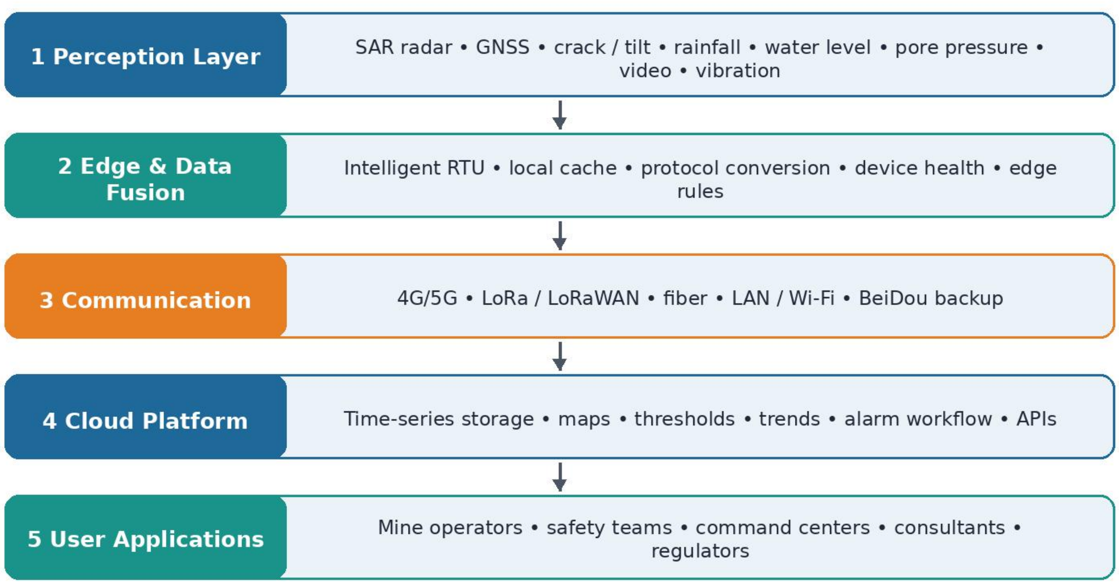
MINE SAFETY MONITORING SOLUTION

A Multi-Sensor White Paper for Slope Stability, Tailings Storage Facilities, Underground Deformation, and Risk Early Warning

Five-Layer Mine Safety Monitoring Architecture



JW-IoT | Standard Edition 1.0 | July 2026
www.jw-iot.com

Contents

Document purpose

This white paper presents a reference architecture. Final sensor selection, warning thresholds, communication design, and compliance requirements must be confirmed through site investigation and engineering review.

1. Executive Summary

Mining operations are exposed to interacting geotechnical, hydrological, environmental, and operational risks. Slope movement, tailings dam deformation, seepage, rainfall, blasting vibration, and underground settlement can evolve at different rates and may not be visible through manual inspection alone.

The JW-IoT mine safety monitoring solution combines area-based radar, high-precision GNSS, distributed IoT sensors, hydrological instruments, video surveillance, intelligent RTUs, redundant communications, and a browser-based monitoring platform. The objective is not simply to collect data, but to establish a reliable chain from field perception to verification, escalation, and operational response.

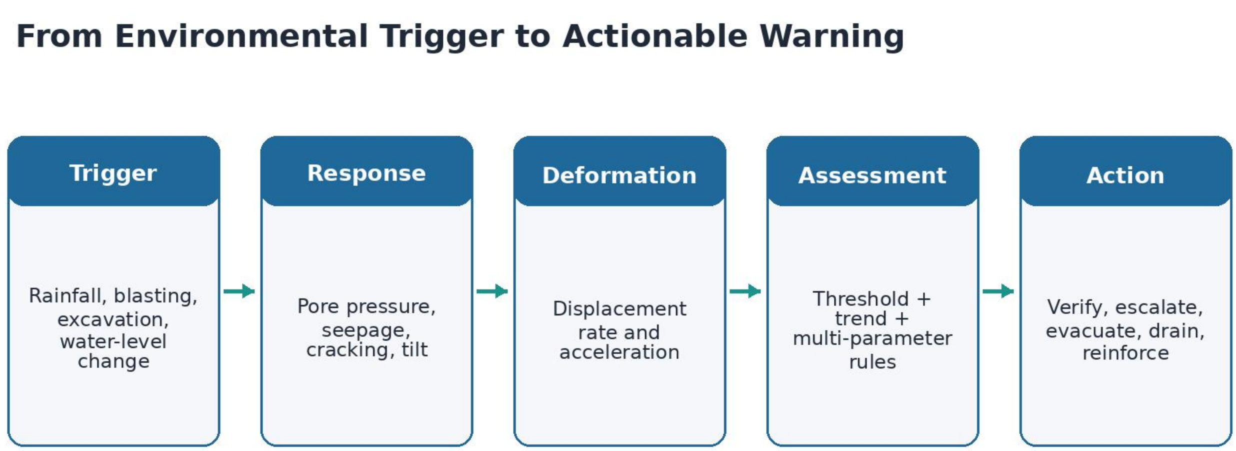
- Continuous observation of surface and internal deformation
- Correlation of rainfall, water level, seepage, pore pressure, vibration, and movement
- Remote verification using video and UAV imagery
- Multi-level alarm distribution through dashboards, mobile access, SMS, email, and on-site devices
- Multi-site management with role-based permissions, historical trends, device health, and audit records

Key principle

No single sensor can describe every failure mechanism. A robust system combines area monitoring, point monitoring, environmental triggers, visual evidence, and communication redundancy.

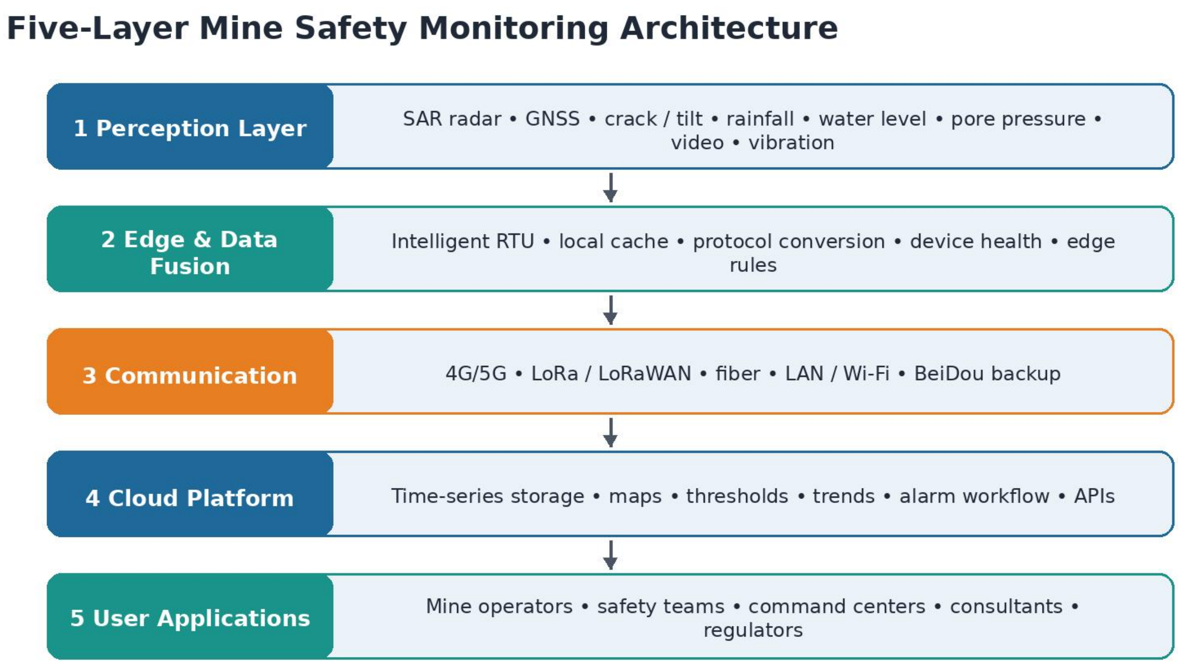
2. Why Multi-Sensor Monitoring Matters

A slope may appear unchanged in a camera image while micro-deformation accelerates. A tailings dam may appear dry at the surface while pore-water pressure or the phreatic line rises internally. Blasting may create short-duration movement that must be distinguished from progressive instability. Multi-sensor monitoring provides independent observations that can be checked against one another.



The recommended warning workflow combines three levels: device-health alarms, parameter-threshold alarms, and correlated risk alarms. Correlated alarms should be configured by qualified engineers using site baselines, rate-of-change indicators, operating conditions, and response procedures.

3. Reference Architecture



The architecture is organized into five layers. This separates field instrumentation from communication and application logic, allowing each mine to select appropriate devices while maintaining unified data and alarm management.

Perception layer: Radar, GNSS, tilt, crack, inclinometer, rainfall, water level, pore pressure, vibration, weather, video, and UAV data.

Edge and data fusion: RTUs and gateways aggregate readings, cache data, convert protocols, execute local rules, and report device health.

Communication: 4G/5G, LoRa or LoRaWAN, fiber, LAN, Wi-Fi, and optional BeiDou or private-radio backup.

Cloud platform: Time-series storage, maps, dashboards, thresholds, trends, alarm workflow, APIs, user permissions, and reporting.

User applications: Mine operators, technical teams, command centers, consultants, and regulators access role-appropriate information.

4. Core Monitoring Scenarios

Open-pit slope monitoring

Area radar identifies broad deformation patterns, while GNSS and distributed sensors verify critical points. Rainfall, vibration, and video provide context for operational decisions.

Tailings storage facility monitoring

Surface displacement, internal movement, water level, phreatic line, pore pressure, rainfall, dry-beach condition, drainage, and video are evaluated together.

Goaf and underground deformation

GNSS, inclinometers, crack sensors, convergence or internal displacement sensors, and visual inspection support the identification of settlement and localized movement.

Emergency landslide monitoring

Portable radar and rapidly deployable low-power nodes provide remote observation where entering the hazard zone is unsafe.

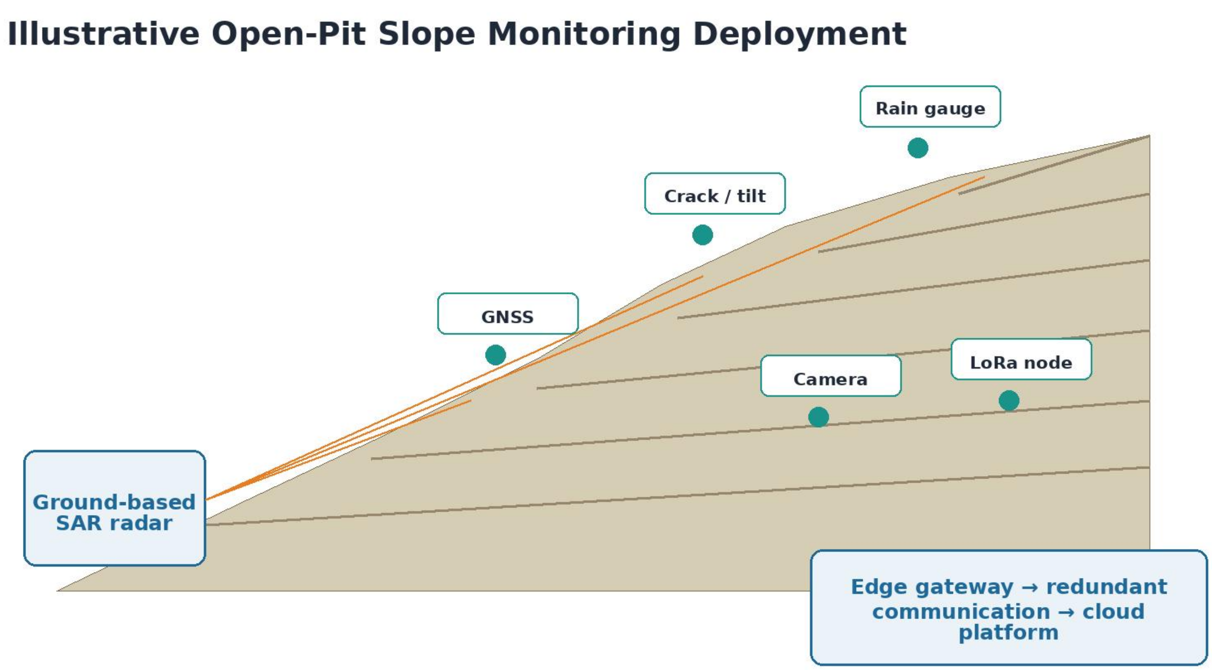
5. Key Technologies and Selection Boundaries

Technology	Primary role	Selection boundary
Ground-based SAR radar	Non-contact area monitoring and high-frequency deformation mapping	Requires suitable siting, line of sight, stable installation, and atmospheric compensation.
GNSS / BeiDou	High-precision three-dimensional point displacement	Requires appropriate point selection, stable monuments, and good satellite visibility.
Tilt, crack, and slope probes	Distributed local monitoring with low-power communication	Measures local behavior only; placement must follow the failure mechanism.
Pore pressure and phreatic-line instruments	Tracks internal hydraulic conditions	Requires correct borehole installation, calibration, and maintenance.
Video and UAV	Operational context and remote verification	Affected by visibility, weather, flight restrictions, and lighting.
Edge RTU and gateway	Local cache, protocol integration, health monitoring, and transmission	Must be sized for power, interfaces, storage, and communication redundancy.

Specification note

Performance is model- and site-dependent. Values such as monitoring distance, deformation sensitivity, scan cycle, operating temperature, and protection level must be verified against the selected product datasheet and deployment geometry.

6. Radar-Based Slope Stability Monitoring

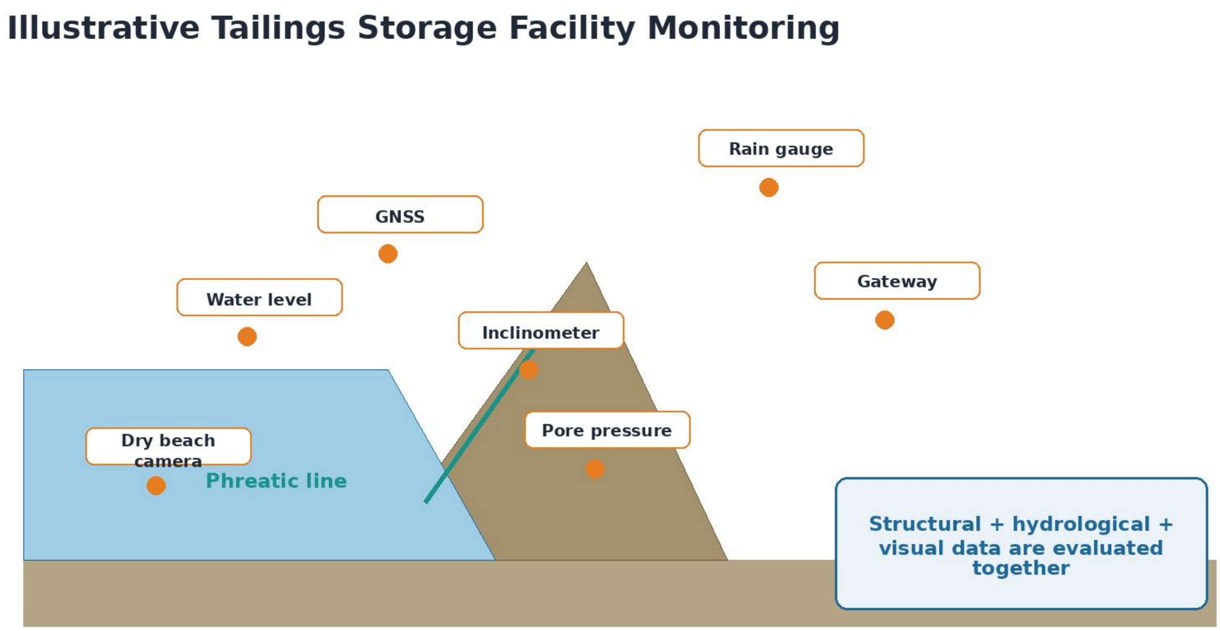


Ground-based radar extends deformation monitoring from isolated points to a broad surface. It is particularly valuable where the monitoring area is large, access is dangerous, frequent updates are required, or optical methods are limited by darkness or poor visibility.

A practical deployment typically combines radar coverage with GNSS control points, localized crack or tilt sensing, rainfall monitoring, cameras, and an edge gateway. Radar data should be interpreted together with site geometry, excavation activity, blasting records, and field verification.

- Confirm line of sight and the expected movement direction during site survey
- Define stable installation, power, communication, and environmental protection
- Establish baseline data before configuring operational thresholds
- Use rate, acceleration, spatial continuity, and cross-sensor evidence in alarm review
- Maintain an alarm verification and escalation procedure

7. Tailings Storage Facility Monitoring



Tailings storage facilities require both structural and hydrological monitoring. The system should provide a combined view of dam-body movement, water level, phreatic-line elevation, pore pressure, rainfall, dry-beach condition, drainage performance, discharge status, and visual observations.

Monitoring points and alarm thresholds must be based on the facility design, operating stage, consequence classification, local regulations, and engineer-approved trigger action response plans. Automated alarms support faster response, but do not replace qualified inspection and engineering judgment.

8. Cloud Platform and Alarm Workflow

The platform centralizes real-time data, maps, device health, trend curves, images, inspection records, alarms, and reports. It can support browser and mobile access, role-based permissions, multi-site management, configurable dashboards, and integration through standard APIs.

Alarm stage	Typical logic	Responsible role
Device-health alarm	Offline device, low battery, sensor fault, abnormal signal	Maintenance team
Parameter alarm	Value or rate exceeds an approved threshold	Site technical team
Correlated risk alarm	Multiple indicators or sustained trends meet a configured rule	Safety manager / command center
Escalation and closure	Verification, field inspection, response	Authorized management users

	action, acknowledgement, audit record	

Prediction or intelligent assessment functions should be described only where validated models are available. For most projects, the reliable starting point is engineer-approved thresholds, rate-of-change rules, baseline comparison, and multi-parameter correlation.

9. Communication, Power, and Data Resilience

- Use primary and backup communication paths according to terrain, coverage, reporting needs, and emergency requirements.
- Provide local storage and automatic retransmission after communication recovery.
- Separate high-bandwidth video traffic from low-power sensor traffic where appropriate.
- Design surge protection, grounding, lightning protection, and enclosure protection for the site environment.
- Select mains, solar, battery, or generator power based on duty cycle, climate, autonomy target, and maintenance access.
- Monitor battery voltage, signal quality, device status, and data freshness as part of the platform.

Data resilience

A monitoring system is only useful when data remain available during adverse conditions. Local cache, communication fallback, power autonomy, device-health alarms, and documented maintenance procedures are essential parts of the solution.

10. Deployment Methodology

1. Risk zoning

Identify slopes, dam sections, goaf areas, drainage structures, underground zones, and operating areas requiring continuous observation.

2. Monitoring objective

Define the failure mechanism and required evidence: area deformation, point displacement, internal movement, hydraulic trigger, vibration, or visual verification.

3. Site survey and design

Confirm geometry, sensor locations, line of sight, communication coverage, power availability, interfaces, and environmental protection.

4. Installation and integration

Install instruments, configure RTUs, validate coordinates and time synchronization, and integrate devices with the platform.

5. Baseline and commissioning

Collect baseline data, validate measurements against field conditions, test alarms, and document response procedures.

6. Operation and optimization

Review trends, maintain sensors, adjust approved thresholds, test communication and power resilience, and audit alarm closure.

11. Reference Deployment

An anonymized reference deployment used ground-based radar to observe an unstable open-pit slope. The system operated continuously, used 4G communication, covered approximately 280 degrees, monitored to about

1,500 m under the project geometry, refreshed data in approximately four-minute groups, and distributed warnings through SMS and email.

The deployment demonstrates the value of unattended area monitoring and multi-user cloud access. The stated figures are project-specific and should not be interpreted as guaranteed performance for other sites.

12. Business and Safety Value

- Earlier recognition of abnormal deformation and hydrological trends
- Reduced exposure of personnel to unstable or restricted areas
- Better-informed decisions on access, blasting, drainage, reinforcement, production suspension, and emergency response
- Lower field workload through remote inspection, device-health monitoring, low-power nodes, and browser-based access
- More transparent reporting through role-based access, historical records, alarm audit trails, and multi-site dashboards

13. Standards and Compliance Considerations

The final system should be designed with reference to applicable mine-safety regulations, tailings governance requirements, geotechnical monitoring practices, electrical and EMC requirements, radio regulations, data-protection rules, and client cybersecurity policies. The following items should be confirmed during project design:

- Instrument accuracy, calibration, environmental rating, and installation standard
- Applicable IP, EMC, electrical safety, radio, and hazardous-area requirements
- Data ownership, retention, backup, export, access control, and audit logging
- Alarm governance, trigger action response plans, and regulatory reporting
- Integration protocols such as Modbus RTU/TCP, MQTT, HTTPS, and project-specific APIs

Compliance statement

JW-IoT does not claim that every reference component automatically meets every jurisdictional requirement. Compliance must be confirmed for the selected configuration, destination market, and project specification.

14. Frequently Asked Questions

Can one technology monitor the entire mine?

No. Radar, GNSS, internal sensors, hydrological instruments, video, and inspection provide different types of evidence. The system should be designed around the site risk model.

Can the system operate in bad weather?

Many devices are designed for harsh outdoor operation, but performance depends on installation, visibility, environmental limits, communication, power, and maintenance.

How are warning thresholds determined?

Thresholds should be approved by qualified engineers using baseline data, design criteria, site conditions, rate-of-change indicators, and response plans.

What happens if communication is lost?

A properly configured edge device stores data locally and retransmits after recovery. Critical sites may use backup communication and local warning devices.

Can JW-IoT integrate third-party sensors?

The architecture can integrate compatible sensors through common industrial interfaces and documented protocols, subject to engineering validation.

Can the platform manage multiple mines?

Yes. Multi-site management, user permissions, dashboards, historical trends, device health, alarm records, and reporting can be configured according to project scope.

15. Conclusion and Next Steps

Effective mine safety monitoring is continuous, connected, and evidence-based. The strongest solutions combine broad-area observation, precise point measurements, environmental triggers, internal instrumentation, visual verification, resilient communications, and a governed alarm workflow.

JW-IoT provides a modular framework that can be adapted to open-pit slopes, tailings storage facilities, goaf areas, underground structures, and emergency monitoring. Final design should begin with a site risk review rather than a fixed equipment list.

Recommended next step

Request a site-specific monitoring architecture. Provide the mine layout, target hazards, required parameters, communication conditions, power availability, reporting requirements, and applicable standards. JW-IoT can then prepare a preliminary monitoring-point plan, equipment list, network architecture, and platform scope.

Contact: www.jw-iot.com/contact-us/
Website: www.jw-iot.com