Settlement monitoring using space-borne radar interferometry in the context of large infrastructure projects

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InSAR applications in large infrastructure projects

**Planning**
- Developing baselines and locating areas of greatest stability/instability

**Asset Management**
- Pinpointing the amount and location of displacement to prioritize inspection and maintenance

**Risk Mitigation**
- Identifying hazards to proactively prevent failures

**Historic Assessment**
- Measuring what moved, when, and by how much

**Source:** own modification, based on Murray Down, 3v Geomatics
Planning / InSAR in the pre-construction phase
New/upgraded highway E18

- 4-lane highway
- additional bicycle lanes
- connections to future public transport
- 2 new tunnels

Wealthy area, potentially many claims

Purpose of InSAR in this phase → Baseline!
No. of measurement points: 220,060
Coverage: 7.3 km²
Average point density, total area: 27,250 pts./km²
Satellite data source: TSX spotlight, April 2014 to December 2018,
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Buildings in the «influence zone»
Buildings monitored with survey markers  and by InSAR  
Buildings that need additional in-situ monitoring  

Asset Management/
Risk Mitigation
InSAR during construction
The Follo Line Project

The project is currently the largest transport project in Norway and includes the country's longest tunnel (20 km). Combined with the existing Østfold line, tracks to the capital Oslo will represent new, faster trains on schedule.

The Follo Line will form the core part of the InterCity development from Oslo. The project will comprise a 20 km long tunnel with first long twin tube rail tunnel.

Satellite monitoring for tunnel neighbours

NGI og Bane NOR/Follobanen har innått en avtale om bruk av målinger fra satellitt for å følge opp terreng og eiendommer mens jernbanen bygges ut. På sikt kan satellitmålinger reducere behovet for målebolter i grunnmurer langs jernbanetraseer.
Tunnel Boring Machine (TBM) advancement

Durchbruch 26.2.2019
No. of measurement points: 211'888
Coverage: 104 km²
Average point density, total area: 3057 pts./km²
Average point density in built-up areas: 6733 pts./km²
## Extend in-situ series with InSAR

<table>
<thead>
<tr>
<th>Address</th>
<th>No. of measurement points</th>
<th>Baseline (month-year)</th>
<th>Last measurement</th>
<th>Settlement (mm)</th>
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</table>
Historic assessment / InSAR in the post-construction phase
Development of the area 2001 vs. 2018 vs. 2026++

Source: Bo i Bjørvika, Facebook, 29.11.2018

Oslo Fjord City, 2026
Settlements due to deep excavations

- Deep excavations have the potential to lower pore pressure and cause settlements over huge areas.
- Extensive construction activities for 15 years.
- Leakages due to drilling activities (piles and anchors).
- Normally consolidated clay.
Settlements in protected old masonry buildings

Image source: Rolf Øhman
Settlements below Oslo S decreasing. Observation based on in-situ measurements and satellite monitoring.
Summary I

Radar interferometry offers substantial added-value to geotechnical and civil engineering work and is today successfully applied in big infrastructure projects, alongside targeted traditional levelling of selected “hot-spot” objects.

Depending on the spatial resolution of the satellite data, the InSAR results can be used to gain an overview over settlement/subsidence hotspots, or they can be directly tied to pre-existing in-situ measurement records.
Summary II

- The method can be applied for **historical assessments**, in order to measure what has moved when and by how much (Oslo central railway station example). This, provided that necessary satellite data is available.

- **Preferably**, however, the method is applied for planning and asset management **prior to construction** (E18 example).

- And/or for risk mitigation **during construction** (Follo Line tunnelling example).
Acknowledgements

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We are grateful to Bane NOR and the Norwegian Public Roads Administration for their permission to present these results.

Data Sources:

– TerraSAR-X: Copyright © 2014-2018 DLR, Distribution Airbus DS/Infoterra GmbH
– Radarsat-2: Copyright © MDA/NSC/KSAT 2014-2019