

Advanced Tailings Monitoring

Understanding Progressive Risk in Tailings Systems

Lessons from the Aerospace Industry

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The Failure Mode

Two industries, 3 decades in high-consequence systems and one pattern that never changes

Normalisation of Deviance

› *“The gradual process by which deviations from design intent, initially recognised and flagged, become absorbed into the organisation’s definition of normal.”*

Diane Vaughan. Challenger post-disaster investigation.

This is an engineering problem. Predictable conditions:

- › 1 Sustained production pressure
- › 2 Weak vertical communication
- › 3 Absent or ignored stop authority
- › 4 Monitoring that measures compliance, not risk state

The Four Normalisation Behaviours

These appear in every failure investigation reviewed today:

- › 1 Known deviations not escalated
- › 2 Monitoring misaligned with the actual failure mode
- › 3 Stop authority available — not exercised
- › 4 Prior warning event not acted upon

Not hindsight. Documented and present in every case.

Case 1: NASA — Same Failure, 17 Years Apart

› Challenger, 28 January 1986

- › Engineers warned against launch at 36°F. Management overruled. 73 seconds into mission it disintegrated
- › 17 prior flights with O-ring anomalies, each normalised as acceptable.

› Columbia, 1 February 2003

- › Engineers flagged foam strike. Imagery requests denied.
- › CAIB: “Organisational culture had as much to do with this accident as the foam strike.”

Same organisation. Same root cause. 17 years apart.





The Dam & Tailings Record

Vajont • Brumadinho • Jagersfontein

Vajont, 1963 — Knowledge Without Control

- › ~1,917 dead. Landslide into reservoir. Dam remained intact.
- › Instability documented. Movements monitored. Chain between signal and decision: failed.
- › **The four behaviours:**
 - › Deviations monitored but not escalated to precautionary intervention
 - › Monitoring measured incremental change, not threshold transitions
 - › Stop authority exercised too late
 - › Historical instability absorbed as prior warning was not acted upon



Brumadinho, 2019 — Modern Monitoring, Same Failure

- › **Modern instrumentation. Compliance-monitored. Passing audits.**
- › Brittle failure. Minimal warning – signals present but ignored
- › Systemic risk.
- › **The four behaviours:**
 - › Monitoring measured deformation, failure was sudden strength loss
 - › Mariana, 2015: same company, same pattern, the prior warning event
 - › Four years elapsed. Pattern not fixed. Deviance normalised.
- › **Monitoring does not prevent normalisation. It can mask it.**



Jagersfontein, 2022

- › You have heard the facts yesterday.
 - › Owner may have known of southern wall instability from 2019. Three years before collapse.
 - › Employee, and community signals dismissed.
 - › DWS directive overturned.
 - › Systemic risk
- › **All four behaviours present.**





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An Engineering Framework for organisation Risk State monitoring

Three questions you can apply to your facility

Dual Monitoring: Two Categories

› Geotechnical Indicators

› Necessary. Not sufficient.

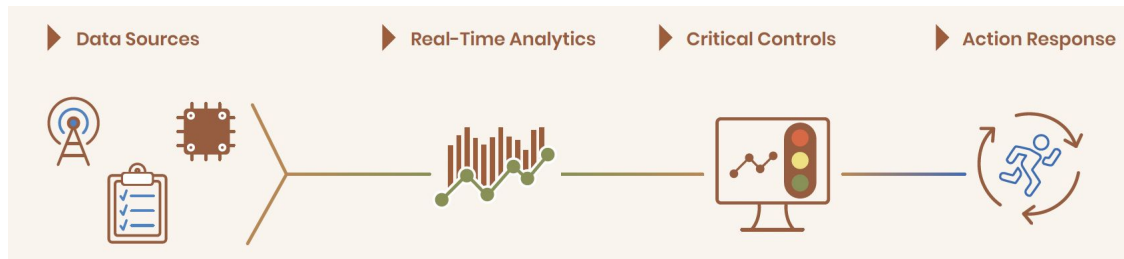
- › Piezometric levels
- › Deformation rates
- › Freeboard / phreatic surface

› Must align with the governing failure mode.

› Organisational Indicators

› Measurable. Rarely tracked.

- › Report modification rate
- › Time-to-close on amber alerts
- › EOR visit-to-finding ratio
- › Near-miss reporting rate
- › Stop-authority exercise (12 months)
- › Failure or risk reporting is celebrated



Organisational Safety State

› BASELINE (GREEN)

- › Deviations documented and managed
- › Escalation paths used
- › 0 behaviours active

› ACCUMULATION (AMBER)

- › Deviations not escalated
- › Amber alerts unresolved
- › 1–2 behaviours active

› CRITICAL (RED)

- › Measuring compliance not risk
- › Stop authority culturally unavailable
- › All four behaviours active

Transitions are gradual , but detectable.

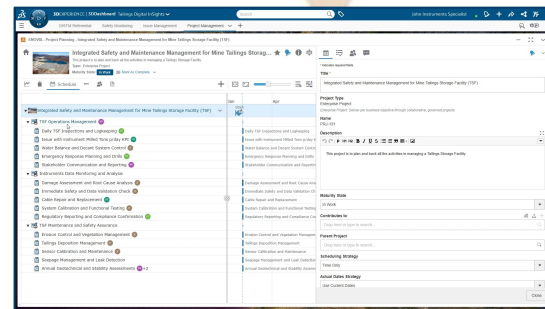
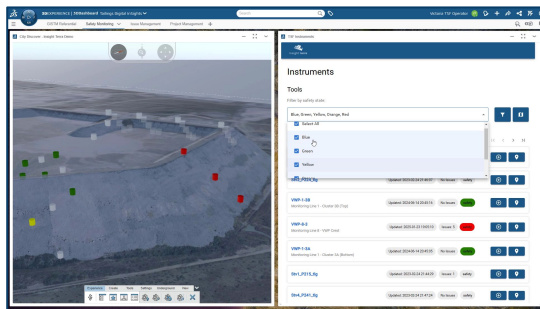
Three Questions.

- › For the last 90 days on your facility:
 - › 01 Who saw the last amber alert?
 - › 02 What decision was made in response?
 - › 03 Who authorised it and is it documented?
- › Cannot answer all three?
- › That gap appears in every investigation report reviewed today.

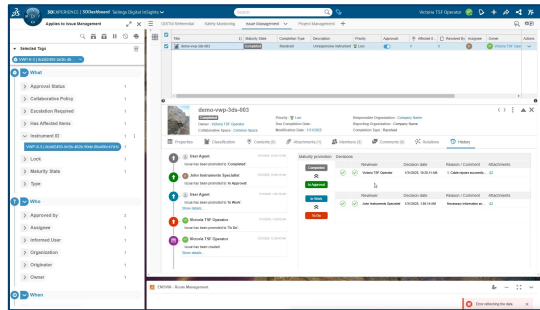
DIGITAL TAILINGS SYSTEM

Joint solution by Insight Terra + GEOVIA

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From alert to documented issue, project task assignment and risk mitigation plan



Capturing knowledge and know-how Building organizational capability

VIRTUAL TWIN

The Lifecycle Digital Continuity

Project Requirements

As-designed

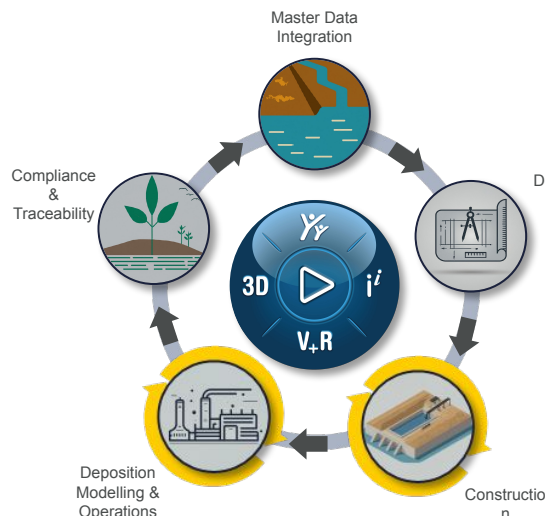
- Design Criteria
- Deposition Requirements
- Design Parameters
- Layouts
- Instrumentation Placement
- Aerial Imagery
- Photogrammetry

As-constructed

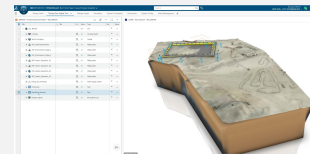
- As-constructed layouts
- As-constructed materials
- Strategical Instrumentation Placement
- Deposition Plan

Monitoring & Metrics

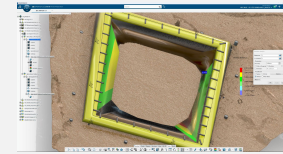
- Layouts
- Instrumentation Placement
- Historical Data
 - Peizometer
 - Monitoring Borewells
 - Rainfall



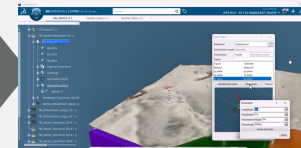
User Experiences



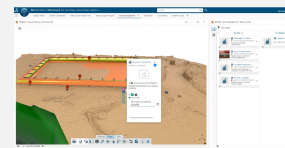
Review of Design Criteria



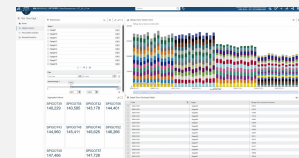
Tailings Behavior Simulation



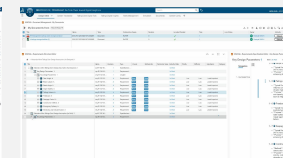
TSF Planning & Design



Project Execution & Alignment



KPI Monitoring & Forecasting



Actionable Insights



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Thank you