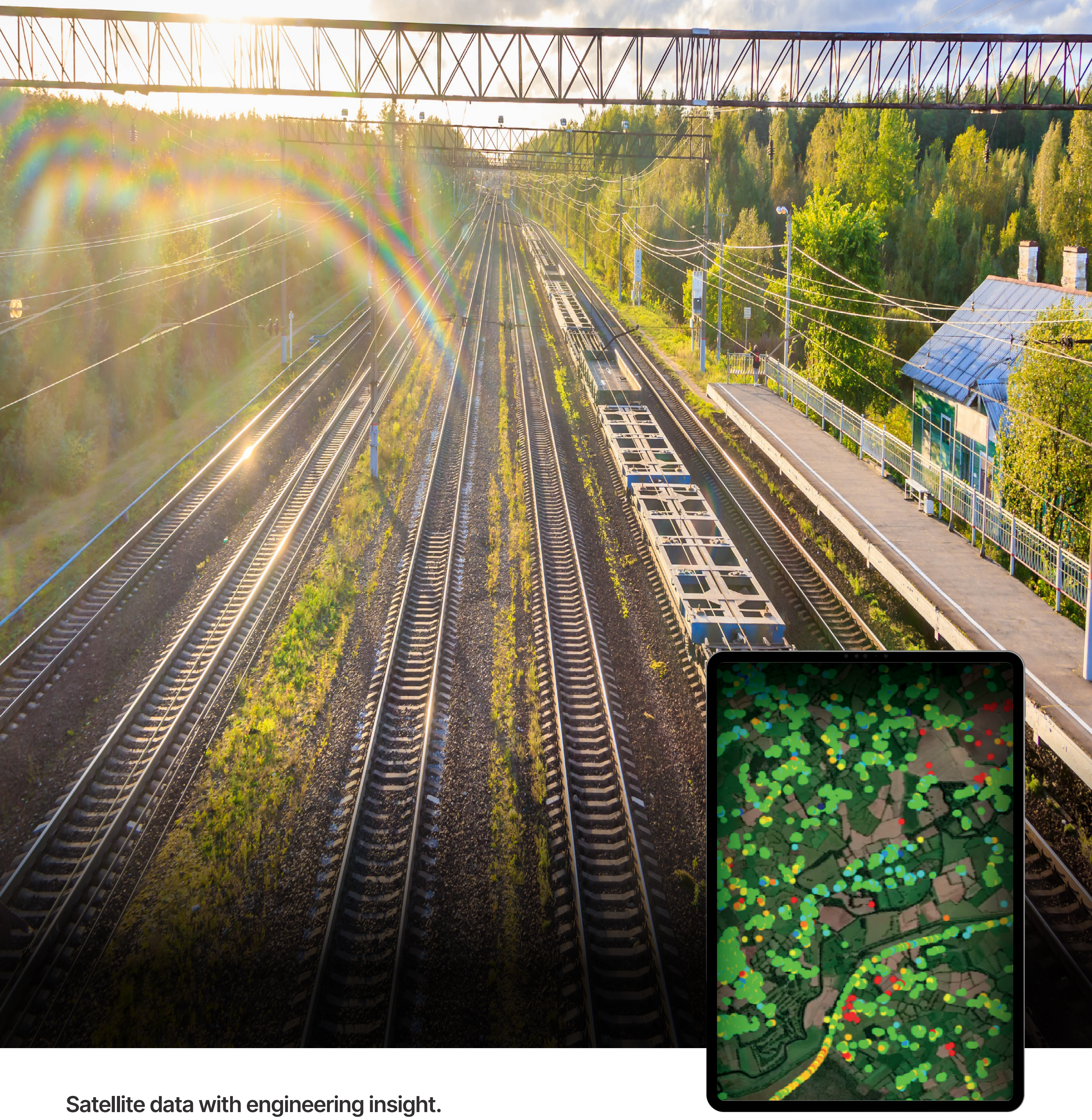
GEOFEM

Unlocking the Future of Rail: A Guide to Satellite Radar Data Analysis for Rail Infrastructure Stakeholders



Satellite data with engineering insight.

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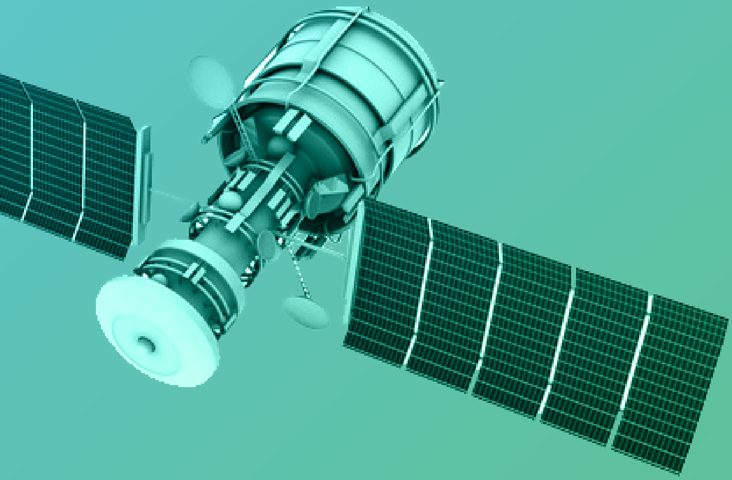


Introduction

With climate challenges evolving, and economic consideration constantly in flux, we are entering a new era of rail infrastructure management. Maintaining the integrity of rail tracks isn't just about keeping trains on schedule – it's about safeguarding assets, ensuring safety, and optimising operations in the face of escalating environmental challenges.

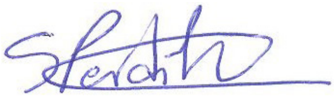
Every minute, trains around the world collectively cover thousands of kilometres of track, connecting communities, driving economies, and shaping industries. Yet, beneath the surface of these busy networks lies a lattice of infrastructure connections susceptible to the forces of nature, human activity, and time. According to a report by the International Union of Railways, global rail freight traffic is projected to increase by 2.3% annually, reaching 28.6 trillion tonne-kilometres by 2030. With such growth comes an urgent need for innovative solutions to monitor, manage, and maintain rail tracks with higher precision.

Satellite Radar Data analysis can answer this call. A groundbreaking technology, this analysis can harness the capabilities of Interferometric Synthetic Aperture Radar (InSAR) to revolutionise how we perceive, predict, and protect rail infrastructure. InSAR is a remote sensing technique that captures high resolution images of surface deformations with millimetre-scale precision. By measuring the phase difference between radar signals reflected from the ground over time, InSAR enables the detection of subtle ground movements.

Join us on a journey into the future of rail asset management, where satellite radar data analysis can redefine the boundaries of possibility. In this guidebook, we will explore the ways in which InSAR technology could empower track owners and managers to proactively safeguard their assets, optimise maintenance practices, and ensure the reliability and resilience of rail infrastructure in the face of evolving challenges.

Welcome aboard,

Dr. Skevi Perdikou
CEO
Geofem Ltd



"Global rail freight traffic is projected to increase by 2.3% annually, reaching 28.6 trillion tonne-kilometres by 2030."

International Union of Railways

Chapter 1: The Rail Challenge

"In the UK, it is estimated that landslides and ground movements cause around £200 million in damage to rail infrastructure each year."

Network Rail

Stewards of rail networks are tasked with monumental responsibilities – to ensure the safety, reliability, and efficiency of infrastructure that fuels economies and communities. Let's delve into some challenges that might get in the way of this mission, from the invisible threats to the imperceptible vulnerabilities that define the landscape of railway management.

The Unseen Menace: Ground Movements

Beneath the seemingly solid ground upon which rail tracks lie, subtle movements can gather and grow. Ground subsidence, uplift, and lateral shifts – imperceptible to the naked eye yet capable of causing damage to rail infrastructure. According to a study by the American Society of Civil Engineers, over 30% of rail track failures are attributed to ground movement-influenced issues, highlighting the urgency of detecting and mitigating these hidden threats.

The challenge lies in the invisibility of these movements. While the human eye may marvel at the sprawling track that stretches to the horizon, it often fails to discern the minute shifts that occur beneath the way. Indeed, ground movements as small as a few millimetres can remain undetected until catastrophic failures occur, disrupting operations, jeopardizing safety, and draining resources.

Drainage Dilemmas

The battle against water intrusion is an ever-evolving conflict for rail engineers. In a survey conducted by the Railway Industry Association, over 70% of rail operators cited drainage-related issues as a significant challenge, with waterlogged tracks contributing to delays, track deformations, and increased maintenance costs.

In an era of climate change-induced extreme weather events, the stakes have never been higher. Failure to adequately manage drainage systems not only compromises track stability but also poses environmental risks, from soil erosion to water contamination.

The Price of Failure

According to a report by the International Railway Journal, the average cost of repairing a single serious track fault can soar into the millions, encompassing expenditure related to labour, materials, equipment, and operational disruptions. With profit margins razor-thin and public scrutiny unforgiving, the financial ramifications of track failures are nothing short of catastrophic.

Despite the best efforts of routine inspections, serious faults often materialize with little warning, leaving rail operators scrambling to contain the damage and restore service. In an industry where every minute counts, the imperative to pre-emptively address potential fault points have never been greater.

> "In the United States, between 2015 and 2020, there were over 500 reported incidents of rail disruptions due to ground movement and subsidence."
>
> Federal Railroad Administration, 2020

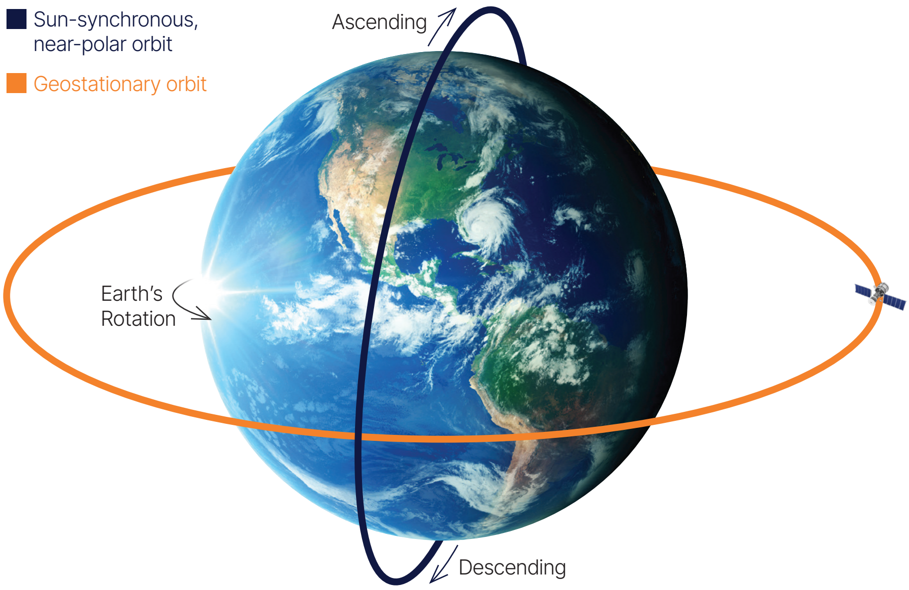
Navigating the Geohazard Maze: Mapping Vulnerabilities

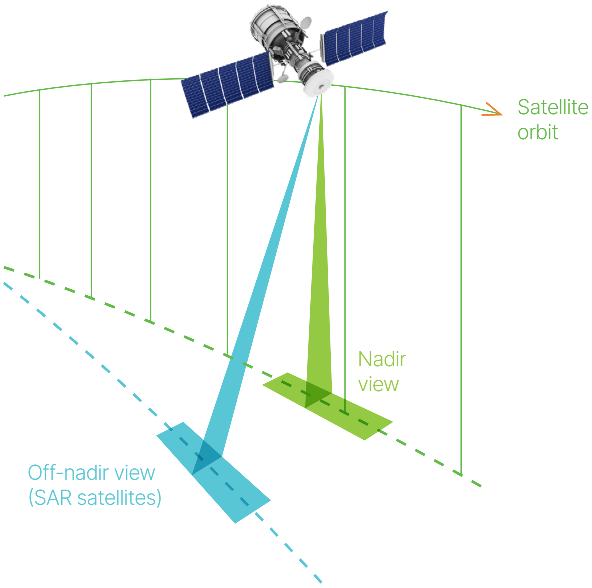
And so, we arrive at the final frontier of the rail challenge—geohazards. From landslides to sinkholes, from seismic activity to coastal erosion, the spectre of natural disasters looms large over rail networks worldwide. Yet, amidst this perilous landscape, a glaring gap persists—a lack of comprehensive knowledge regarding which areas of the rail are most susceptible to geohazards.

According to a study by the International Union of Geological Sciences, over 60% of rail operators admit to having limited insight into the geological risks posed to their infrastructure. This knowledge gap poses a formidable obstacle to effective risk management, leaving rail networks vulnerable.

Chapter 2: The Basics of SAR (Synthetic Aperture Radar)

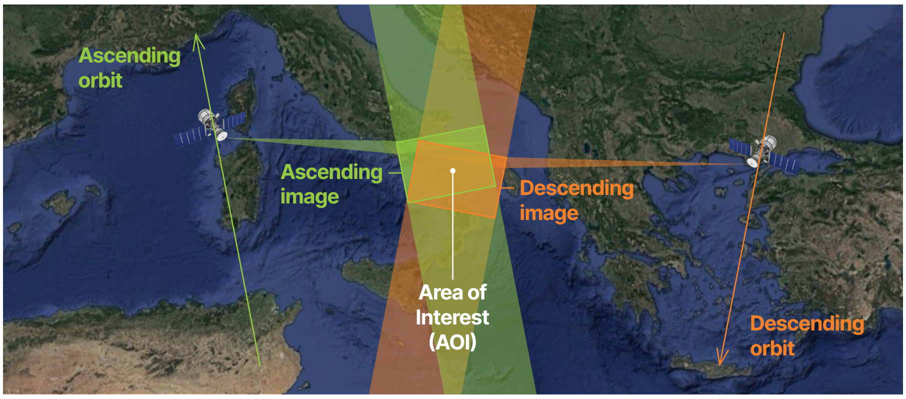
At its base, SAR is a remote sensing technology that allows analysts to observe the Earth's surface using radar pulses to create detailed images of terrain features and surface characteristics. Unlike optical imaging, which relies on visible light, SAR operates in the microwave portion of the electromagnetic spectrum, allowing it to penetrate clouds, vegetation, and the darkness of night.





The Marvel on Interferometry

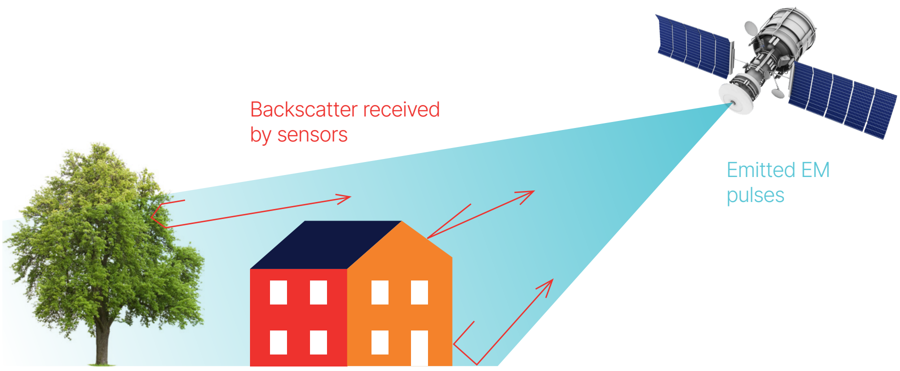
Let's dive deeper into one of SAR's most powerful techniques: Interferometric Synthetic Aperture Radar, or InSAR for short. Imagine two SAR images of the same area, captured on different days. By comparing these images and measuring the phase difference between the radar signals, we can create detailed maps of surface deformation with a high degree of precision. This process, known as interferometry, unlocks a wealth of information about ground movements, subsidence, and structural changes – key factors in assessing the health and stability of infrastructure.



Radar Waves

So, how does SAR actually work? Essentially, by emitting microwave pulses toward the Earth's surface and detecting the return of the reflected signals, or backscatter, to the sensor. By analysing the properties of the reflected radar waves, such as their amplitude and phase, SAR systems can extract a wealth of information about surface features, including topography, roughness, and moisture content.

From detecting ground movements to mapping surface moisture, SAR provides a window into the dynamic processes shaping our world – and, with it, the opportunity to safeguard our assets and secure our future in an ever-changing landscape.



Chapter 3: Applications of SAR to Rail

"The cost of InSAR monitoring is significantly lower than traditional ground survey methods. Monitoring rail networks with InSAR can cost as little as $500 per km per year, compared to $5000 per km per year for conventional methods."

Earth Science Information Partners

Section A: Mind the Gap!

Satellites equipped with synthetic aperture radar (SAR) sensors capture images of the Earth's surface at regular intervals, typically every few days on a continuous basis. These images contain information that can be converted into ground displacement. InSAR relies on interferometric processing techniques to measure changes in the phase of radar signals between successive images. By comparing these phase differences, known as interferograms, InSAR can detect subtle ground movements with millimetric precision.

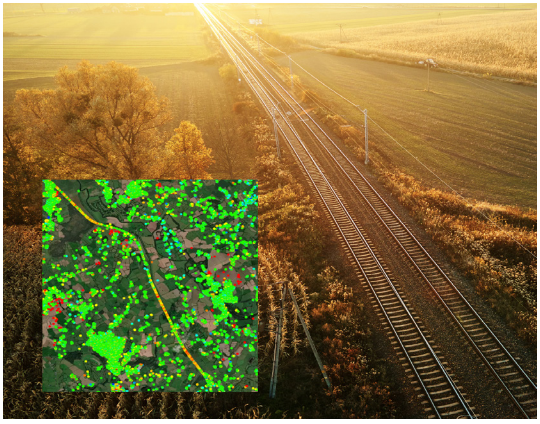
In the next stage of analysis, algorithms are employed to convert the data into meaningful displacement values, allowing for the precise quantification of ground movement. InSAR data can then be integrated with geotechnical models to interpret ground movement patterns and identify underlying causes such as slope instability.

Section B: Managing Drainage

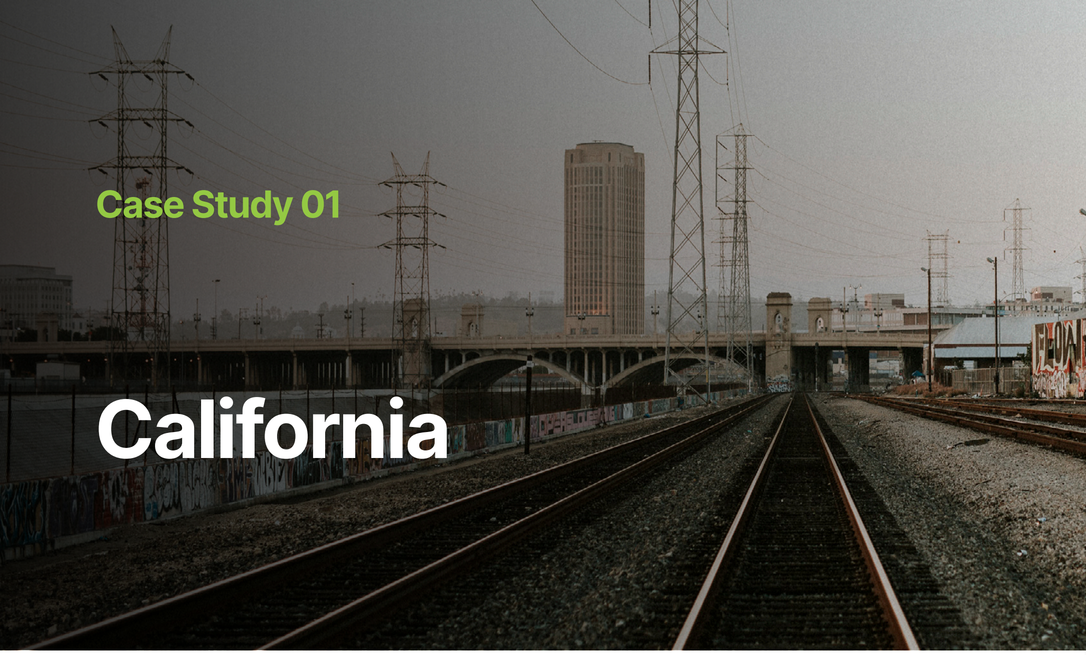
SAR satellites can capture high-resolution images of railway corridors and surrounding terrain. Applying algorithms to the data in these images provides a snapshot of soil moisture distribution, influenced by factors such as rainfall, topography, and vegetation cover. SAR-derived soil moisture maps are integrated with geospatial data, including digital elevation models, land cover maps, and hydrological models. This integration enables a holistic understanding of drainage dynamics along rail corridors and facilitates informed decision-making for drainage management strategies.

Section C: Geohazard Susceptibility and Failure Prevention

InSAR detects ground movements indicative of geohazard activity, such as slope deformation, subsidence, or uplift. By analysing changes in radar signals over time, InSAR identifies areas of heightened susceptibility to landslides, sinkholes, and erosion, allowing for targeted intervention and mitigation measures. InSAR-derived insights feed into geohazard risk modelling frameworks, enabling the quantification of potential hazards, their likelihood of occurrence, and the potential consequences for rail infrastructure.



The application of InSAR technology in geotechnical management offers a range of benefits for rail infrastructure stakeholders, from early detection of sinkholes, landslides, and erosion, to proactive prevention of catastrophic failures.



Case Study 01

California

This estimated 70km rail track in California is vital to transportation between the cities of Hercules and Fremont. As part of the wider GAIA project, Geofem investigated the potential for track movement that could compromise the safety and reliability of the track.

The Challenge

All 70kms of this rail corridor needed to be monitored regularly, but visual inspections can only be performed intermittently meaning ground or track movements occurring between inspections could go unnoticed.

The Solution

Displacement data was obtained between December 2018 and November 2021 to develop trends and identify sections of the railway exhibiting consistently higher displacement.

The Benefits

Areas of higher displacement were pinpointed allowing for preventive measures to be taken before they develop into costly failures.

"Regular maintenance of infrastructure is essential for ensuring safe operations. As of January 2022, the American Public Transport Association (APTA) reports the average cost for regular maintenance of railways in the United States to be approximately $5,000 to $12,000 per mile annually."

SCAN THE QR CODE
to find out more about this project.

Chapter 4: The Business Case

By harnessing the transformative capabilities of Synthetic Aperture Radar (SAR) technology, stakeholders can unlock a wealth of benefits that bolster their bottom line and enhance their operational resilience. Let's delve into the compelling business case for applying SAR to monitoring railways.

Proactive Risk Management:

SAR enables early detection of ground movements, drainage issues, and geohazard susceptibility factors, allowing stakeholders to proactively identify and mitigate risks before they escalate into costly failures. By implementing targeted maintenance interventions and risk mitigation measures, stakeholders can minimise downtime, reduce repair costs, and safeguard critical assets.

Operational Maintenance Practices:

SAR-derived insights inform data-driven maintenance strategies, enabling stakeholders to prioritise resources, allocate budgets, and optimise maintenance schedules based on the real-time condition of rail infrastructure. By identifying areas of concern and scheduling interventions accordingly, stakeholders can maximise asset lifespan, minimise service disruptions, and improve operational efficiencies.

Enhanced Safety and Reliability:

Leveraging SAR technology, means stakeholders can enhance the safety and reliability of their networks by detecting and addressing potential hazards before they compromise track integrity or pose risks to passengers and freight. By implementing proactive safety measures and preventive maintenance practices, stakeholders can mitigate the risk of accidents, improve service reliability, and enhance customer satisfaction.

Cost Savings and Operational Efficiency:

SAR-driven insights enable stakeholders to streamline operations, reduce maintenance costs, and optimise resource allocation by identifying areas of inefficiency and implementing targeted interventions to improve performance. By leveraging SAR data for predictive analytics and asset management, stakeholders can minimise operational expenses, maximise revenue generation, and achieve greater profitability.

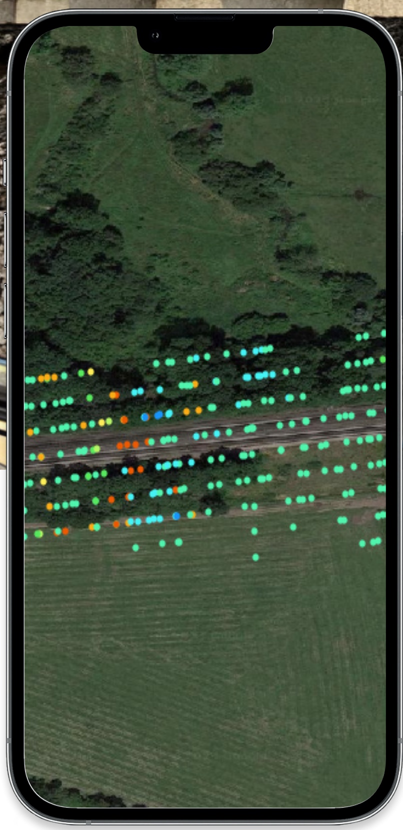
Want to learn more about how to safeguard your infrastructure with satellite intelligence? Contact Geofem to start a conversation.

"InSAR has been widely adopted in European rail networks for monitoring ground stability. For example, Deutsche Bahn in Germany uses InSAR to monitor over 30,000km of rail tracks, resulting in a reported 25% reduction in maintenance costs and a 30% increase in the reliability of rail services."

Duetsche Bahn

Case Study 02

Hook, United Kingdom



A section of the main rail line between Basingstoke and London suffered a sizeable collapse in January 2023, having major impacts on services. The 44-metre-long landslip, which occurred near Hook in Hampshire, undermined a track, leaving only the London-bound tracks safe to use.

The Challenge

The infrastructure owners spent thousands of pounds and operators and customers suffered weeks of disruption while the landslip was repaired. A far more cost-effective preventive approach could have been implemented to identify and address the impending landslip before it undermined the track

The Solution

Using InSAR analysis of satellite radar data can provide millimetric ground displacement readings in all weather conditions. Moreover, SAR analysis is the only method that allows analysts to go back in time, and factor in historical displacement data in susceptibility analysis.

The Benefits

Had rail stakeholders implemented satellite data analysis into their maintenance and remediation plan, the impending landslip at Hook could have been detected and addressed before the costly failure occured.

“The infrastructure stakeholders spent weeks and thousands of pounds on creating a landslip bypass from one of the London-bound lines but a far more cost-effective preventive approach could have been implemented to identify and address the impending landslip before the incident."

SCAN THE QR CODE
to find out more about this project.