Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

Project Description: Object Monitoring based on InSAR-analysis (EU tender, lot 1)

InSAR based deformation for the Dutch built environment

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Content

1 Project Description Lot 1: monitoring of tunnels and historical analysis of other objects

1.1 General: the role of satellite data in Rijkswaterstaat

Rijkswaterstaat manages the Dutch national roads, part of the primary dikes, locks and storm surge barriers. A significant part of that infrastructure was built in the 1950's to 1980's. The focus of Rijkswaterstaat in the coming decades will be on maintenance, renovation and replacement of aging infrastructural assets. Satellite radar observations based on interferometric synthetic aperture radar (InSAR) can be used to accurately monitor subsidence and rise of critical infrastructure, such as dikes, freeways and tunnels. As such, InSAR data can support Rijkswaterstaat's renovation and replacement task in two ways: firstly, to analyze historical behavior of structures and/or subsurface to inform (re)designing renovation or replacement. Secondly, to monitor object deformation behavior for anomalies which can indicate processes related to structural failure to enable threat response and project prioritization.

This project is set up to advance InSAR use to enable large scale infrastructural monitoring at Rijkswaterstaat. The project consist of two parts, called lots.

Lot 1: Monitoring of tunnels and historical analysis of other objects
This lot is composed of call-off-contracts under framework agreement for operational InSAR monitoring and one-off analyses for objects with established measurement feasibility (e.g., dikes, freeways and tunnels).
Lot 2: Developing and applying InSAR analysis to bridges and viaducts
This lot is an applied research on applying InSAR to bridges and viaducts.

This document contains the description for **Lot 1.**

1.2 Background and objectives Lot 1, tunnel monitoring and historical analysis

In December 2022, the anchoring of one of the tunnel segments of the Prinses Margriettunnel failed. As a result, the tunnel element was lifted up by groundwater pressure. Rijkswaterstaat was forced to close off the A7 highway for almost two months. Surrounding areas and traffic will be inconvenienced for over 3 years as repairs are made. In hindsight, the first indication of movement could be seen two years in advance in InSAR satellite data.

Rijkswaterstaat maintains several other tunnels with a similar anchoring, which could be prone to failure. Therefore, Rijkswaterstaat has defined a monitoring strategy to detect the potential failure of tunnel elements and take timely measures to prevent uplift of tunnel elements due to failure of the ground anchors. The first step in this monitoring strategy is to analyze the displacement of tunnel elements twice a year using high-resolution InSAR time-series. These InSAR analyses are used to classify tunnel elements as low-risk or high-risk elements, which is used to decide whether further measures and/or 24-hour monitoring of these elements is needed.
To distinguish between low-risk and high-risk elements, a measurement accuracy of about 1mm per individual measurement and about 0.1mm/year for long term vertical movements is needed.

Furthermore, Rijkswaterstaat regularly needs historical data as mentioned in the introduction, specifically before a renovation or replacement project. This can range from sections of roads to dikes or other tunnels. The need for historical data comes in two variations: 1) a quick general scan (*quickscan*) and 2) full analysis focused on behavior of different segments of objects. The intention is to facilitate the requests from different parts of Rijkswaterstaat on an ad hoc basis and build a track record which can be viewed by anyone within Rijkswaterstaat. Bridges and viaducts are not seen as objects with established measurement feasibility and are thus not within scope for these analyses, but are part of Lot 2.

Chapter two contains the details of the first *Nadere overeenkomst* (NOK 001) (also referred to as call-off-contract) of Lot 1: tunnel monitoring. This call-off-contract can be signed and started immediately after the signing of the framework agreement.
Chapter three contains the general definitions of the ad hoc NOKs under lot 1, which can be called off until the last day of the framework agreement.

1.3 Dataset end user licenses

The contractor must sign the end user license (EULA) of the corresponding provider (TerraSAR-X: Airbus, Cosmo-SkyMed: e-GEOS, RadarSat-2: MDA) before use.
Furthermore, the contractor must adhere to the following:

1. The contractor should comply with the EULA's for both satellite datasets in the way they store, process and distribute the data.
2. The use of the datasets provided by Rijkswaterstaat is strictly limited to this project (entire framework contract).
3. At the end of the contract all provided datasets should be destroyed by the contractor. This should be confirmed by the contractor in writing.

2 Assignment description: monitoring three objects (NOK 001)

2.1 Monitoring three objects (NOK 001)

The first call-off-contract under the framework agreement involves the InSAR monitoring of three, predefined objects in the Netherlands for the duration of the contract (two years with an optional extra year), which is split in one InSAR analysis in spring (analysis up until 1st of April, processed and received 1st of June) and one in autumn (analysis up until 1st of August, processed and received 1st of October) of each year.

The three objects of interest are the sunken road at the Kleinpolderplein, the Heinenoordtunnel and the Vollenhoventunnel. The final product should include a level-2 point dataset for an area around the tunnels, a level-3 dataset of the line of sight, vertical and horizontal movements of the individual tunnel elements and an accompanying InSAR analysis report of the processing and output datasets. To be able to assess the quality of the level-2 products before the creation of the level-3 products, every InSAR analysis is split up in three parts:

A. **Level-2 dataset:** The delivery of point data sets with displacement time-series (level-2) for the three tunnels in the line of sight for each satellite track:
    1. Based on TerraSAR-X data for the Kleinpolderplein and Heinenoordtunnel.
    2. Based on Cosmo-Skymed and TerraSAR-X data for the Vollenhoventunnel.
B. **Level-3 dataset:** The delivery of the line of sight, horizontal and vertical displacements of the individual tunnel elements (level-3) for the three tunnels:
    1. Based on the point data for the Kleinpolderplein and Heinenoordtunnel as delivered under point A1.
    2. Based on the point data for the Vollenhoventunnel as delivered under point A2.
C. **Report:** InSAR analysis reports which describe the InSAR processing and quality of the level-2 and level-3 products according to the Technical Requirements consisting of:
    a. Project report
    b. Quality report

The needed SAR Single Look Complex (SLC) data as input for this project will be made available by Rijkswaterstaat. This dataset includes three tracks of TerraSAR-X stripmap data and one track of Cosmo-Skymed stripmap data with a ground resolution of approximately 3x3 meter.

For the level-2 data, we expect different products for all individual tunnels and satellite tracks that cover the respective tunnels. The available time-series for both Cosmo-Skymed and TerraSAR-X images cover a period from beginning or end 2021 till now. For the level-3 data we expect a product with the horizontal and vertical deformation of the individual tunnel elements and the average line of sight displacement for the individual tunnel elements for the individual tracks. To derive the horizontal movement of the individual elements it can be assumed that the elements only move horizontally in the longitudinal direction of the tunnel.

2.2 Area description (NOK 001)

The area of interest (AOI) are the relevant object elements at three locations in the Netherlands. Those are:

- Kleinpolderplein – Open tunnel at the traffic junction of the A13 and A20 highways just north of Rotterdam. (*lat 51.931, lon 4.439*)
- Heinenoordtunnel – Tunnel underneath the Oude Maas along the A29 highway. (*lat 51.833, lon 4.512*)
- Vollenhoventunnel – Tunnel as part of the A28 highway between Utrecht and Amersfoort. (*lat 52.099, lon 5.210*)

The exact AOI will be shared by means of a geopackage with all the individual tunnel elements as separate shapes. The geopackage also includes the minimal project area for which the intermediate pointwise time-series (level-2 data) should be provided. In Figure 1-3 the three locations are shown, where the sunken road elements / tunnel elements are given as polygons and the minimal project area as a black line. Reference points can be chosen outside this area.

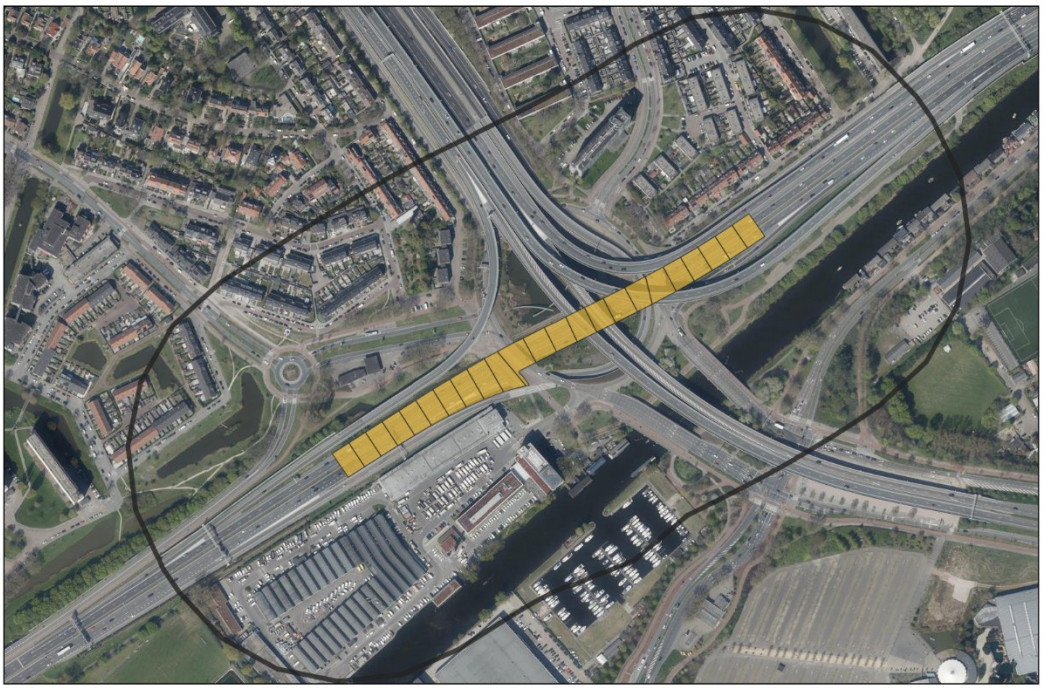

Figure 1 - Project area Kleinpolderplein

Figure 2 - Project area Heinenoordtunnel

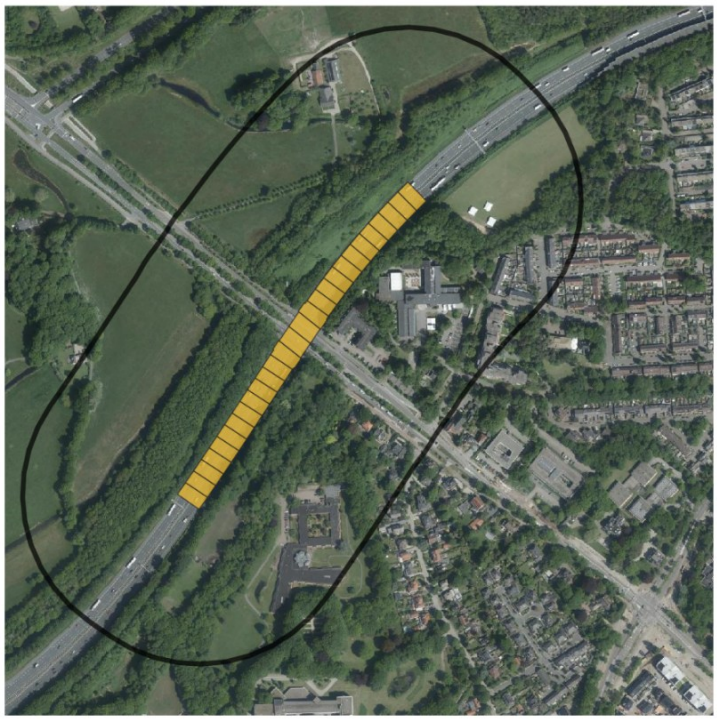

Figure 1 – Project Area Vollenhoventunnel

2.3 Datasets to be processed (NOK 001)

All available SAR images for both TerraSAR-X and Cosmo-Skymed data should be processed. The available datasets for the sunken road and two tunnels is summarized in the table below, where the tunnels covered by the different stack are denoted with an x. All SAR images will be provided by Rijkswaterstaat at the beginning of the project.

Satellite	Cosmo-Skymed	TerraSAR-X		
Direction	Descending	Ascending		Descending
Track	01	25	114	48
Kleinpolderplein		**x**		**x**
Heinenoordtunnel		**x**		**x**
Vollenhoventunnel	**x**		**x**	

2.4 Data delivery by Rijkswaterstaat (NOK 001)

Data will be delivered by Rijkswaterstaat on the SFTP server of the contractor. SFTP address, username and password should be provided by the contractor after which the data will be uploaded by Rijkswaterstaat on their SFTP server.

2.5 Maintenance history of objects of interest (NOK 001)

Because maintenance of the objects or partial replacement can disturb InSAR time-series, also the maintenance history for the study period will be provided. This information can be used by the contractor to adapt to optimize the data processing.

Maintenance Kleinpolderplein (since 2021) within the project area:

Year	Maintenance	Impact on InSAR data
-	No large maintenance	-

Maintenance Heinenoordtunnel (since 2021) within the project area:

Year	Maintenance	Impact on InSAR data
Aug 2023	Replacement of asphalt light grids (lichtroosters) and coating of concrete	Discontinuity in data expected

Maintenance Vollenhoventunnel (since 2021) within the project area:

Year	Maintenance	Impact on InSAR data
2023	One leaning side panel put upright	No impact expected
2024	Two tunnel elements have started to rise from 5th of January onwards	No impact on quality of data
2024	Concrete barriers placed on jan 13th	Discontinuity in data expected

Maintenance history will be shared with the contractor for the additional objects on request prior to the assignment. However, maintenance records may be incomplete or lack sufficient detail, requiring the contractor to identify and account for additional coherence disruptions. This information can be used by the contractor to adapt and optimize the data processing accordingly.

2.6 Technical Requirements (NOK 001)

Processing must take place according to the requirements as included in: "Technical Requirements".

2.7 Delivery and assessment terms (NOK 001)

The table below applies to the delivery terms of the Contractor and the assessment terms of the Client.

Delivery	Data	Delivery date
1st delivery of 1st InSAR analysis	Point data (level-2) for three tunnels	1 May 2026
Assessment 1st delivery		Within 10 working days after delivery
2nd delivery of 1st InSAR analysis	Shape data (level-3) and InSAR analysis reports	1 June 2026
Assessment 2nd delivery		Within 10 working days after delivery
1st delivery of 2nd InSAR analysis	Point Data (level-2) for three tunnels	1 September 2026
Assessment 1st delivery		Within 10 working days after delivery
2nd delivery of 2nd InSAR analysis	Shape data (level-3) and InSAR analysis reports	1 October 2026
Assessment 2nd delivery		Within 10 working days after delivery

The delivery schedule for the second contract year is similar to the first year.

2.8 Payment after acceptance (NOK 001)

Payment takes place after acceptance of the results of the Services in accordance with the table below.

Delivery Acceptance (NOK 001: monitoring three objects)	Percentage per delivery
L2 dataset	50%
L3 dataset and InSAR analysis reports	50%

3 Assignment description: on-demand / ad-hoc analyses (NOK 002, 003, …)

3.1 On-demand / ad-hoc analyses (NOK 002, 003, …)

The additional call-off-contract(s) under the framework agreement involves the on-demand processing and InSAR monitoring of objects for which technical requirements have already been set (such as tunnels, roads and dikes) upon request of Rijkswaterstaat. These on-demand analyses concern one-time or incidental analyses of objects that are not subject to regular monitoring but require further investigation at the request of Rijkswaterstaat. The object-specific information, as well as the required satellite data, will be provided by Rijkswaterstaat at the time of request. Two categories are distinguished:

1. InSAR processing of objects of limited size[1] amongst others:
    - Tunnels (e.g., Heinenoordtunnel)
    - Specific highway junctions of limited complexity (e.g., Knooppunt Empel)
2. InSAR processing of objects larger extents[2]:
    - Dike or dam (e.g., Oesterdam)
    - Larger segments of roads, including entranceways and exits (not limited to highway junctions)

These categories require a different pricing strategy. Therefore, we aim to receive a cost indication based on the categories as follows:

- InSAR processing and analysis of the first category with medium- or high-resolution satellite data for a fixed price per object/request
- InSAR processing and analysis of the second category with medium- or high-resolution satellite data for a price that is composed of a fixed starting fee with an additional cost structure based on the length (e.g., per linear kilometer)

The requirements for the additional call-off-contract(s) under the framework agreement (on-demand / ad-hoc analyses) are identical to first call-off-contract (monitoring three objects (NOK001)).

[1] Objects of limited size refer to tunnels, sunken roads, bridges and viaducts, including possible entrance and exit ramps. Typically, these are objects within an area of approximately 2x2 km.
[2] Objects of larger extents are calculated per linear kilometer. They generally consist of segments between 5 and 15 km in length.

Deliverables – full analysis

A. The delivery of point data sets with displacement time-series (level-2) in line of sight for each satellite track
B. The delivery of the line of sight, horizontal and vertical displacements of the object in (if applicable) uniformly moving segments (e.g., tunnel elements). In some cases, the contract must develop a segmentation using provided and/or public (e.g., AHN, DTB) and InSAR-derived deformation to identify uniformly moving segments, requiring Rijkswaterstaat approval before level-3 processing. This approval process is designed as a single review cycle (initial submission plus one potential revision) based on technical justification.
C. InSAR analysis reports which describe the InSAR processing and quality of the level-2 and level-3 products according to the Technical Requirements consisting of:
    1. Project report
    2. Quality report

Deliverables - Quickscan

Furthermore, Rijkswaterstaat wants to be able to call of a subset of these products namely deliverable A (level-2) with a report which describes processing and quality of level-2 data only.

3.2 Procedure call-off-contracts (NOK 002, 003, …)

Each ad-hoc call-off will be formulated as a condense call containing the same items as NOK 001 in the previous chapter.

For the ad-hoc call-off-contracts we require an agreed timeframe for delivery of L2 and L3 data starting from the moment of supplied satellite data and additional required information of objects.

1. Background and objectives of the specific call-off
2. Scope of delivery: quickscan (deliverable A + quality report) or full processing (deliverables A, B and C)
3. Area description. The exact AOI will be shared by means of a geopackage.
4. Datasets to be processed
5. Datasets to be delivered by Rijkswaterstaat
6. Maintenance history of objects of interest
7. Technical Requirements – the TR shall remain unchanged except for modifications that are mutually agreed upon by both parties
8. Delivery and assessment terms
9. Payment

Payment takes place after acceptance of the results of the Services in accordance with the table below.

Delivery Acceptance on demand / ad-hoc (Quickscan)	Percentage per delivery
L2 dataset and quality report (Quickscan)	100%

Delivery Acceptance on demand / ad-hoc (Full processing)	Percentage per delivery
L2 dataset	50%
L3 dataset and InSAR analysis reports	50%

3.3 Estimated number of ad-hoc call-offs each year

The current estimate for call-off-contracts is 5 of limited scope (quickscan) and 5 full processing per year. No rights can be derived from these estimates.