DMT

STINGS

Mine Tailings Monitoring

Supervision of tailings by an integrated novel approach to combine ground-based and space-borne sensor data

eit RawMaterials Connecting matters

EIT RawMaterials is supported by the EIT, a body of the European Union

Engineering. Insight. **Values.**

ABOUT THE PRESENTER

Karsten Zimmermann – DMT Group, Germany

- PhD in mine surveying from Bergakademie Freiberg – Germany
- Head of Geomonitoring and Data Management at DMT

Geodetic and geotechnical monitoring using our monitoring sensor platform DMT SAFEGUARD

Subsidence and deformation forecasting, damage mitigation

Terrestrial and satellite based radar-interferometry

Seismology, mining induced vibrations

3D laser scanning, mine shaft scanning

High-precision GNSS measurements, on- and offshore

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DMT CIVIL & MINING ENGINEERING

Webinar Agenda

1. DMT COMPANY PRESENTATION
2. TAILINGS MONITORING - INTRODUCTION
3. TAILINGS MONITORING - TECHNOLOGIES
4. DISCUSSION
   - *OPERATIONAL DEMANDS FOR MONITORING SYSTEMS*
   - *LEGAL REQUIREMENTS FOR ACTIVE AND ABANDONED TAILINGS*
   - *TECHNICAL REQUIREMENTS, KEY INFORMATION REQUIRED*

DMT

1. Company Presentation

TÜV NORD GROUP

Facts and Figures

We create **sustainable value** for our customers **through quality-assured, specialized and innovative services.**

We provide independent services in engineering, consulting, exploration and geotechnics, as well as measuring and research.

DMT´s **roots** date back to **1737**	Approx. **1,100 employees** mainly with academic background
DMT comprises **14 operational engineering and consulting companies and more than 30 branches worldwide**	DMT´s attitude is dedicated to **excellence, responsibility & innovation**

Proof of our Performance

Worldwide on site

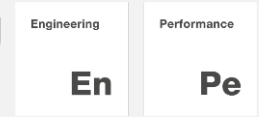
30 German and international locations

>10,000 Projects

annually in more than 150 countries

Added Value

High customer satisfaction through engineering performance



Practical experience

and certification

- ISO 9001
- ISO 14001
- SCC^{P}: 2011

Highly networked

in all relevant committees, associations and networks worldwide

360° Service

Cross-interface from analysis to approval

>40

current research projects

The campaign „Engineering Performance“

„Elektromobilität“

Dirk Harbecke, CEO Rock Tech Lithium

„Wasser“

Dr. Oliver Stoschek, Head of Hydrology & Water Management, DMT

„Monitoring“

Prof. Dr. Manfred Joswig, Director of the Institute for Geophysics, University of Stuttgart

„Operator Responsibility Management“

Daniel Michalek, registered inspector in accordance with building legislation

„Industrial Engineering“

Antonio Esposito, Vice President, Head of Business Unit Coke, Paul Wurth Italien S.p.A.

„Sustainability“

Dr. Andreas Hucke, project director CERA, and Nadine Kohl, project manager sustainability and raw materials, DMT

„Elektromobilität“

Rüdiger Durchholz, Head of Business Segment International Mining Consulting DMT

„Industrial Engineering“

Björn Otten, Head of DMT´s Coke Oven Gas Technology business segment and Frank Schlüter, ENCOS` Technical Manager / R&D Manager

Selected Customers

Selected Customers

Focus Markets

Plant Engineering & Process Engineering

Civil Engineering & Infrastructure

Mining

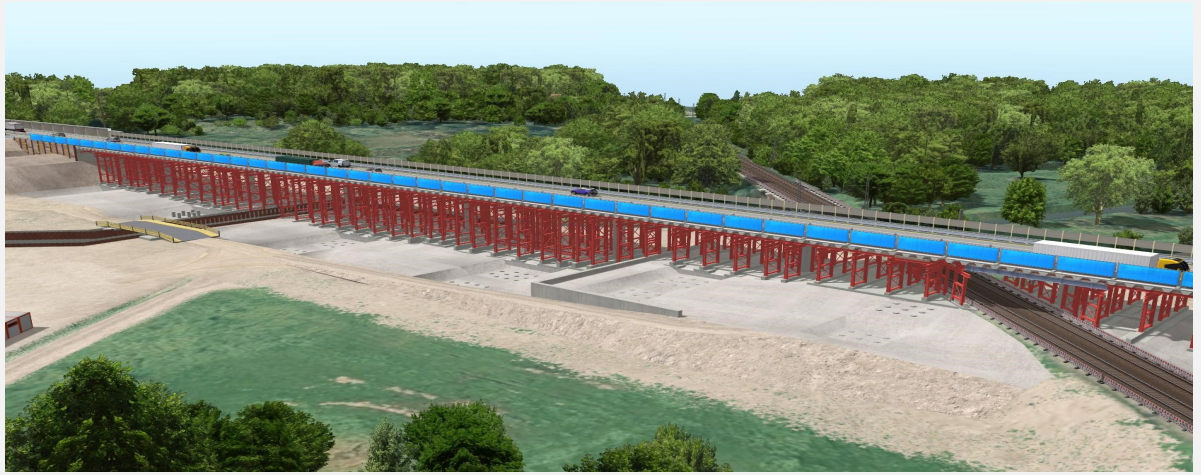
Energy

Project Example

Structural monitoring of “Dütebrücke” bridge - A1 highway in Germany

PORR AG
Osnabrück, Germany

- Monitoring of the bridge structure with geodetic and geotechnical sensors
- Permanent monitoring of deformation and stability
- Installation and operation of > 500 sensors: water level gauges, inclination sensors, extensometers, strain gauges, tachymeter measuring points
- Operation of DMT SAFEGUARD monitoring portal for integration of measurement data and alarming
- 3D laser scanning geometry mapping

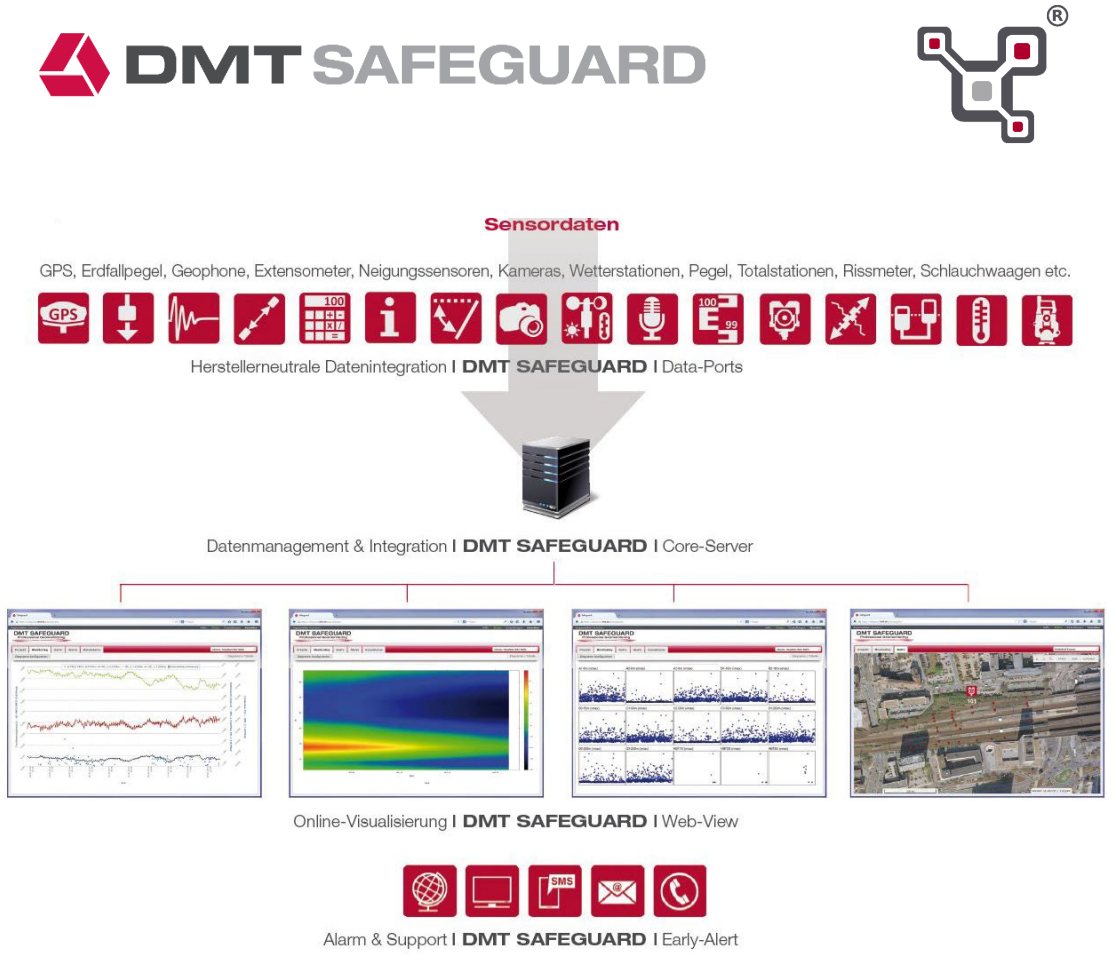


Project Example

Structural monitoring of “Dütebrücke” bridge - A1 highway in Germany

PORR AG
Osnabrück, Germany

- Provision of a universal IoT data platform (SaaS)
- Connection of any sensors according to customer requirements
- Secure web-based and interactive presentation of measurement data
- Automated reporting, data analysis and alerting
- Complete service: system assembly, installation, operation and maintenance

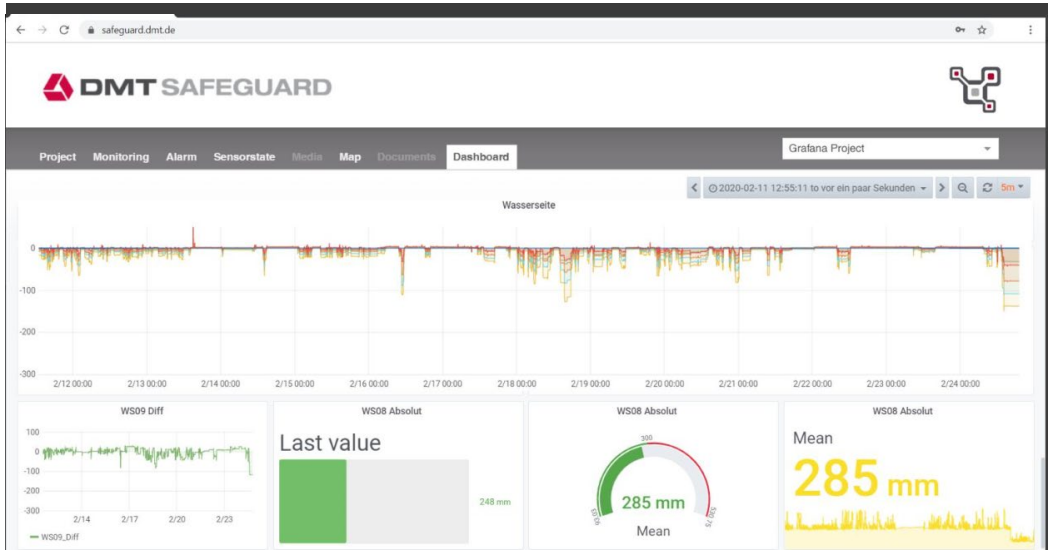


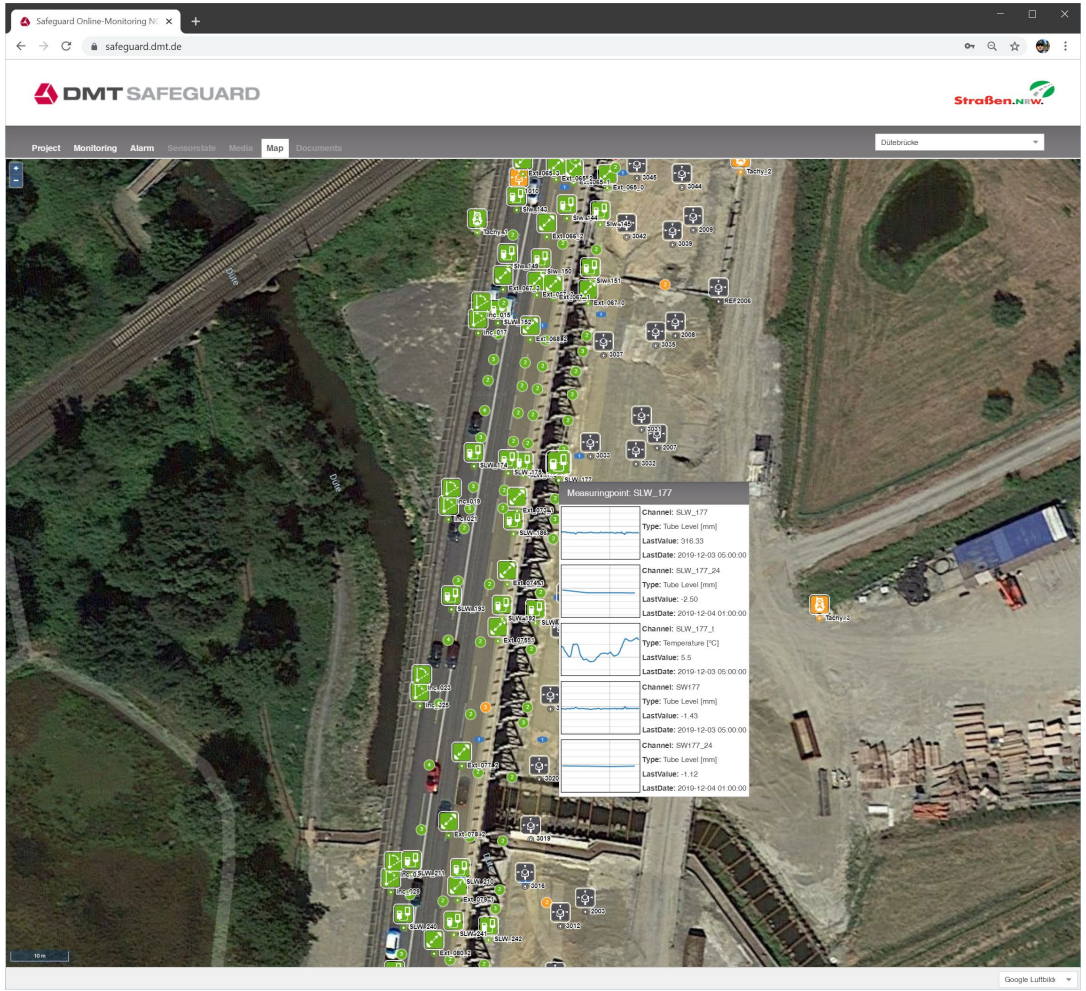
Project Example

Structural monitoring of “Dütebrücke” bridge - A1 highway in Germany

PORR AG
Osnabrück, Germany

- Data visualization and analysis





2. Tailing Monitoring - Intro

Tailings Facilities - Types

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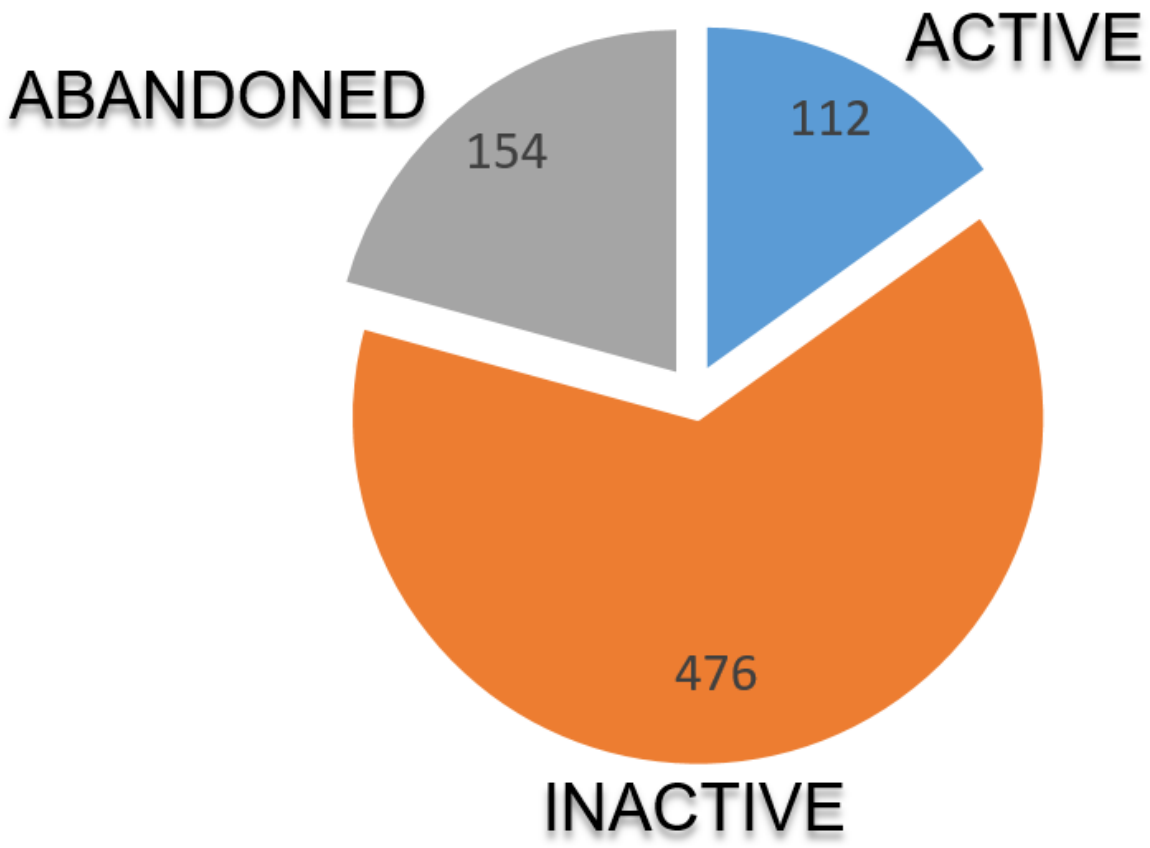
Tailings Facilities - Example Chile



Majority of tailings in Chile are currently not in operation or abandoned.

- Who is the owner/responsible?
- Risk assessment conducted?
- Financing of risk mitigation actions?
- Are they under observation/monitored?

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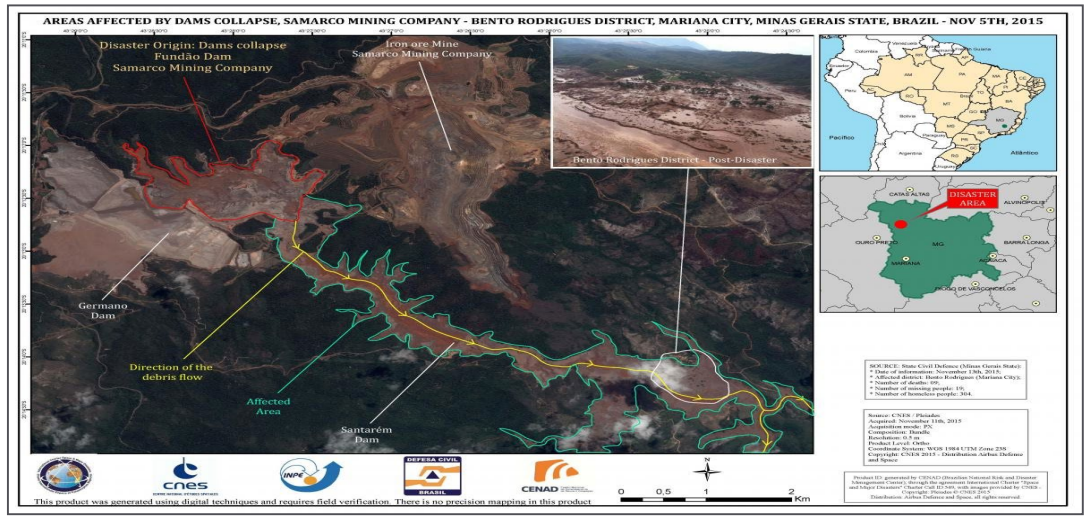
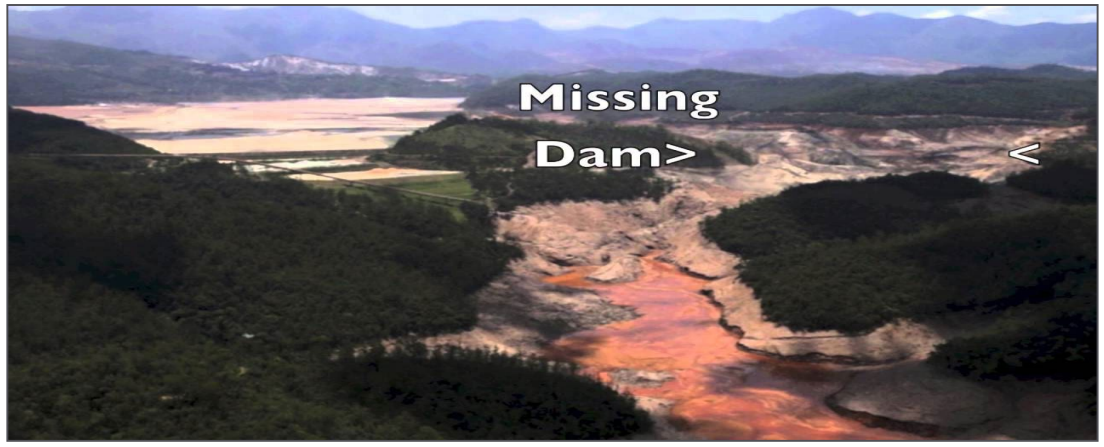
Tailings Accidents - Risk for Failure





Tailing dam disaster Bento Rodrigues - Iron Ore Tailing Dam (Source: PUCV)

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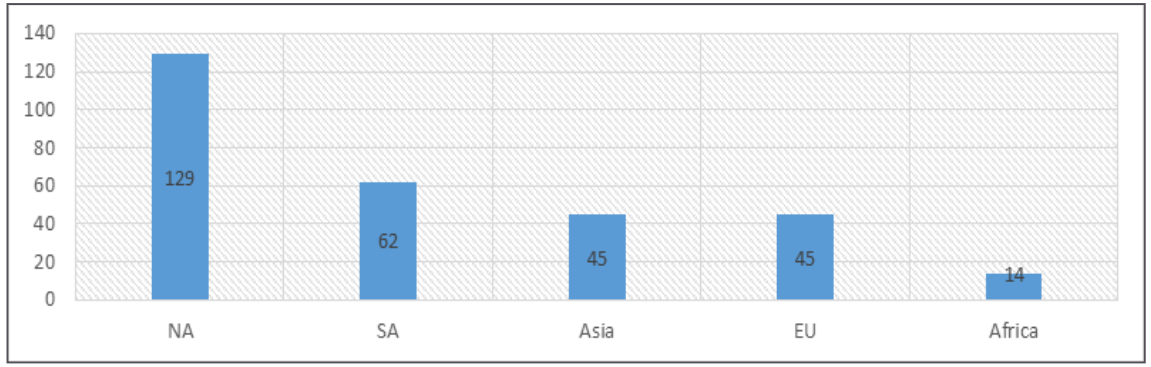
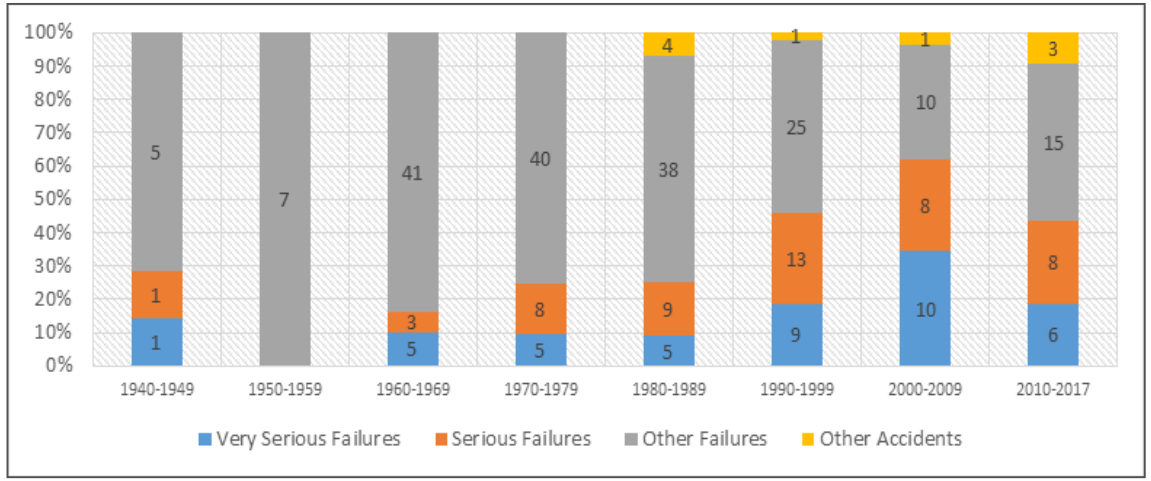
Tailings Accidents - Risk for Failure

- During the last 100 years a significant amount of tailings dam failures, with massive environmental impact and fatalities are recorded
- The number of failures as well as the severity of failures increases over time
- The majority of tailings failures in the previous 15 years clearly depicts the environmental, social and monetary risks
- The total average cost of failure is approx. 455 million EUR , which renders a situation where most mining operations cannot recover financially in case of an accident
- This financial risk is the key driving need for improving tailings monitoring



Global reported tailing dam failures from 1915 – 2017 per region (Source: own illustration based on Bowker, L. N., Chambers M. D., CSP2 database)



Time-line of severity of global tailings failures 1915 – 2017 (Source: own illustration based on Bowker, L. N., Chambers M. D., CSP2 database)

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Tailings Management Initiatives - Example Chile

NATIONAL TAILING POLICY - Chile

Servicio Nacional de Geología y Minería

- Objective of the initiative: Creation of guidelines, programs and instruments for the management of tailings
- Actions: Academic Ideas Platform, Cooperation with other Institutions, Studies

PROGRAMA TRANQUE - Fundación Chile

Safety for the public

Environmental protection

Circular economy and innovation

DMT

3. Tailing Monitoring Technologies

TÜV NORD GROUP

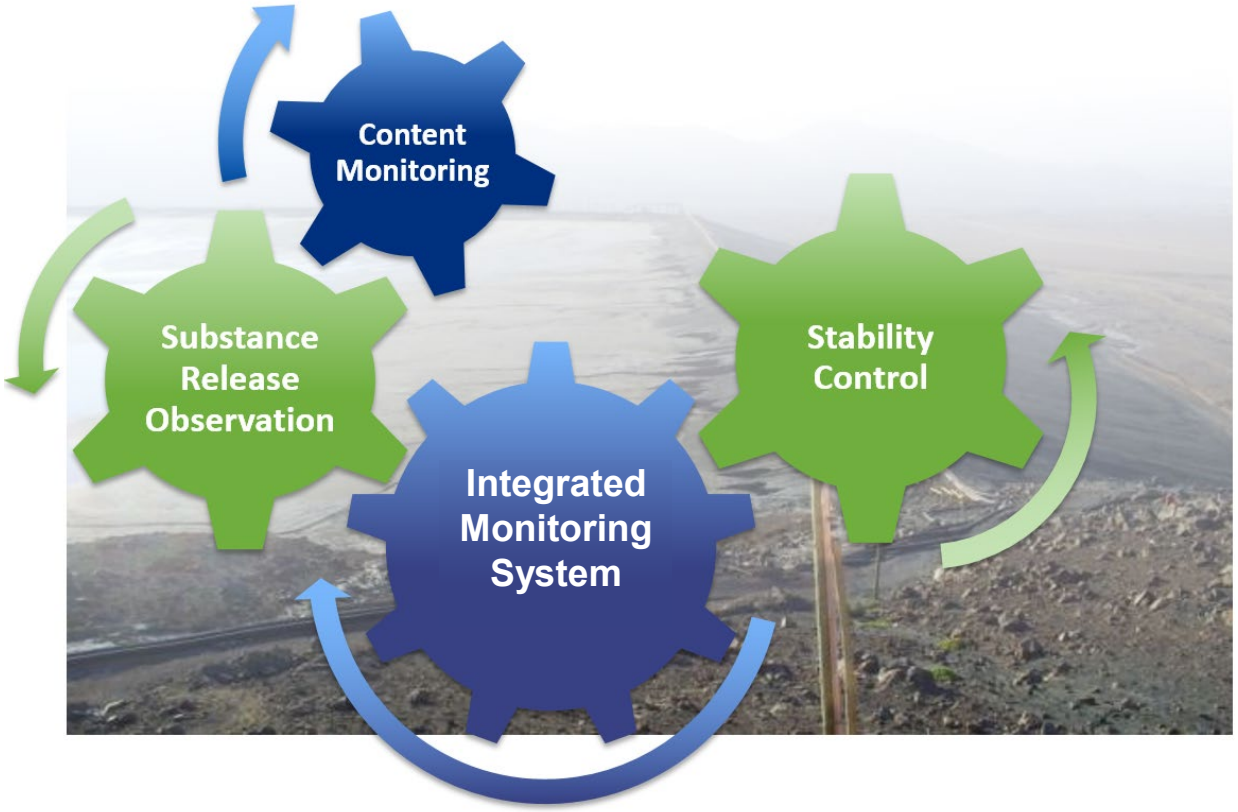
One-Stop Service for Mine Tailings Monitoring

STINGS

Multi-Sensor Tailings Monitoring integrating

- stability control,
- substance release observation
- and content monitoring

in one unified monitoring platform.



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One-Stop Service for Mine Tailings Monitoring

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EFTAS

GeoZS
Geološki zavod Slovenije

PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAÍSO

UNIVERSITATEA „OVIDIUS" DIN CONSTANȚA

BERGAKADEMIE FREIBERG · TECHNISCHE UNIVERSITÄT

Mine Tailing Monitoring Service

Universität Stuttgart

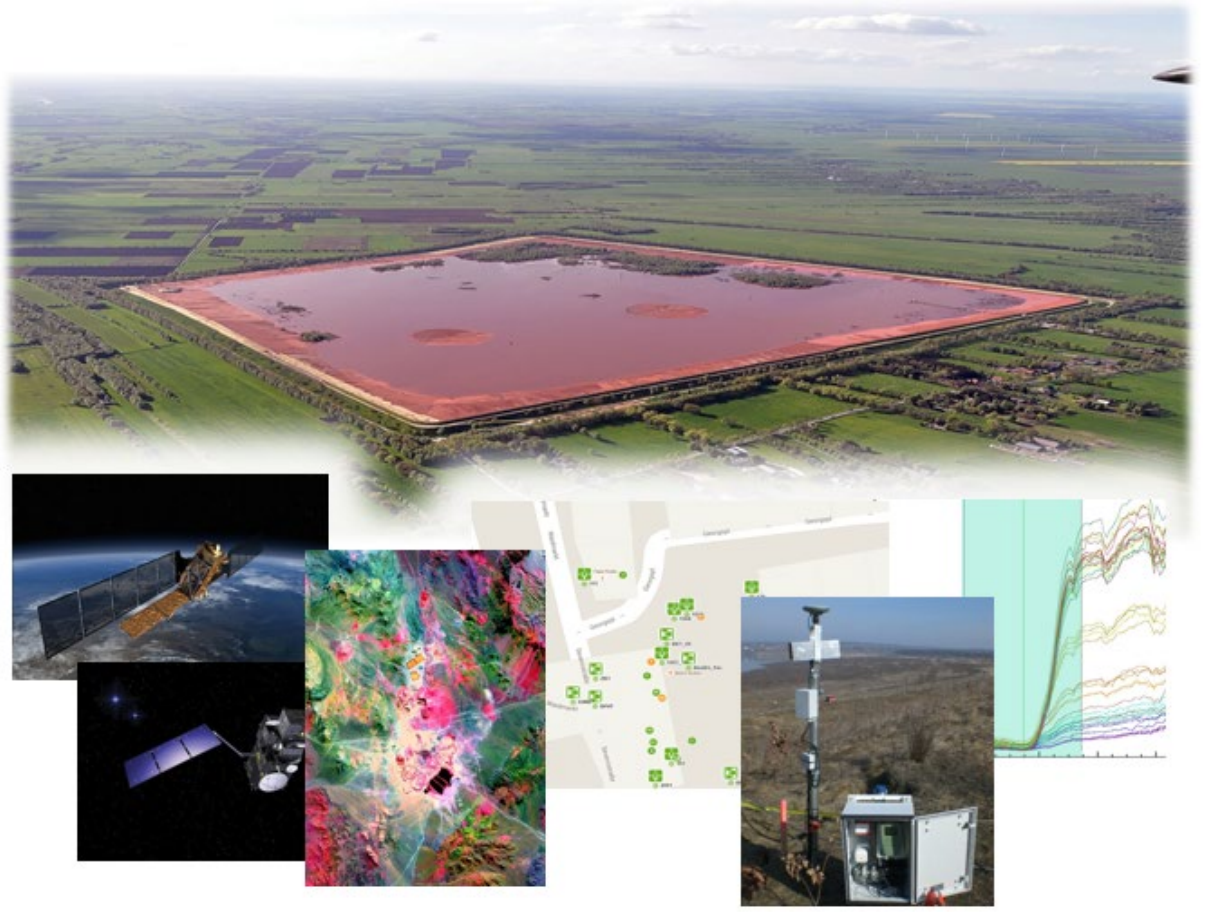
LTU BUSINESS AB

EIT RawMaterials is supported by the EIT, a body of the European Union

One-Stop Service for Mine Tailings Monitoring

Technologies:

- Geotechnical Monitoring – sensor network installation and operation on site
- Radar remote sensing – processing and analysis of satellite radar data
- Optical remote sensing – processing and analysis of optical satellite data
- Stability Modelling – advanced numerical analysis
- Geo-hydraulic modelling – analysis with DMT hydro toolbox
- Data integration – operation of unified sensor data and information platform



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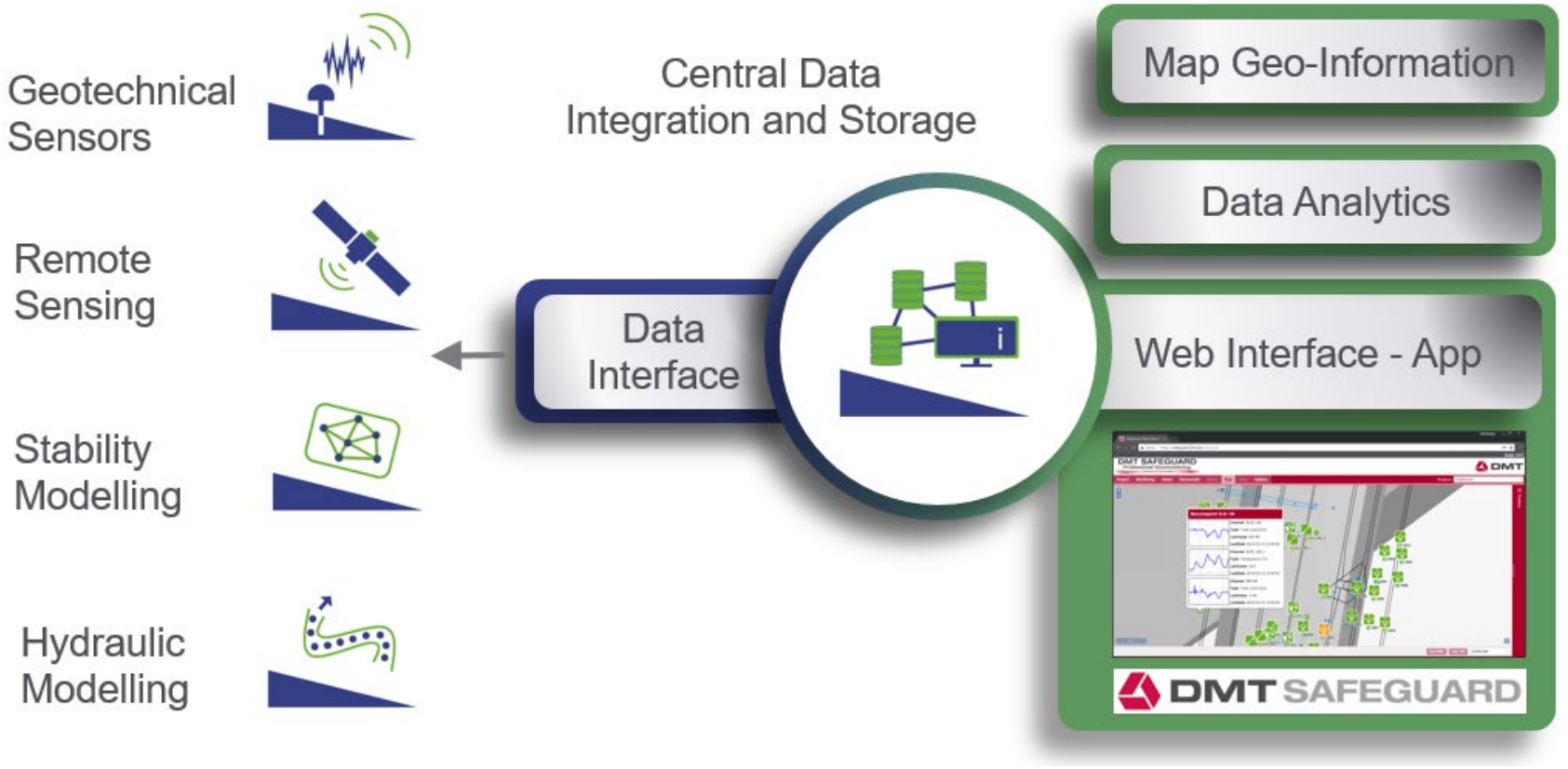
One-Stop Service for Mine Tailings Monitoring

Our platform solution:

- Data acquisition at tailing site
- Data transmission to central database
- In-depth information analysis
- Comprehensive online visualization
- Early warning
- Reporting



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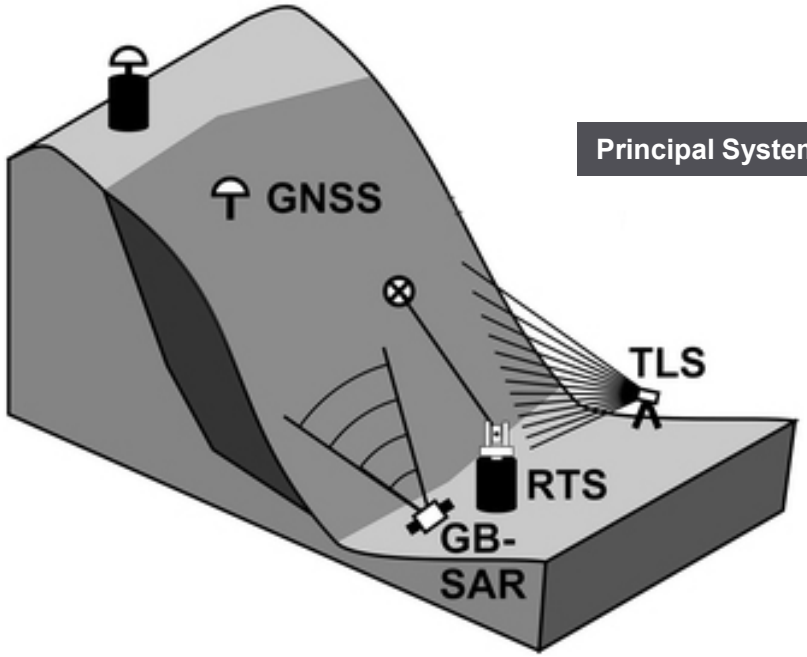
Geotechnical/Geodetical Monitoring - Systems Overview

- GNSS – DMT SAFEGUARD GPS System
- RTS – Total Station Monitoring System
- TLS – Terrestrial Laserscanning
- GB-SAR – Ground Based Radar



Principal Systems Setup

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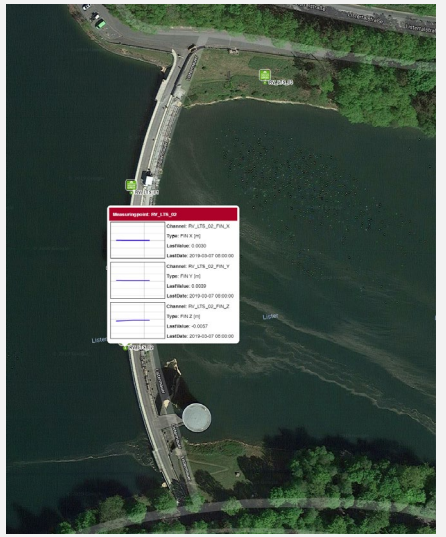
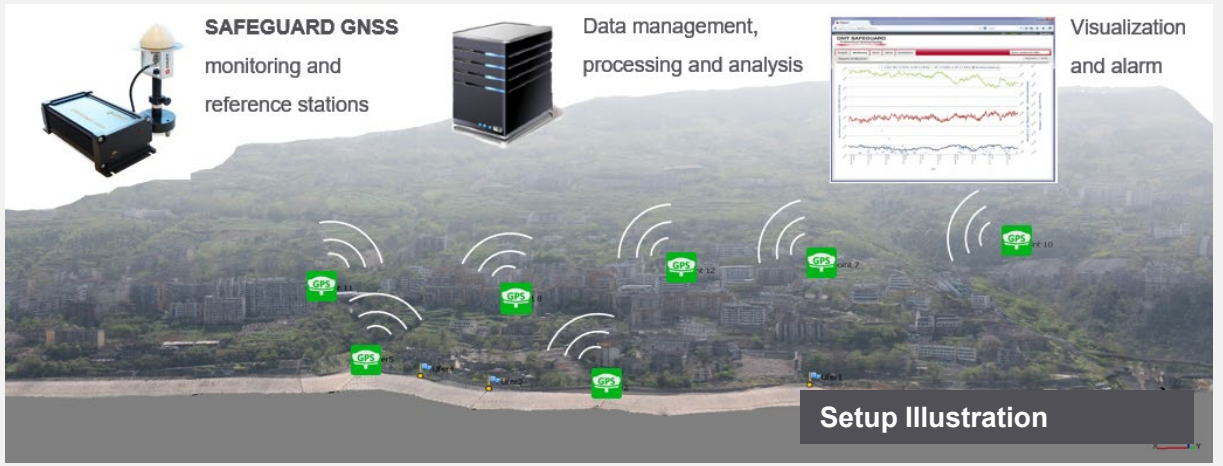
GNSS - SAFEGUARD GPS Systems

- Pointwise movement and deformation control
- Local installation at points of interest at tailing and at reference station at stable place outside
- One system per point with ground foundation necessary
- Local power supply for each station necessary
- Automatic measurement, remote maintenance
- Automatic data transfer via cell phone network
- Automatic data processing at DMT servers
- Automatic reporting
- One measurement result value per 24h/12h/6h
- Result presentation via protected website
- Alert message service
- Accuracy: horizontal and vertical <5 mm
- Established technology, high reliability
- All equipment manufactured and provided by DMT





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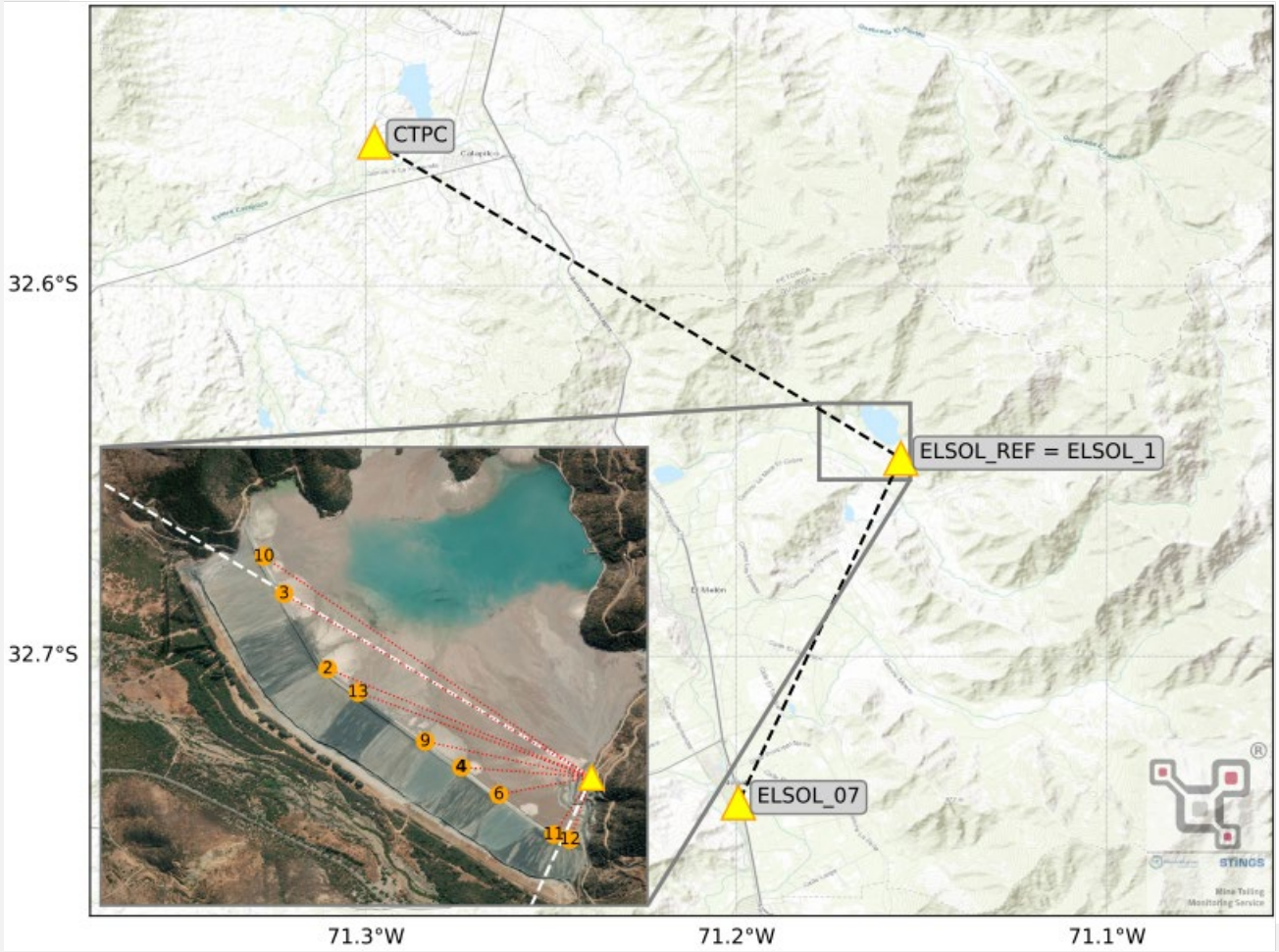
GNSS - SAFEGUARD GPS Systems



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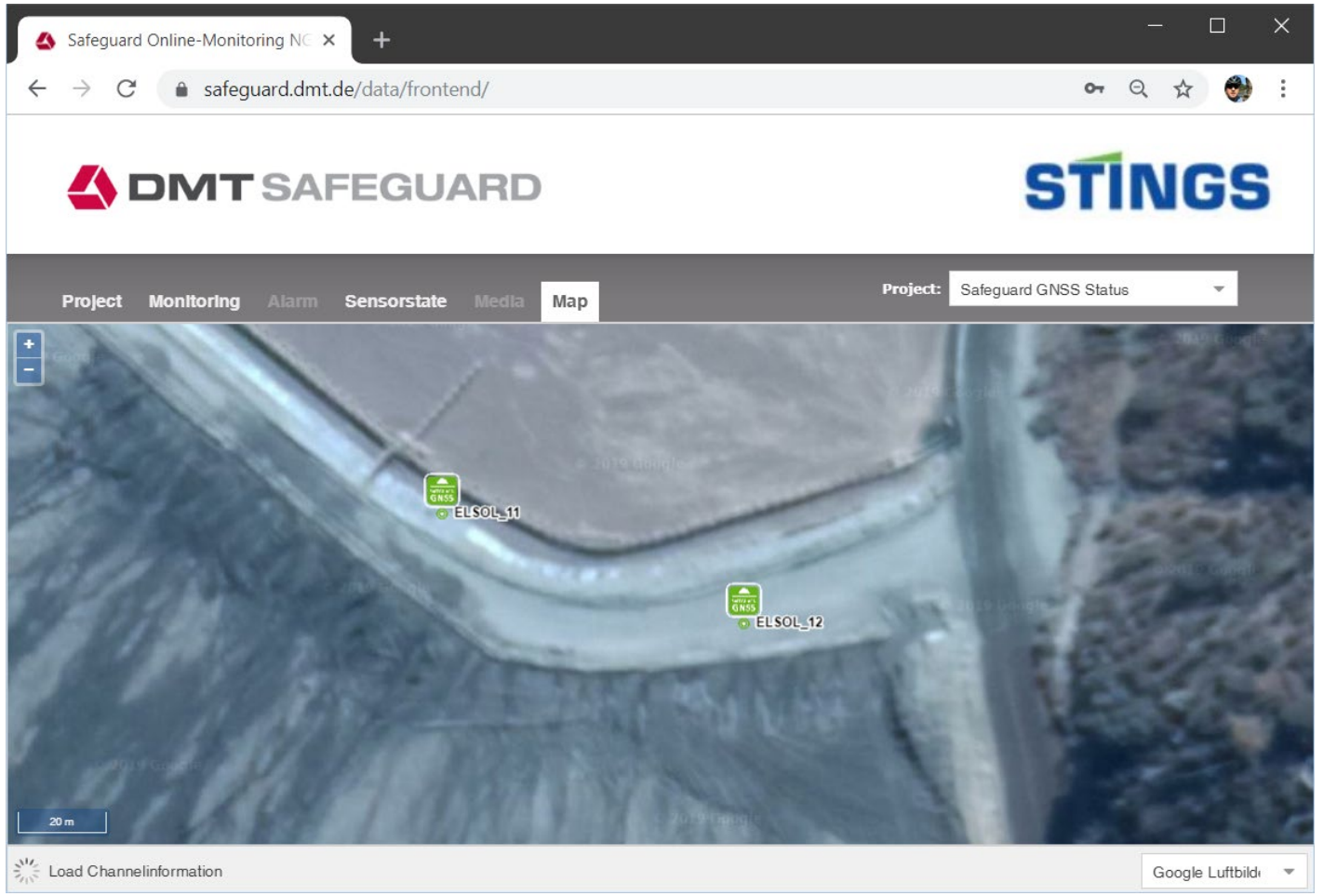
GNSS - SAFEGUARD GPS Systems



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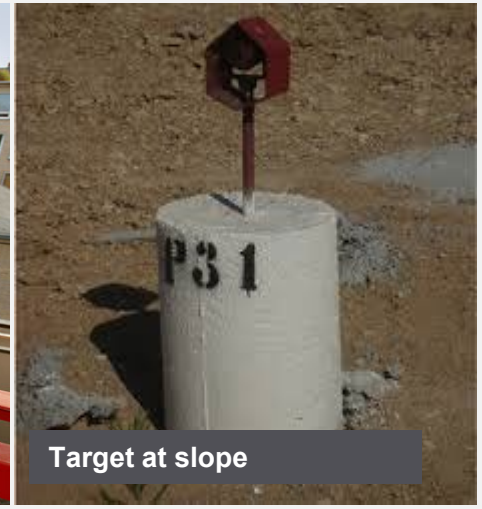
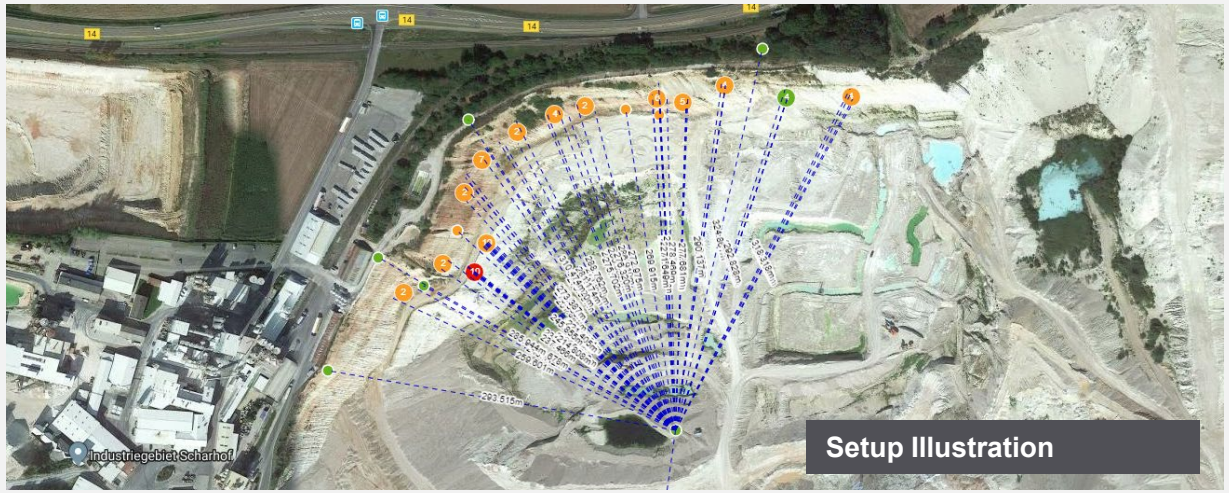
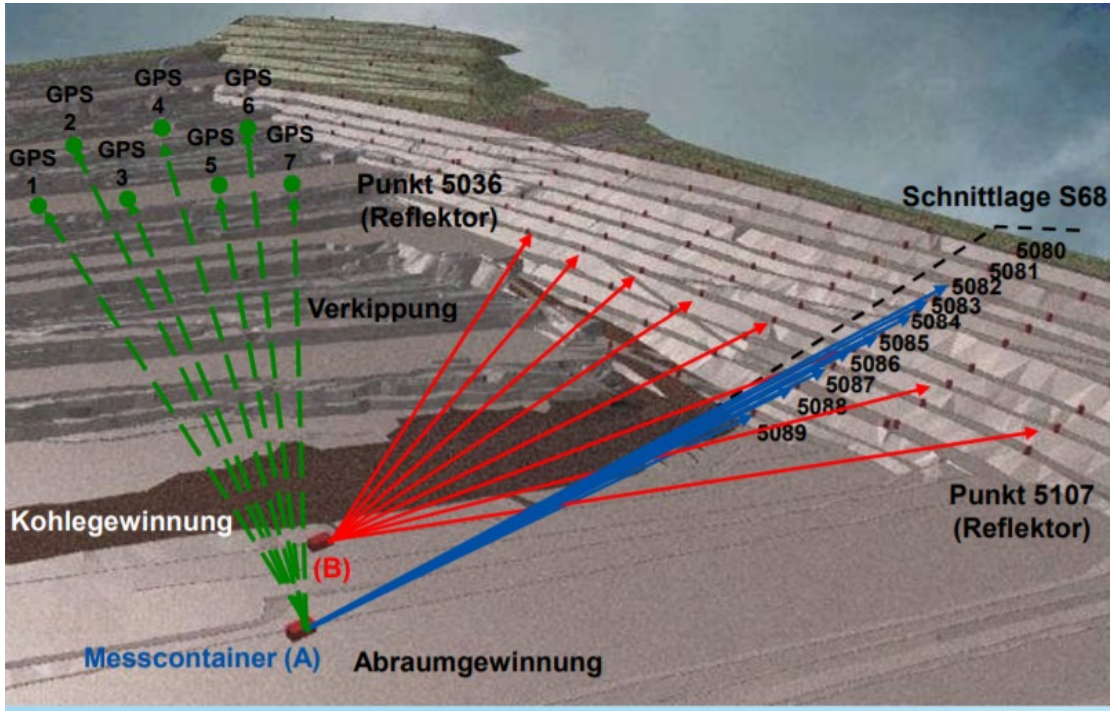
RTS - Total Station Monitoring Systems

- Pointwise movement and deformation control
- Local installation of target points (prisms) with ground foundation at AOI
- Local power supply for Total Station necessary
- Automatic measurement, remote maintenance
- Automatic data transfer via cell phone network
- Automatic data processing at DMT servers
- One measurement result value per 20 minutes
- Result presentation via protected website
- Alert message service
- Accuracy: horizontal and vertical <5 mm
- Established technology, high reliability
- Equipment by various manufacturers (e.g. Leica)
- On-site maintenance necessary for target cleaning
- Visibility from total station to targets necessary





RTS - Total Station Monitoring Systems



Source: Werner Guder, Dr. Dieter Dahmen, RWE Power AG

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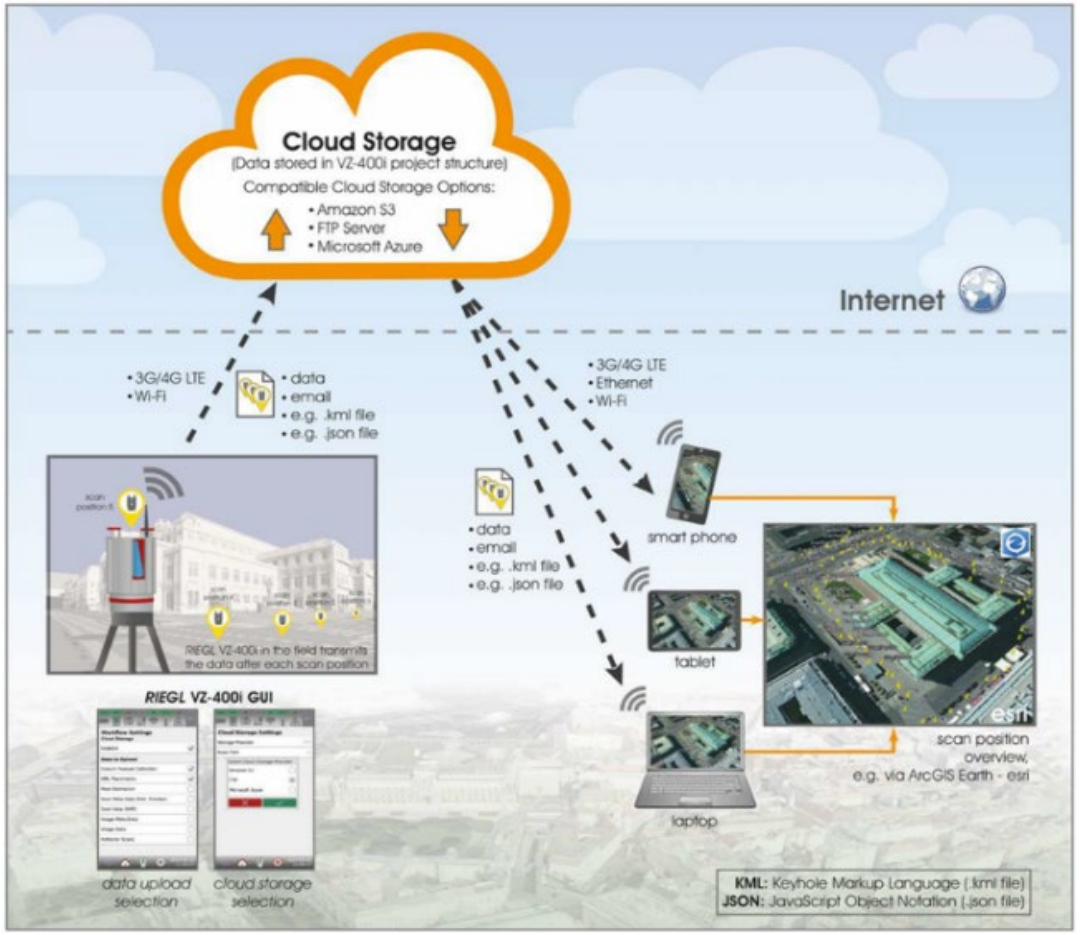
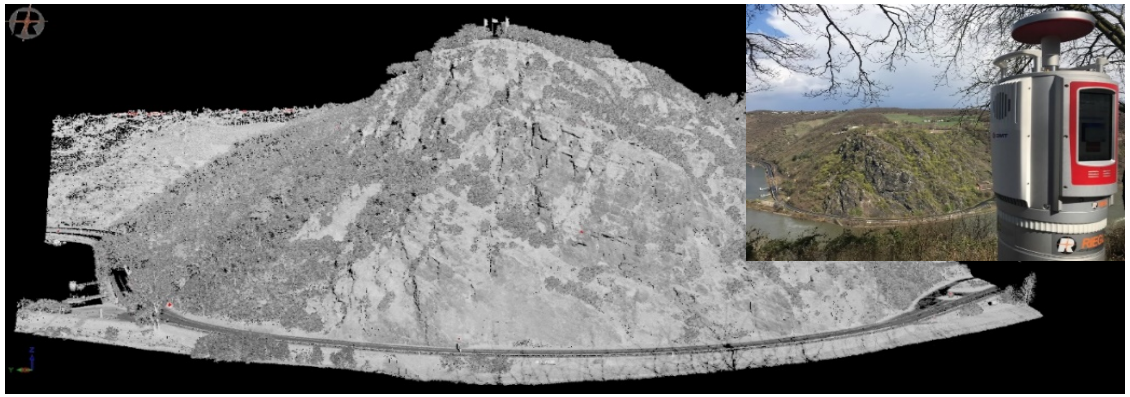
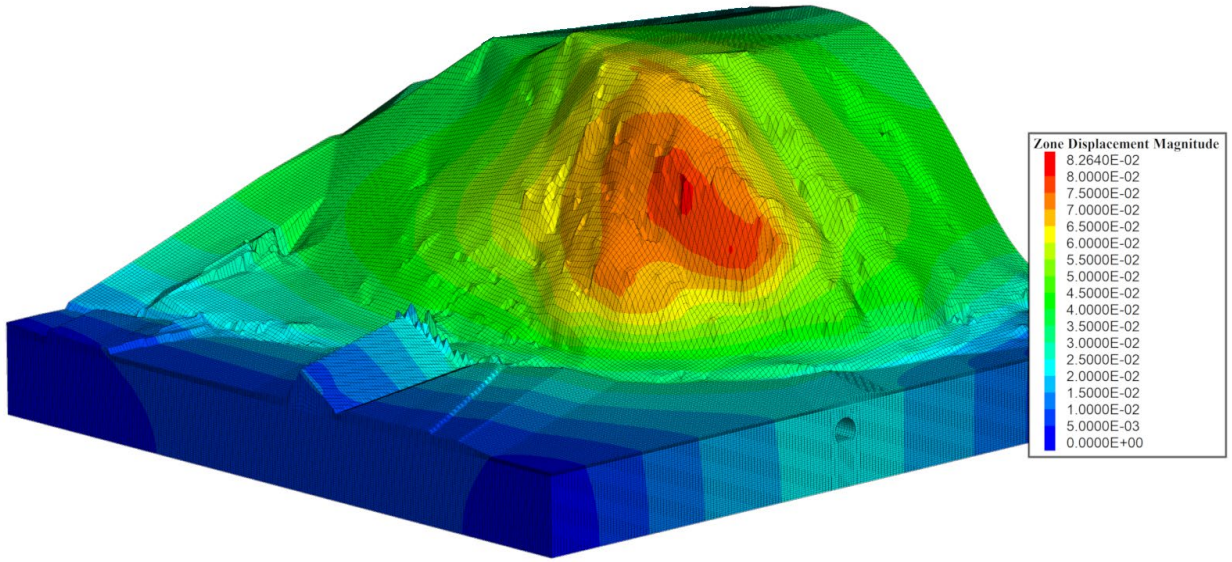
TLS - Terrestrial Laserscanning

- Campaign wise areal measurements of tailing surface geometry and deformation
- No installations at slope surface necessary
- Installation of fixed targets for scan geo-referencing necessary
- Local power supply for scanner necessary
- Data transfer via high-bandwith internet connection
- Data post processing at DMT for deformation detection
- One measurement result per scan
- Result presentation via special visualization software
- Accuracy: horizontal and vertical <10 mm
- Established technology, high reliability > however, automatic TLS monitoring is still a research topic
- Equipment by various manufacturers (e.g. Riegl)

TLS - Terrestrial Laserscanning







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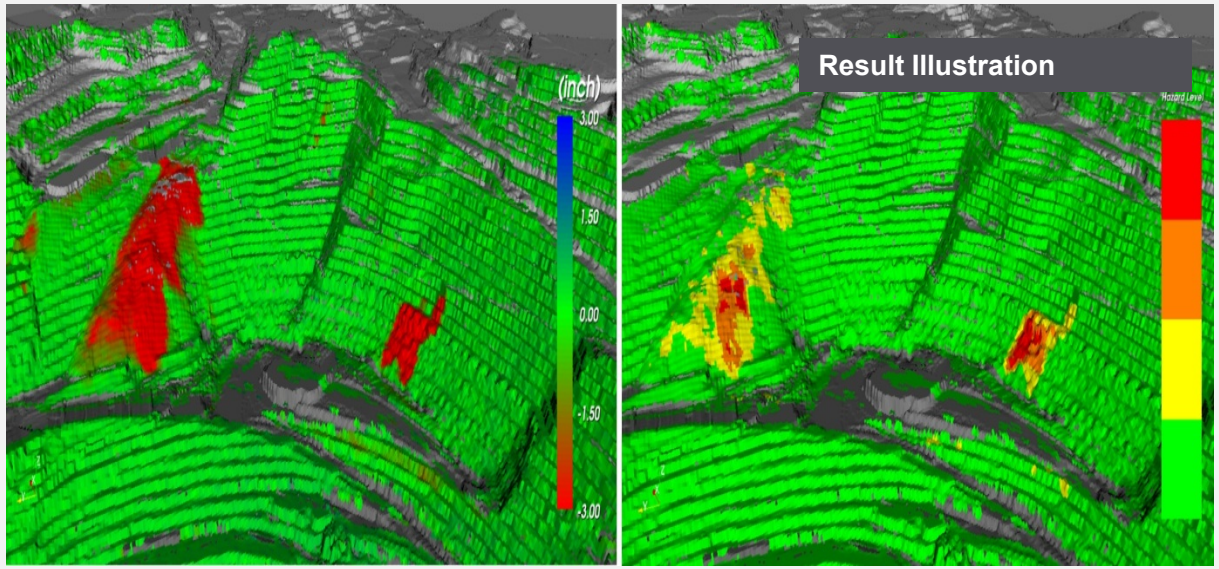
GBR – Ground Based Radar

- Continuous areal measurements of tailing surface deformation (only line of sight component)
- No installations at slope surface necessary
- Permanent stable installation of GBR instrument and local power supply necessary
- Automatic measurement, remote maintenance
- Automatic data transfer via high-bandwith internet connection
- Automatic data processing at site controller
- One measurement result per measurement, each ~10 minutes
- Result presentation via special visualization software
- Accuracy: line of sight <10 mm
- Results are highly interpretable because influenced by local weather changes and varying slope surface conditions (e.g. moisture, vegetation)
- Equipment by various manufacturers (e.g. IDS)

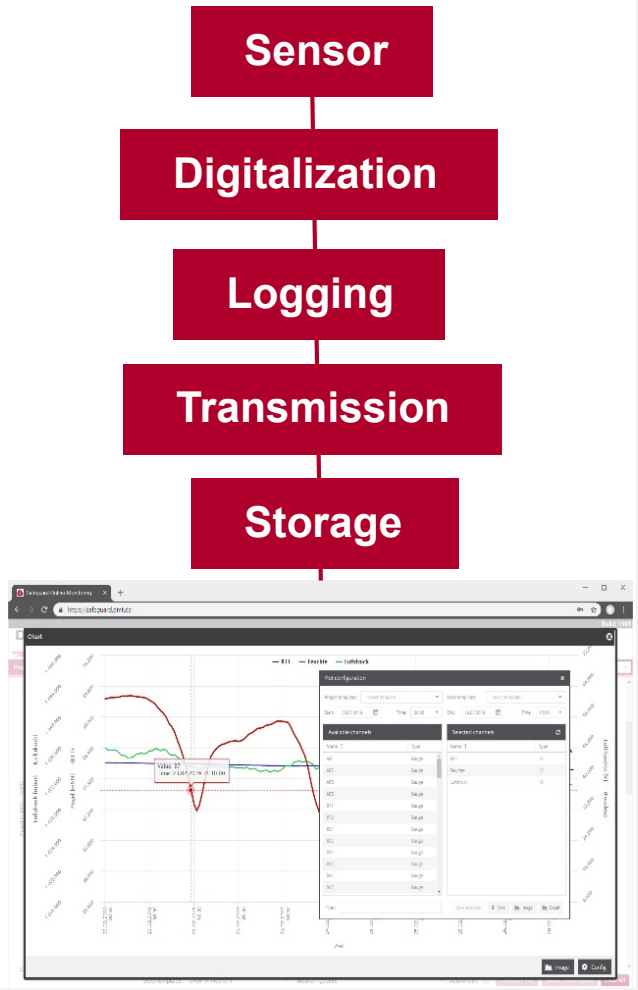


Geotechnical/Geophysical Sensors

Stability monitoring of tailing structures requires in general: monitoring of the ground surface for changes, robust monitoring of changes below the surface (e.g. along boreholes), monitoring of seismic signals from the environment. For this various sensor and logging system are available:

- Pointwise measurements with installation at points of interest
- Local power supply for each station necessary, autarkic low-power systems available
- Automatic measurement, remote maintenance
- Automatic data transfer via cell phone network
- Automatic data processing at DMT servers
- Automatic reporting
- Real-time measurements possible
- Result presentation via protected website
- Established technology, high reliability

Type/System
Geodetic monitoring with total station and target network
Terrestrial Laserscanning
Terrestrial Radarinterferometry
GNSS
Soil Strain Meters – Extensometer
Piezometer Pressure Sensors
Temperature Sensors
Earth Pressure Cells
Inclinometers
Microseismic Sensors
Water Level Sensors
Flow Meter Sensors
Rainfall Sensors
Video camera



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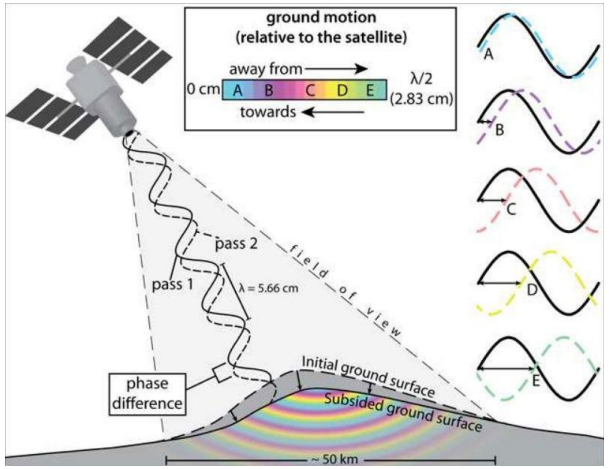
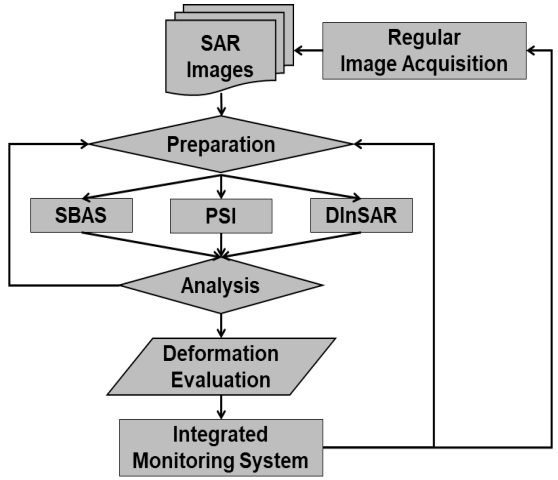
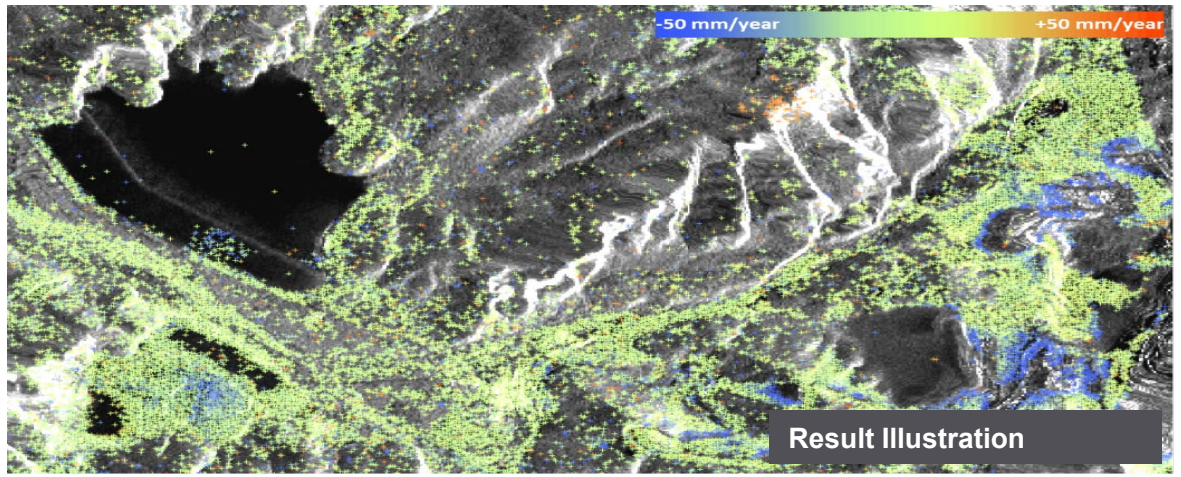
Radar Remote Sensing - System Overview

- Large area information using satellite radar observations and ground back scatterer analysis
- No installations at AOI surface necessary, depending on surface structure (e.g. vegetation, earth works) artificial back scatterers might be necessary
- One measurement result each 6 days (frequency depending on satellite type)
- Good quality free of charge data from EU Sentinel 1 satellite available, high level data available for purchase (e.g. TerraSAR-X) offering higher ground resolution
- Satellite image stack necessary to start processing (~15 scenes)
- LOS (line-of-sight) movement detection – no direct vertical movement is measured
- Centimetre level accuracy







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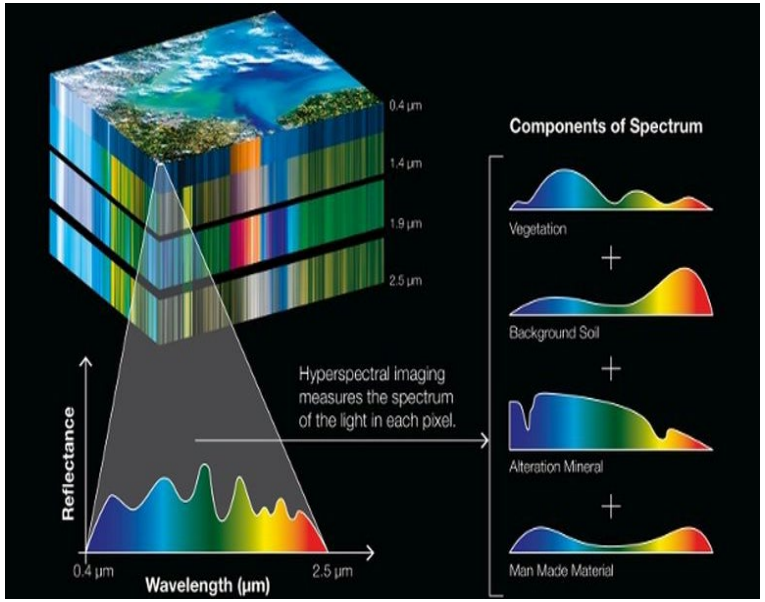
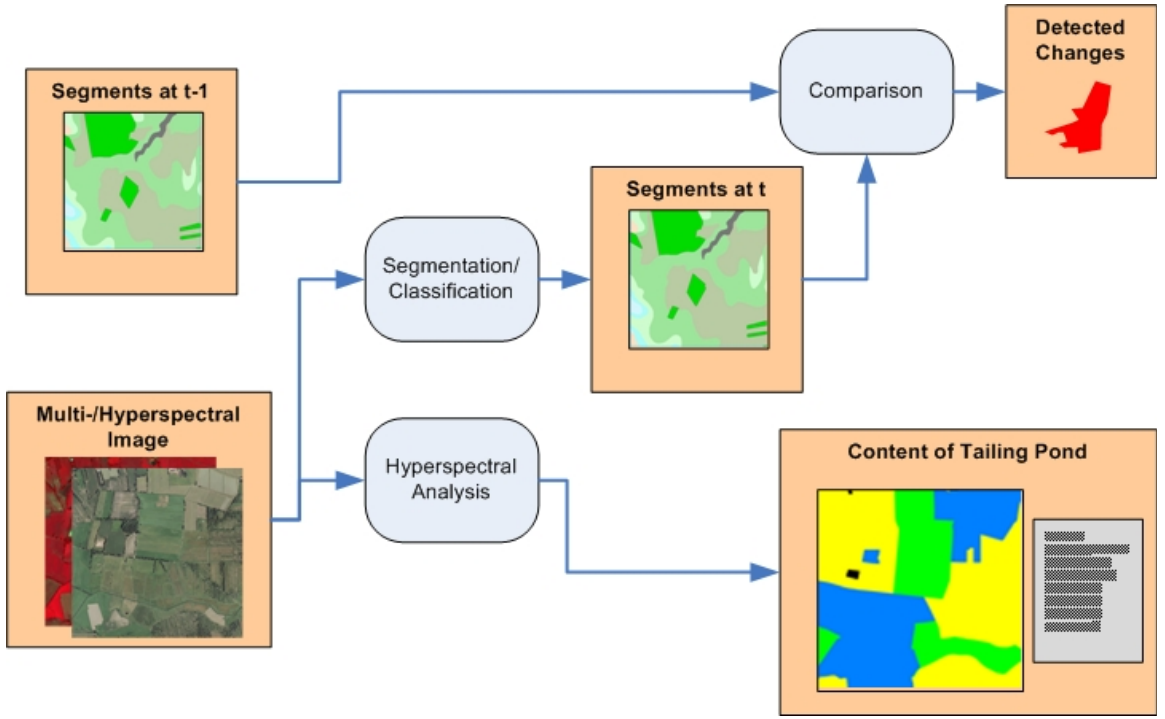
Optical Remote Sensing - System Overview

- Multispectral and hyperspectral satellite image processing (e.g. Sentinel 2 data)
- Surface change detection: soil moisture changes, vegetation changes, colour changes
- Content change detection requires calibration with on situ material sample data





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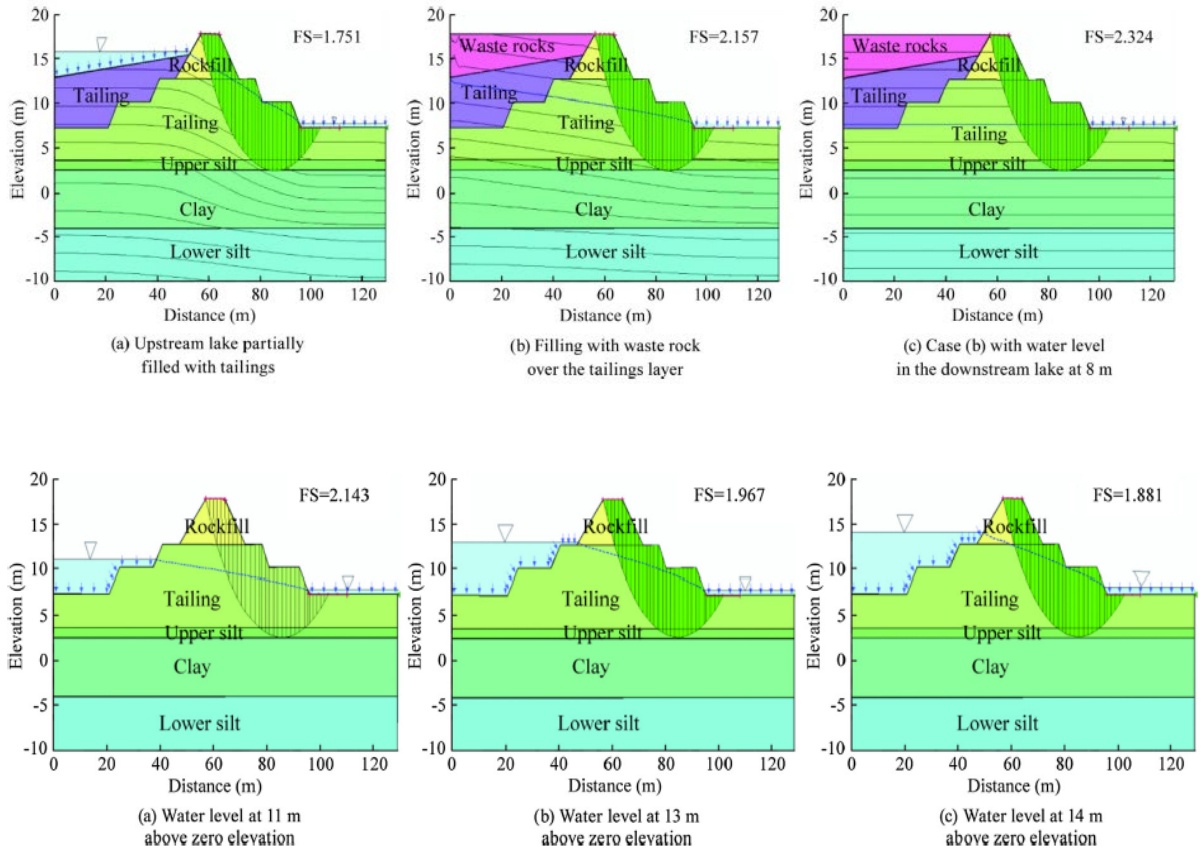
Stability Modelling - Systems Overview

- Advanced numerical analysis with regards to tailing construction and filling conditions, geophysical ground analysis, coupled hydraulic-mechanical modelling
- Analysis for different upstream lake filling conditions
- Analysis for different water levels
- Modell calibration and constant adjustment with monitoring data
- Modelling provides valuable information for monitoring sensor network design and threshold information for alerts



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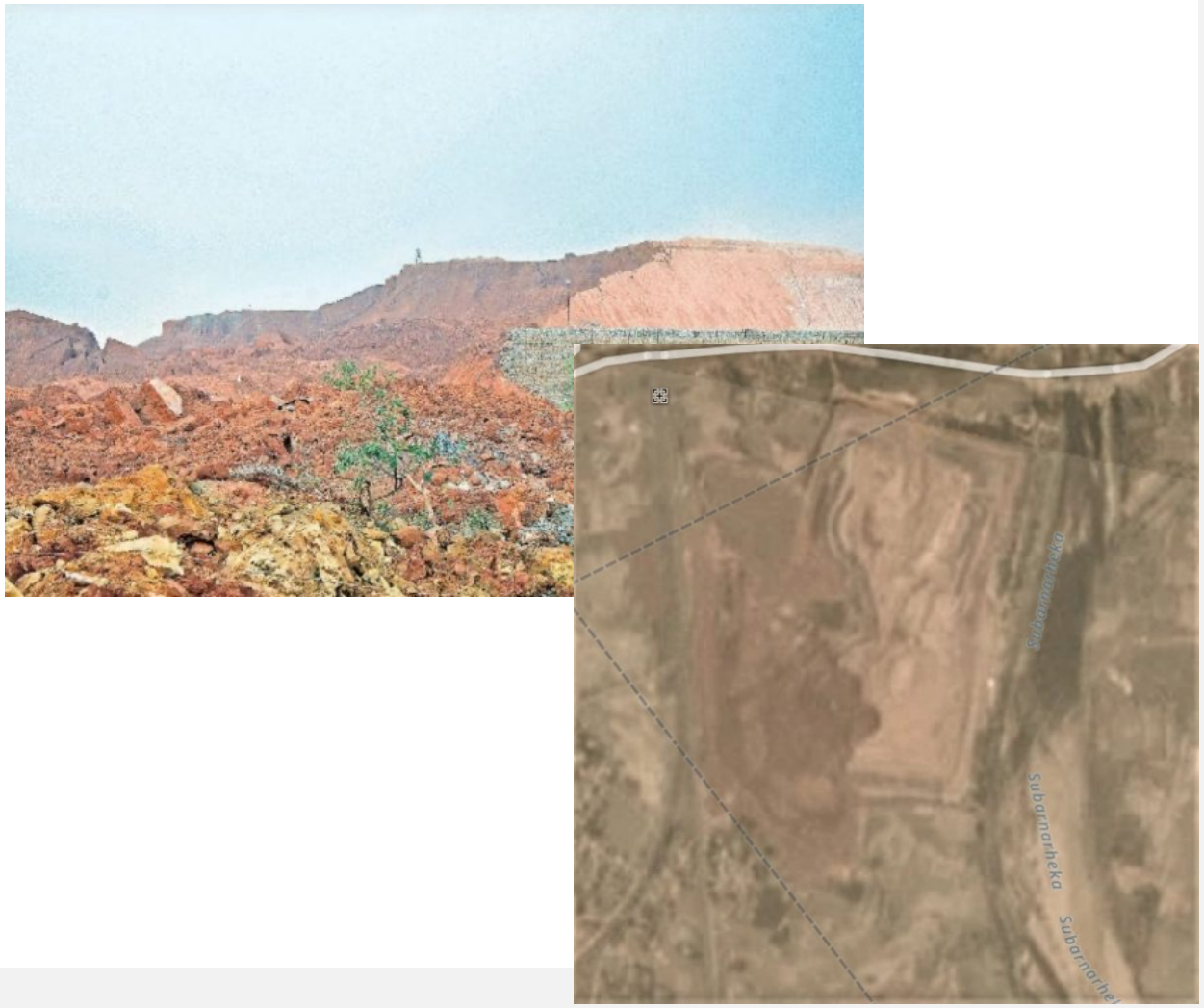
Stability Modelling - Systems Overview

- Bauxite Tailings – Red Mud
- Composition of wet slurry and dry sludge (mud cake from pressure filtration) can cause instabilities
- Modelling allows to access the stability



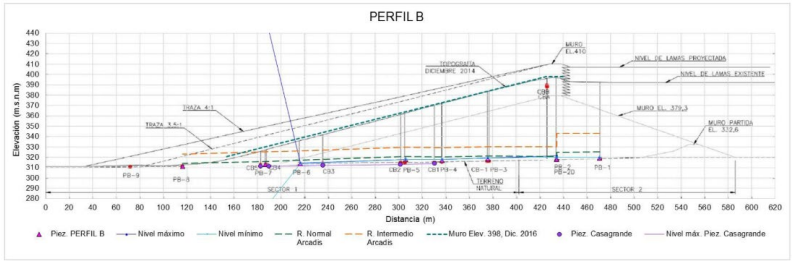
Engineering. Insight. Values.

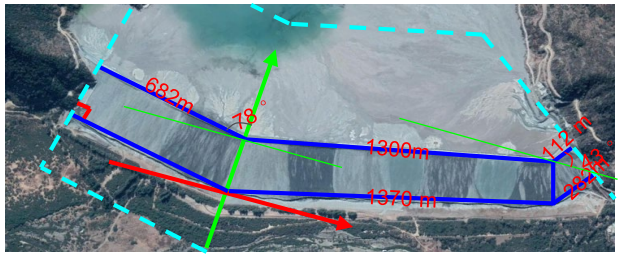
Stability Modelling - Systems Overview

- Creation of 2D and 3D models
- Modeling based on dam plans, construction details, material properties - extensive set of reliable information is necessary
- Pilot Scenario calculations:

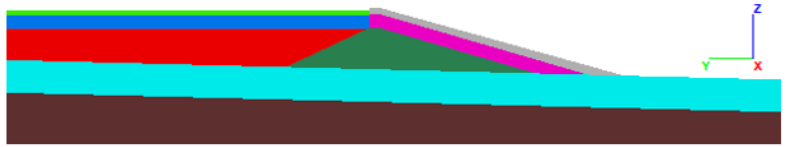
  Dam height

  Water level at 5m below crown and extreme scenario of water level equal to crown
- Result: pore pressure distribution, maximum strains distribution
- Delivering critical areas and limit values to be observed by monitoring

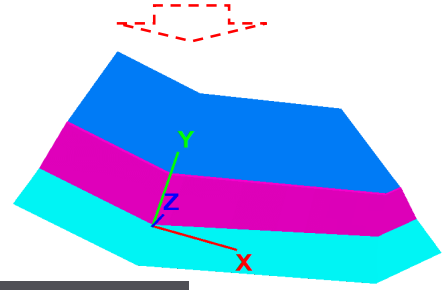




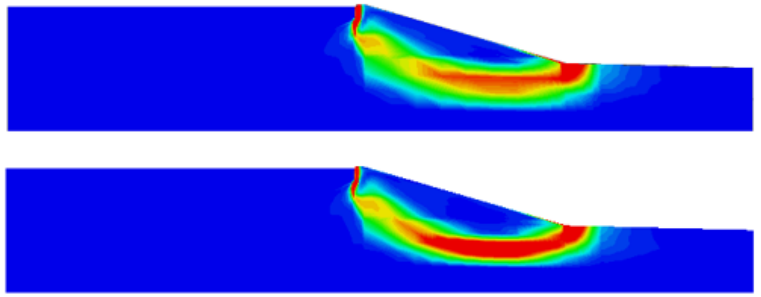
(a) Current



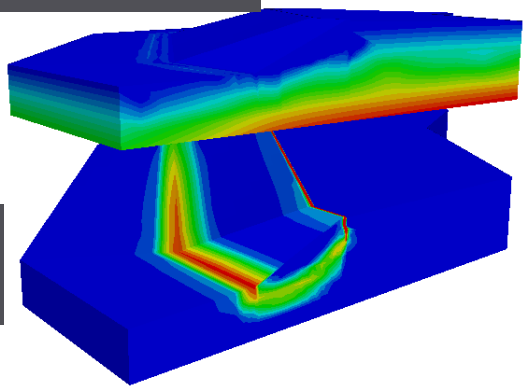
(b) Final



Pore pressure distribution



Max shear strain increment

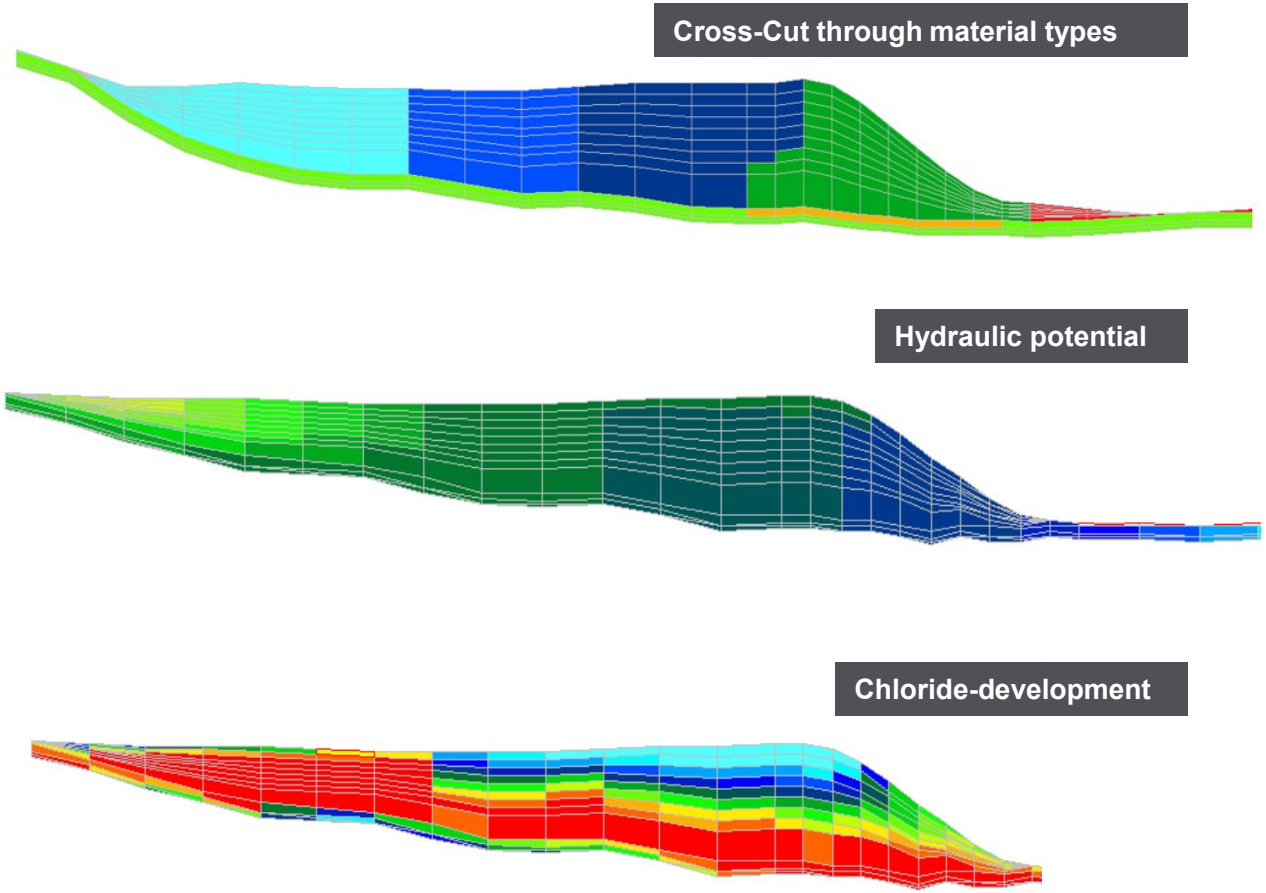


Geo-hydraulic Modelling - Systems Overview

- Analysis of saturation and pressure and mass transport applying DMT hydro modelling toolbox
- Prognostic modelling of internal water flow to assess the dam stability under extreme conditions.

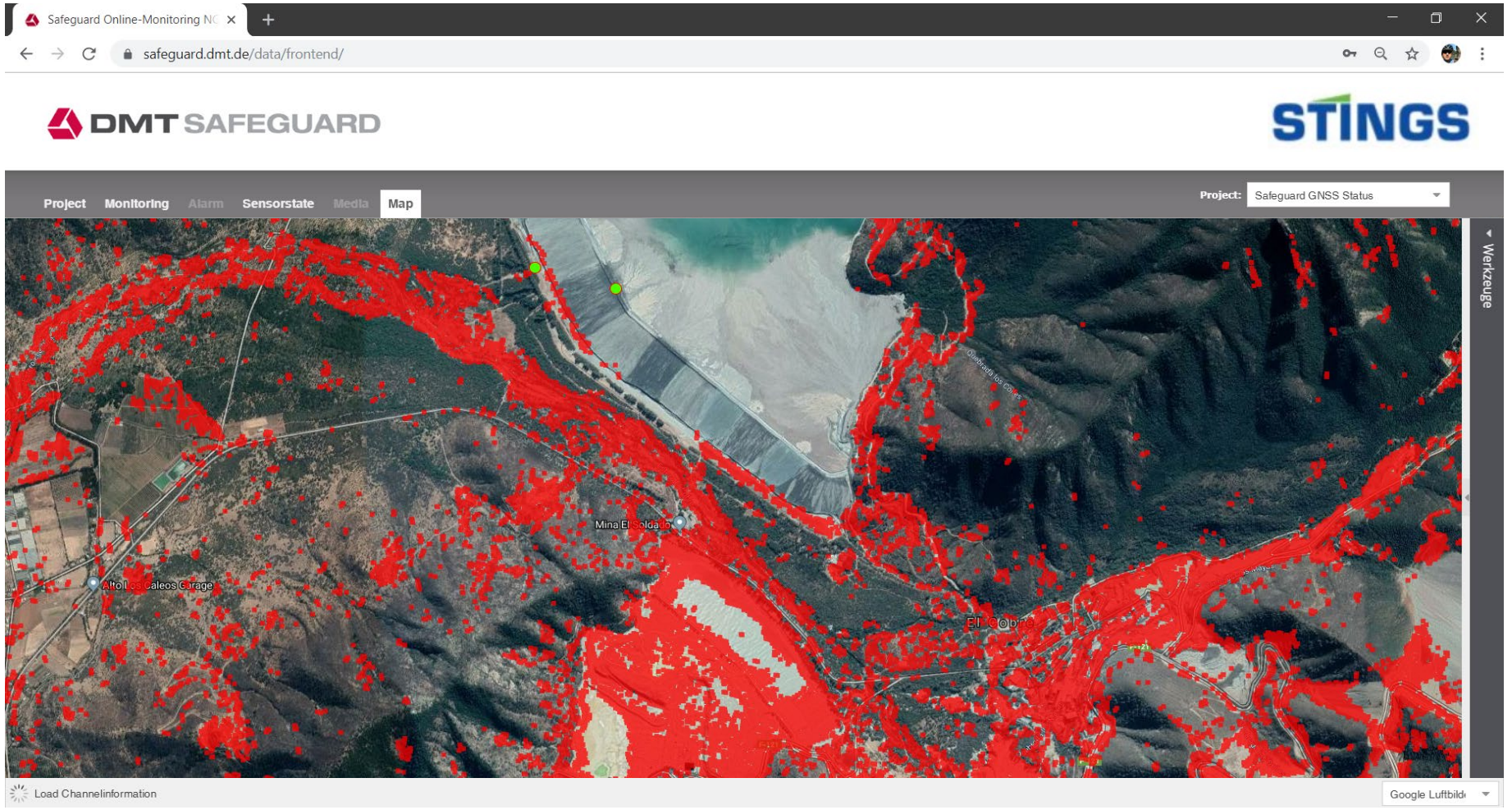
Related services:

- Flood Area Modelling to estimate the impact of an accidental failure.
- Development of decommissioning concepts – dewatering, covering
- Cleaning of discharge
- Groundwater and reactive mass-transport modeling downstream of the pond

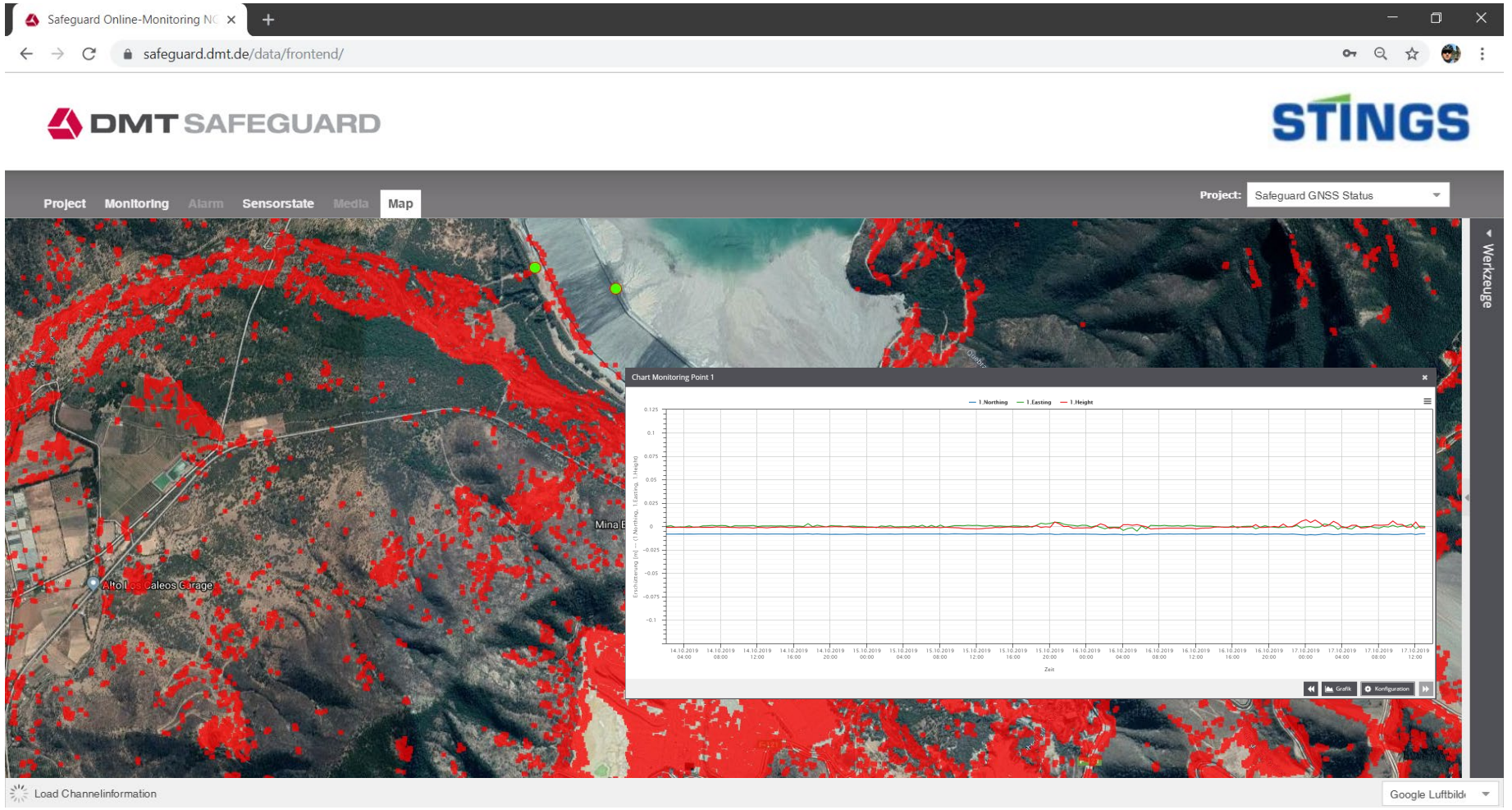


Engineering. Insight. Values.

Integrated Monitoring System

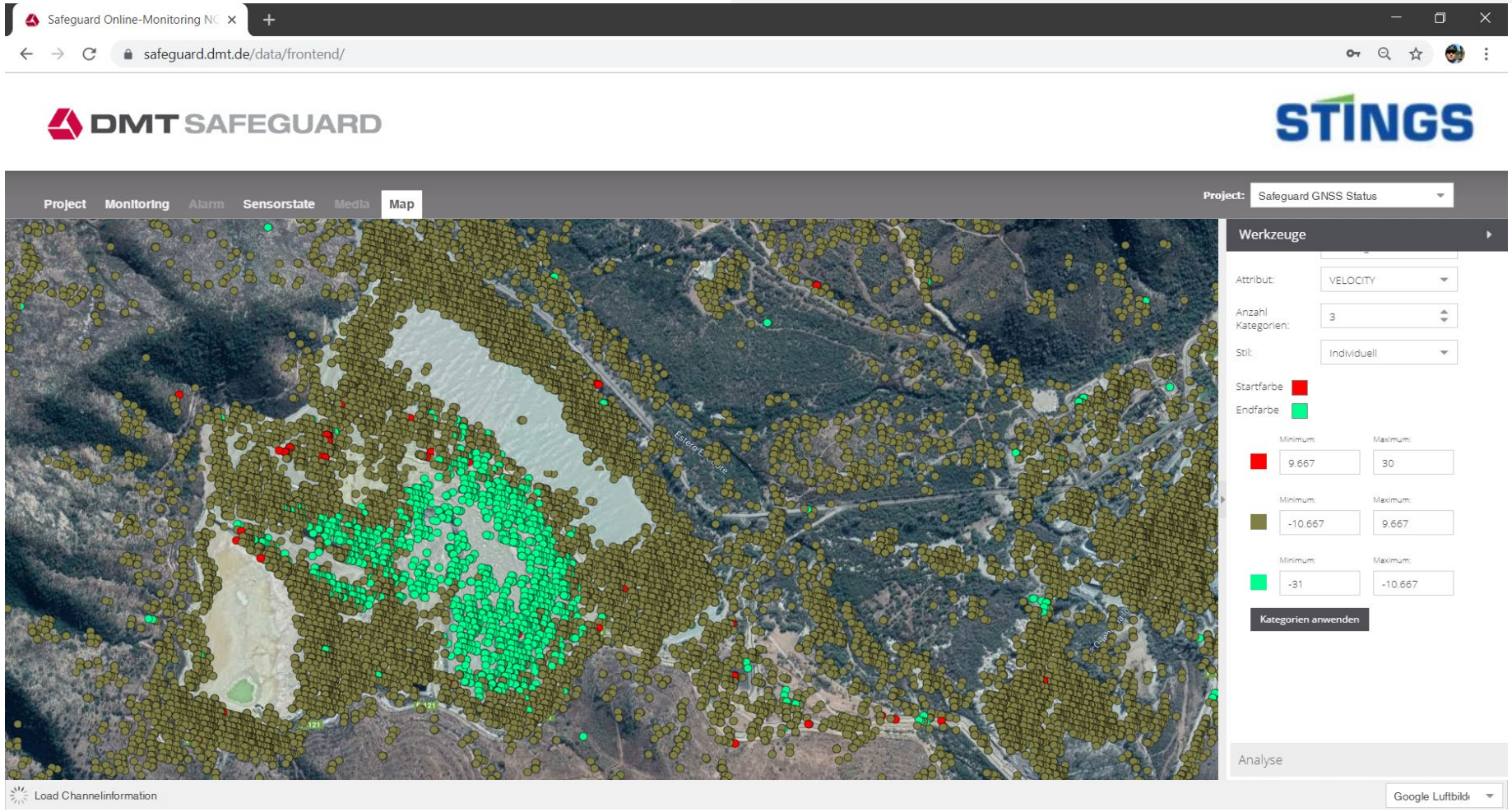


Integrated Monitoring System

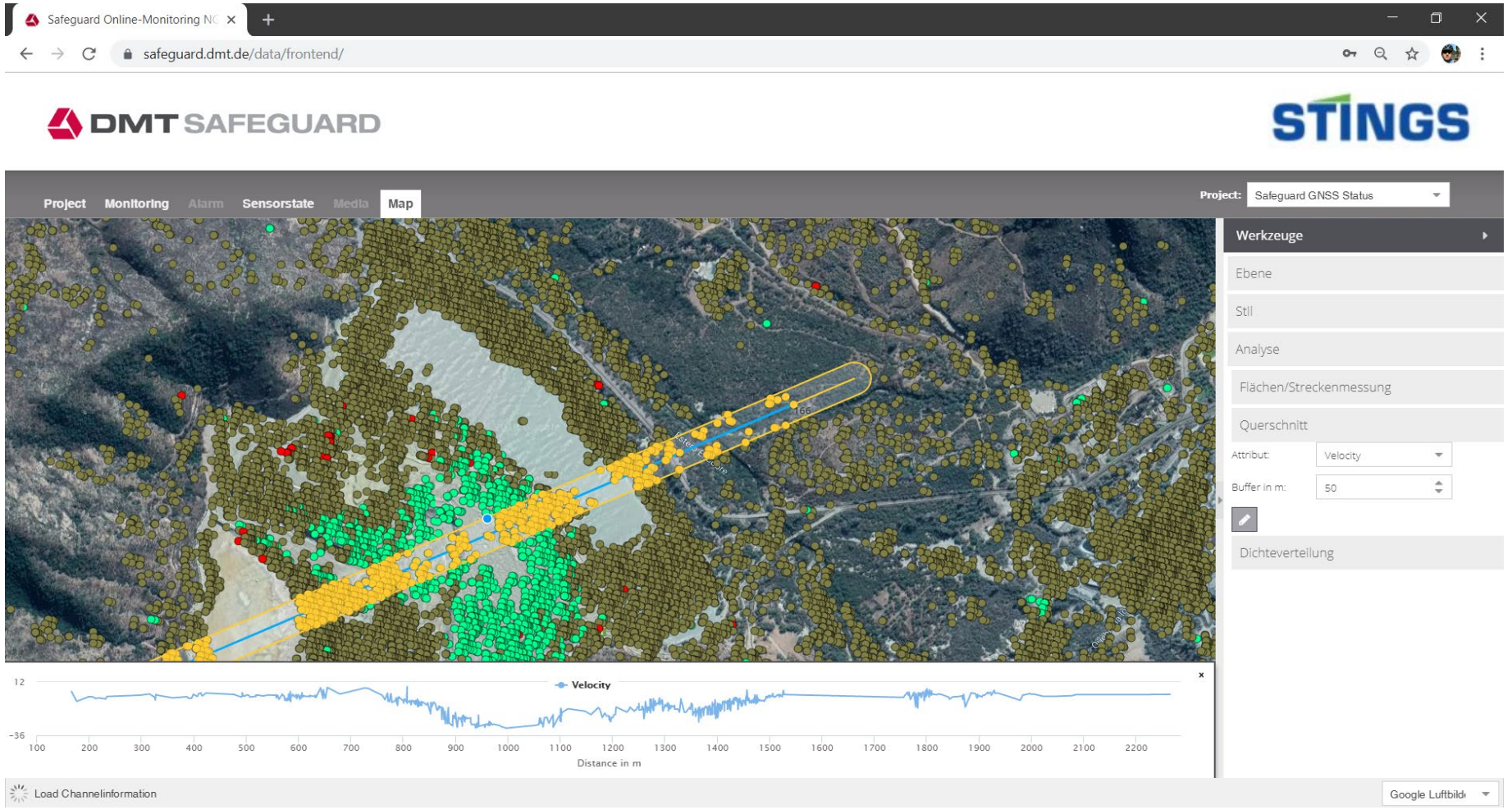


Engineering. Insight. Values.

Integrated Monitoring System



Integrated Monitoring System

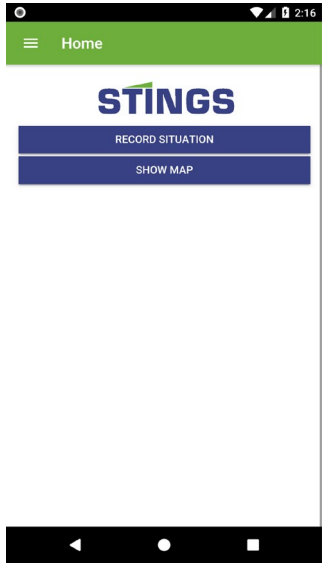


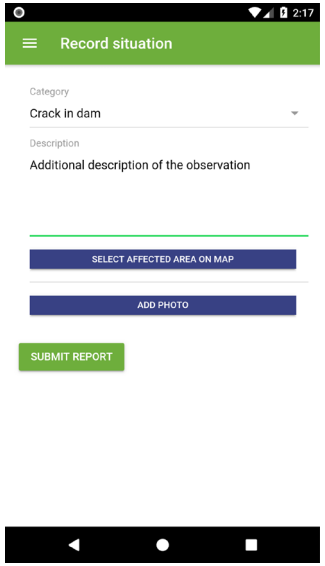
Engineering. Insight. Values.

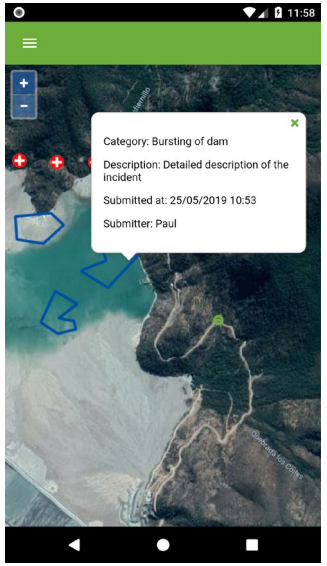
Integrated Monitoring System

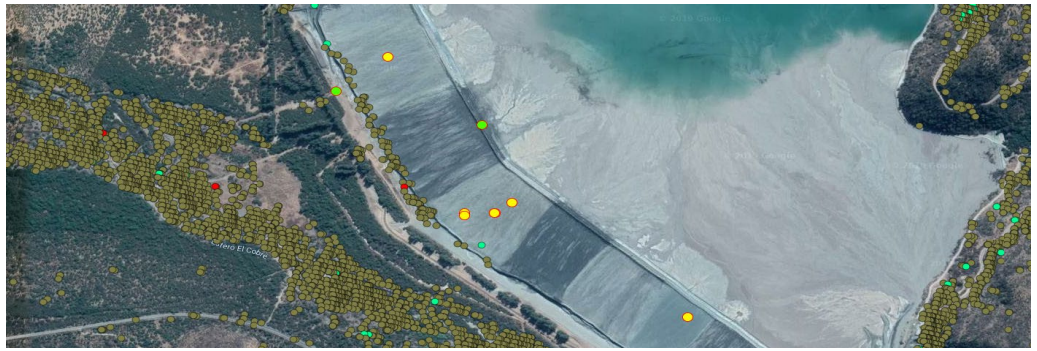
Ground Truthing - Smartphone APP

- for capturing terrestrial information e.g. critical situations
- consists of an app for smartphones / tablets and a backend that can provide, receive and process data
- Employees can document on-site situations via app including photo, position, category and textual information
- App user can see tailings and other assets on the map and their own position for orientation
- In return alerts can be received via app
- available in different languages









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4. Discussion

Save the Date !

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