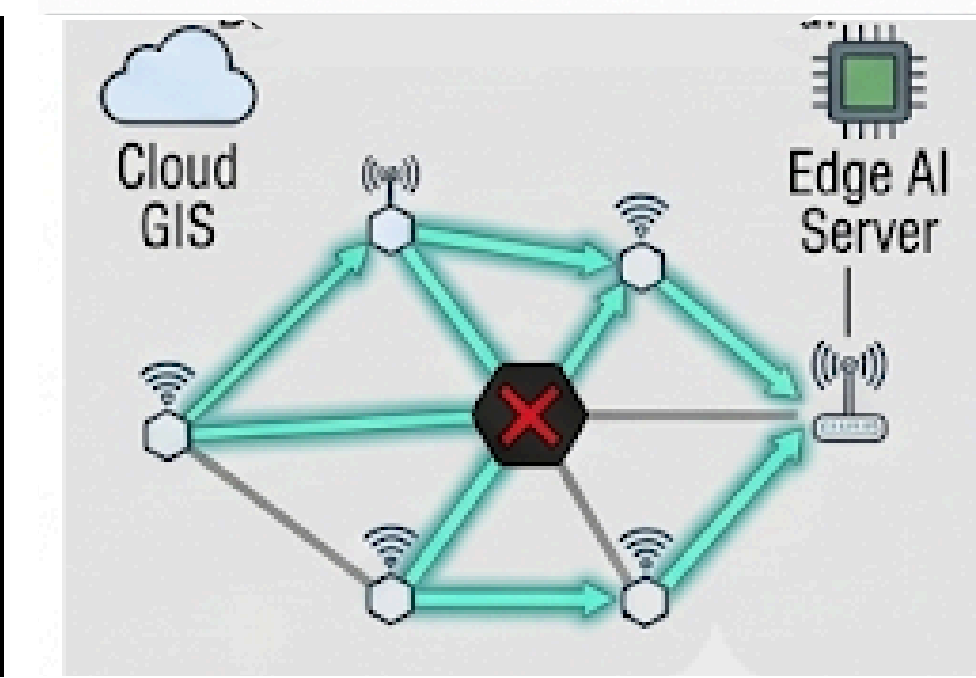
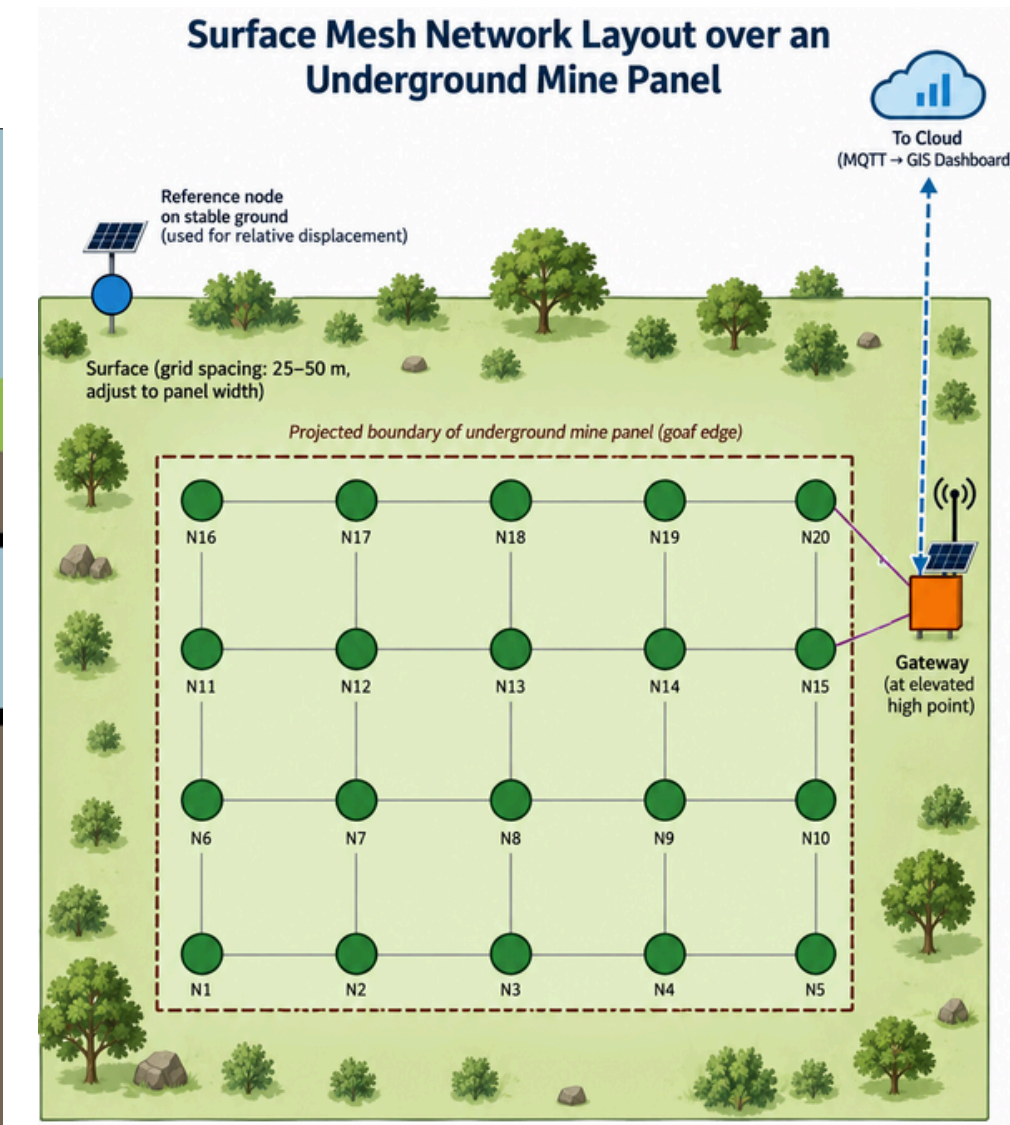
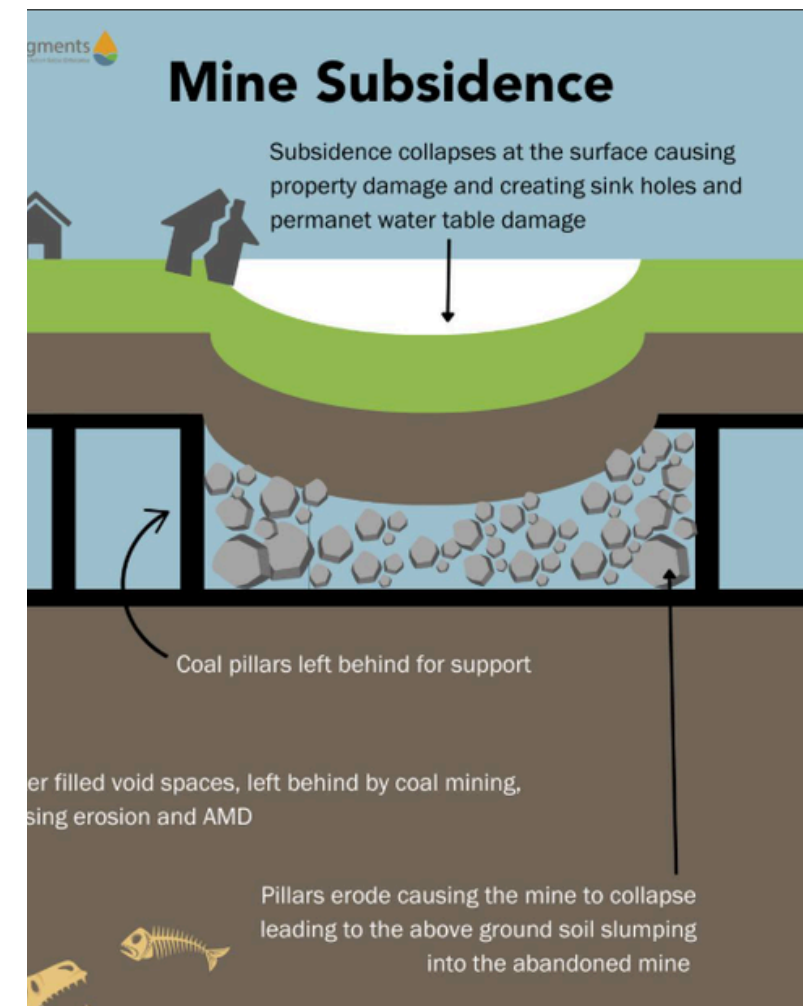
- Replaces periodic manual surveys – continuous edge monitoring across the full panel.
- Shifts from reactive to predictive – flags abnormal micro-movement before collapse.
- Closes the visibility gap – colour-coded risk zones replace a survey report weeks late.
- Filters nuisance events – alert needs coherent multi-node drift, not one sensor spike.

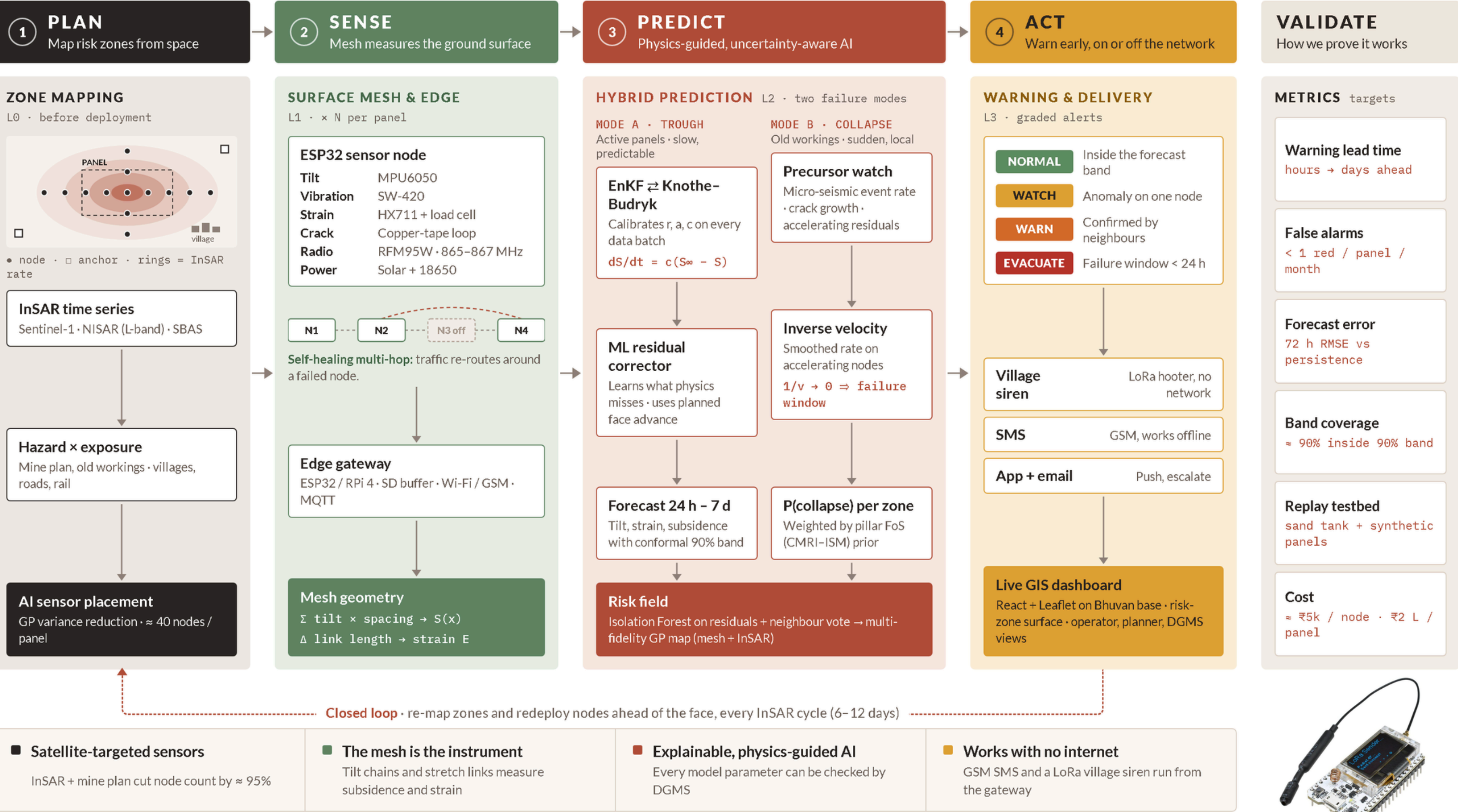
Innovation & Uniqueness:

- First self-healing LoRa surface mesh purpose-built for Indian coalfield subsidence.
- Hybrid detection – Isolation Forest scored against CIMFR's Modified Influence Function model.
- Works with zero connectivity – GSM SMS + LoRa village siren run off the gateway alone.
- ~₹2,300/node on commodity hardware, de-licensed 865–867 MHz band – no spectrum fee.

Prototype: collisionni.tech

Jharia Coal Mine
Subsidence →





FEASIBILITY AND VIABILITY

FEASIBILITY

Off-the-shelf hardware. ESP32, MPU6050, SW-420, HX711, RFM95W — all commodity parts, nothing fabricated.

No licence, no operator. 865–867 MHz is de-licensed — no spectrum fee, no telecom contract, no data plan.

Works with zero network. LoRa mesh + gateway SD buffering — the normal condition across remote coalfields.

Using established integrated methods. Mesh routing, Isolation Forest, IDW and the subsidence profile model are all published work.

CHALLENGES & RISKS

Nuisance events look like subsidence. Cattle, blasting and monsoon runoff can move a node or snap crack tape.

Coarse sensors, thermal drift. MPU6050 resolves only tenths of a degree; daily heat swings outrun early subsidence.

Power budget fights the mesh. Always-on relay nodes drain a solar cell fastest, right through monsoon weeks.

No field dataset exists currently. No labelled Indian subsidence telemetry to train the model on, or validate lead time against.

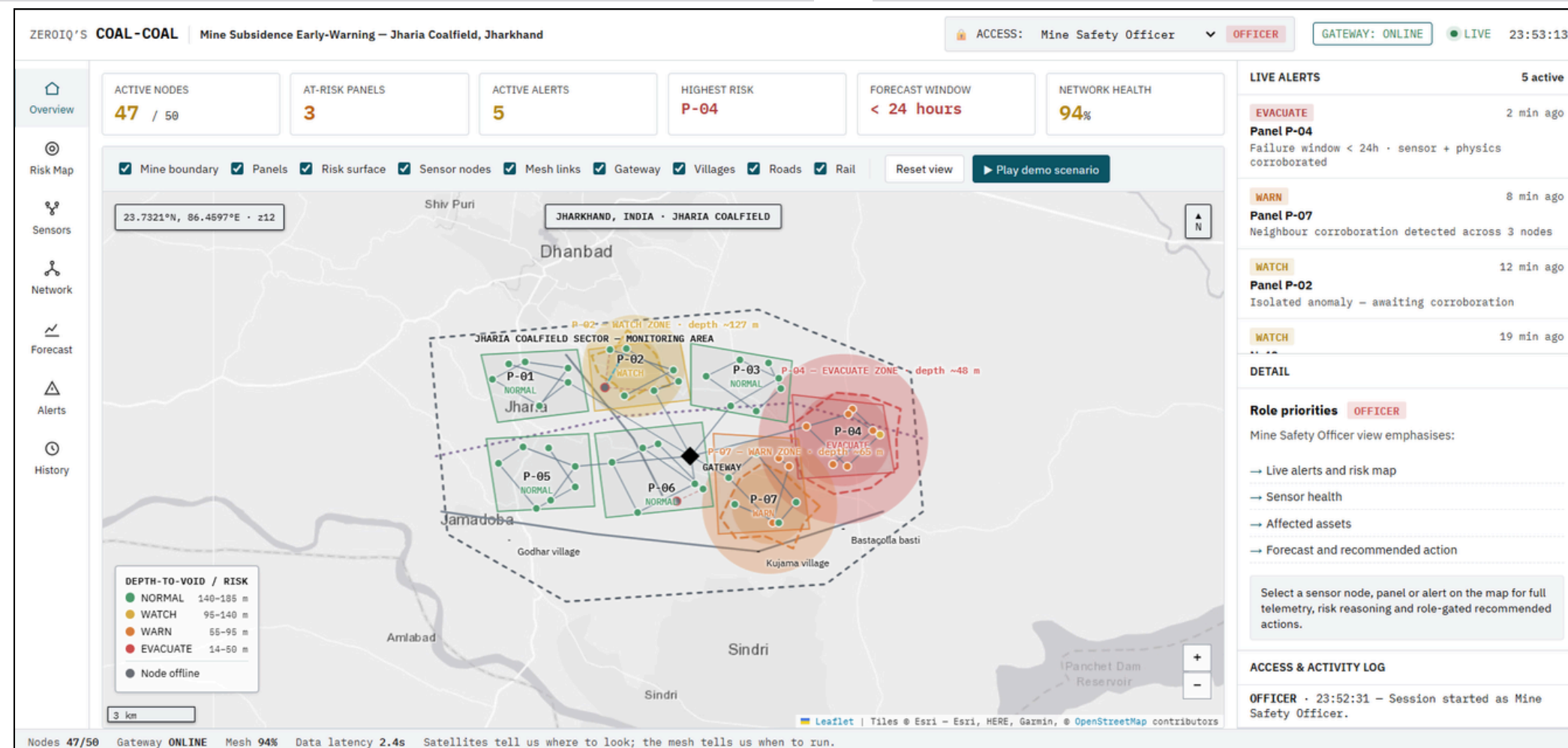
MITIGATION STRATEGIES

Corroboration before alarm. One sensor triggers an inspection, never an evacuation; alert needs 2+ nodes moving together.

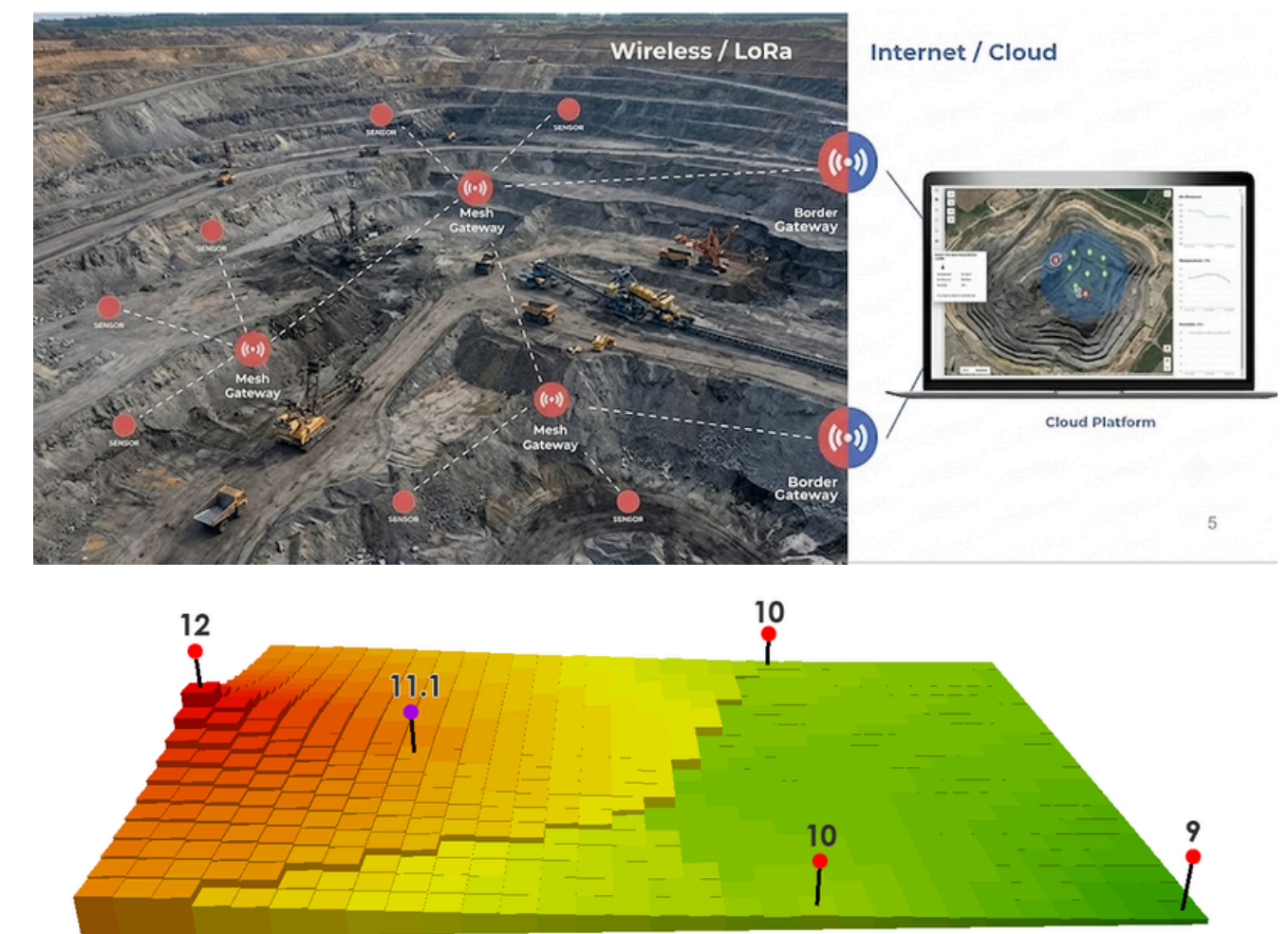
Density over precision. A 24-hr moving-median baseline removes thermal drift; correlated nodes read the trough's shape.

Splitting the node roles. An always-on relay backbone and duty-cycled leaf nodes run on separate power budgets.

Training on physics, then validating on a rig. Synthetic data from the subsidence profile model, tested on a sand-tray rig, re-fit on live telemetry.



Our proposed GIS dashboard



IMPACT AND BENEFITS

BENEFITS

SOCIAL

Warning instead of compensation

Communities above the panel are told **before houses crack**; evacuation becomes an orderly decision with hours-to-days notice.

ECONOMIC

≈ ₹1.2 lakh instruments a full panel

At ≈ ₹2,300 per node, a 50-node mesh costs a fraction of survey-grade instruments or commercial InSAR services. Damage is prevented, not repaid.

ENVIRONMENTAL

Land saved before it's lost

Troughs waterlog farmland and kill forest cover; catching one early allows **managed backfilling** instead of abandonment.

REGULATORY & STRATEGIC

Indigenous, and it scales

Commodity hardware in the de-licensed 865–867 MHz band; the same node design transfers to **landslide zones, dam embankments and highway cuts**.

TARGET AUDIENCE IMPACT

Mine safety officers

TODAY Periodic levelling surveys and after-the-fact damage reports.

WITH SUBSINET A **live risk map** and a ranked list of which panel to walk this shift.

Villages & infrastructure

TODAY Emergency response once cracks have already appeared.

WITH SUBSINET Proactive warning enables an **orderly, planned relocation** with hours-to-days notice.

Planners, CMPDI & DGMS

TODAY Sporadic survey records that are hard to audit or learn from.

WITH SUBSINET Continuous, **auditable movement records**: compliance today, calibration for prediction tomorrow.

KEY BOTTLENECKS & MITIGATIONS

Node theft / vandalism

Lost units leave gaps in the mesh over the panel.

MITIGATION Tamper-evident enclosures; GPS-tagged nodes alert the moment a unit is moved or opened.

Data loss on relay failure

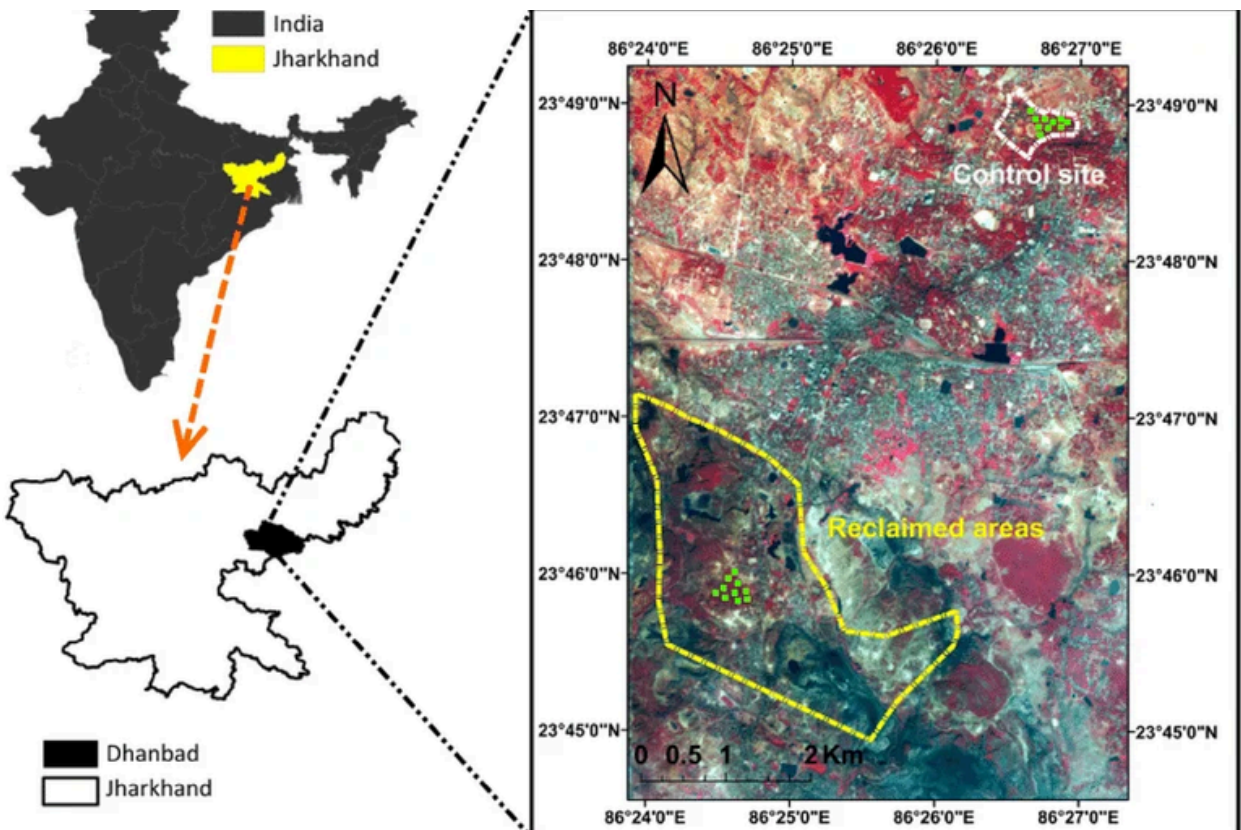
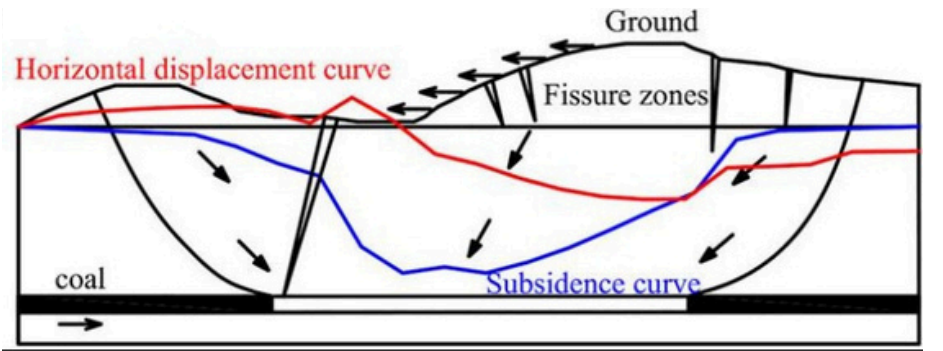
Readings go missing exactly when the ground is moving.

MITIGATION Redundant multi-hop routing, plus local SD buffering that replays queued data on reconnect.

Sensor drift (thermal cycling)

Daily temperature swings create false tilt trends and false alarms.

MITIGATION Automated daily self-calibration and remote diagnostics run from the gateway.



RESEARCH AND REFERENCES

Prototype: collisioni.tech

Indian subsidence does not follow the British model

CSIR-CIMFR developed a Modified Influence Function method and the Non-Effective Width concept specifically for Indian geo-mining conditions, including multi-seam workings at shallow cover.

— **So we** generate training data from an influence-function trough calibrated to Indian panel geometry, rather than from synthetic noise. [1] [4]

Existing Indian monitoring is periodic, not continuous

Published work over Raniganj and other coalfields uses field levelling, DGPS and InSAR. All are accurate, and all are limited by survey interval, satellite revisit and cloud cover.

— **So we** target the gap *between* those passes. This complements survey and InSAR practice; it does not replace it. [4]

Detection has to work without labelled data

Isolation Forest isolates outliers efficiently on unlabelled, high-volume data and returns a graded score rather than a bare yes or no.

— **So we** use it for per-reading scoring and surface the reasons in the dashboard, because an unexplained alert will not be acted on. [5]

Turning points into zones is a solved problem

Inverse-distance weighting has been standard practice for interpolating scattered measurements into a continuous surface since 1968.

— **So we** interpolate node risk scores across the panel to produce the risk-zone map the problem statement asks for. [6]

- 1. Knothe, S. (1957).** Observations of surface movements under influence of mining and their theoretical interpretation. Proc. European Congress on Ground Movement, Leeds, pp. 210–218. (subsidence profile model)
- 2. He, K., Zhang, X., Li, Z., Jiang, W., Zhou, J. & Han, B. (2024).** A Mask R-CNN network for wide-area mining subsidence automatic detection with InSAR observations. IEEE Trans. Geoscience and Remote Sensing, 62, pp. 1–14. (InSAR zone mapping)
- 3. Evensen, G. (1994).** Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics. J. Geophysical Research, 99(C5), 10143–10162. (Ensemble Kalman Filter calibration)
- 4. Liu, F.T., Ting, K.M. & Zhou, Z.-H. (2008).** Isolation Forest. IEEE Int. Conf. on Data Mining (ICDM), pp. 413–422. (anomaly detection)
- 5. Fukuzono, T. (1985).** A new method for predicting the failure time of a slope. Proc. 4th Int. Conf. & Field Workshop on Landslides, Tokyo, pp. 145–150. (time-to-failure warning)