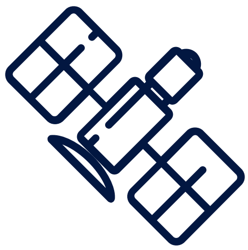
How do satellite observations replace helicopter RoW monitoring?

It cannot be ignored; we are living in the golden age of big-data and Artificial Intelligence.
Although maybe less known, the same holds for Earth Observation.

The number of satellites observing Earth and the amount of data they produce is growing at exponential rates. Nowadays, any place on Earth can be observed by satellites on a daily basis, and in the coming years, this is expected to increase further - to multiple times per day.
At the same time, the variety of satellite sensors and their capabilities are growing strongly, enabling more and more advanced applications, while the associated data costs are dropping significantly with the maturing Earth Observation (EO) market.
These trends - together with the developments across Big Data and AI - reinforce each other, spurring new possibilities at a rate that is difficult to keep up with. The tipping point is reached in the pipeline sector too. EO-based solutions are now viable options to replace existing inspection and monitoring procedures, rivalling traditional methods both in terms of reliability and costs too.
Orbital Eye, a Dutch company specialized in monitoring and inspection solutions based on space technology, has been pioneering this field since 2012. They went on a mission to bring the benefits of EO derived information deep into organizations, beyond their GIS departments, all the way down into the hands of operators and field staff.
They are convinced that these levels in the organization will ultimately benefit most from EO derived actionable information, making their daily work more efficient, less wearisome and more enjoyable.
The paradigm shift needed to realize this was that the EO industry should stop selling EO data, and offer information services providing actionable intelligence that does not require any in-depth knowledge of earth-observation data to be used. As their CTO Sven van Haver states: “Using satellite EO data for monitoring and safety applications should be as simple as using satellite GPS in a navigation app!"



This article will focus on one of the EO based solutions developed by Orbital Eye.
It aims at pipeline operators that need to monitor and manage Third-Party-Interferences along the pipeline Right-of-Way (RoW). A brief description of the technology used for this use-case tailored solution is presented, and an overview is given of a number of validation campaigns that were executed together with in-sector partners during the past two years.

Row Monitoring

One of the clearest use-cases for EO data in the pipeline sector evolves around Right-of-Way monitoring.

Traditionally, this is done by a manned aircraft with a human observer detecting potentially hazardous activities in or near the Right-of-Way. These so-called Third-Party Interferences (TPIs) are globally the foremost cause of pipeline incidents, besides geohazards and corrosion. Although human observations from aerial platforms are widely perceived as sufficient and are accepted by both the industry and legislators, they are in fact not optimal in terms of the maximum achievable safety level, costs and impact on the environment.
Therefore, working closely together with earth observation data providers and pipeline industry partners, Orbital Eye has developed the Combined Sar Multi-spectral Change detection technology (CoSMiC-EYE), as a better, more cost-effective and sustainable alternative for pipeline RoW monitoring.

CoSMiC-EYE How does it work?

The biggest challenge for any EO-based application is weather dependence. Most satellites have optical sensors, which are severely hampered by clouds. Thus, it is not possible to base reliable monitoring services on them. CoSMiC-EYE circumvents this issue by basing its services mainly on radar satellites. These satellites have the stunning ability to see through clouds and image earth reliably, regardless of weather and day-light conditions, thus ideal for monitoring applications. The downside to radar imagery, however, is that it is quite difficult for humans to interpret them (see figure 1a).

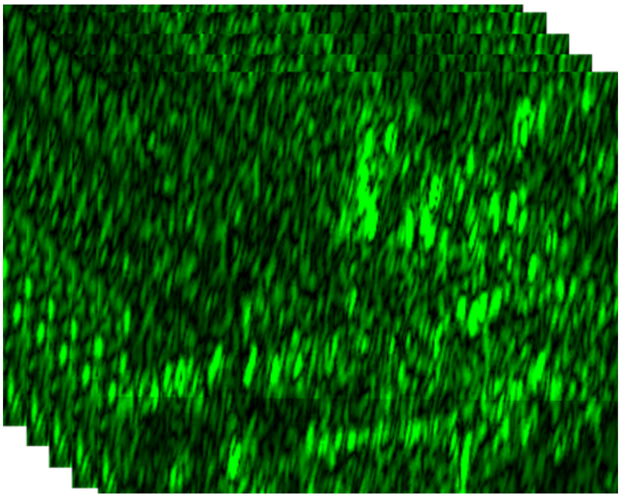


Figure 1: a) A stack of satellite radar images is difficult to interpret for humans, but it can serve as input to accurately detect changes in a given area.

Nevertheless, computers are very capable of processing radar data. Especially when it is combined into a stack of multiple images (time-series), accurate maps can be produced which indicate the probability of change for each location (see figure 1b).

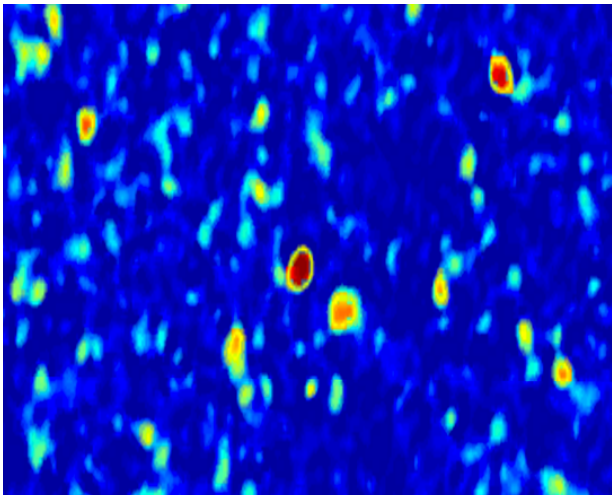


Figure 1: b) Change map derived from the input radar stack, giving the probability of change for each location in this area on a scale from blue (no change), via green (possible change) to red (certain change).

Of course, not all these changes observed by the satellite are relevant and therefore the most important step in CoSMiC-EYE processing is the automated filtering.

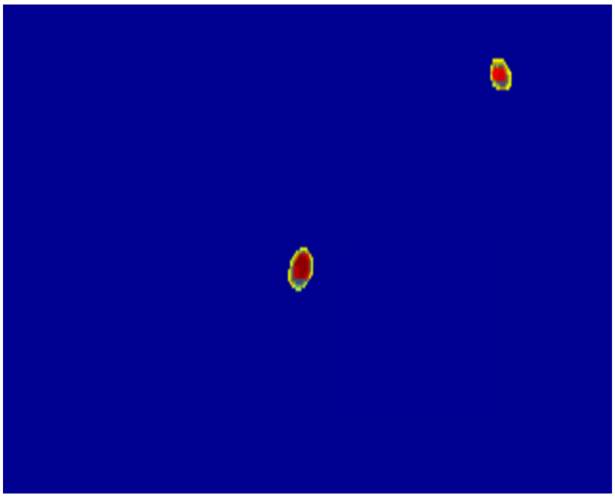


Figure 1: c) Filtered change map; marking only those locations that remain after filtering containing relevant activities.

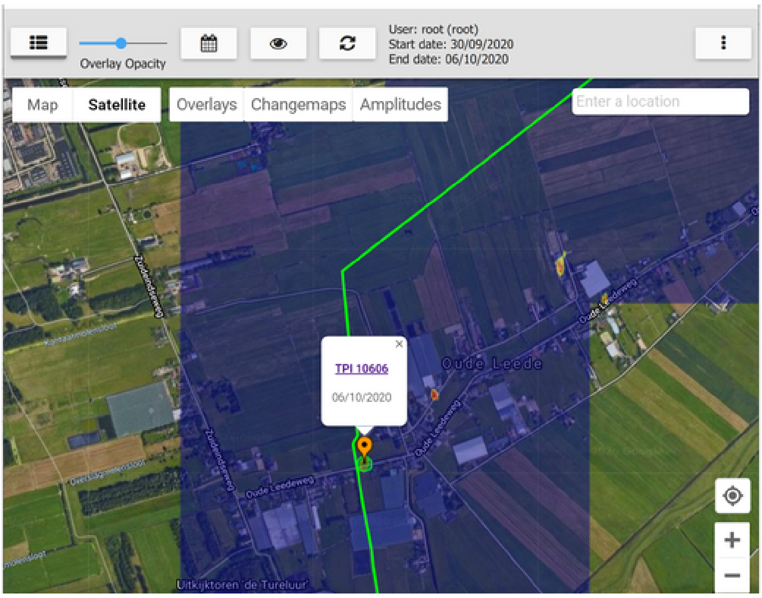
Using both classical and AI-based filtering and classification techniques, irrelevant changes are discarded and only those activities, relevant in the context of ROW monitoring remain and are passed along (Figure 1c).

Finally, those detected activities that are in proximity of the pipeline RoW, trigger an alert and are reported to the users in the CoSMiC-EYE Application (see Figure 2a and 2b below).

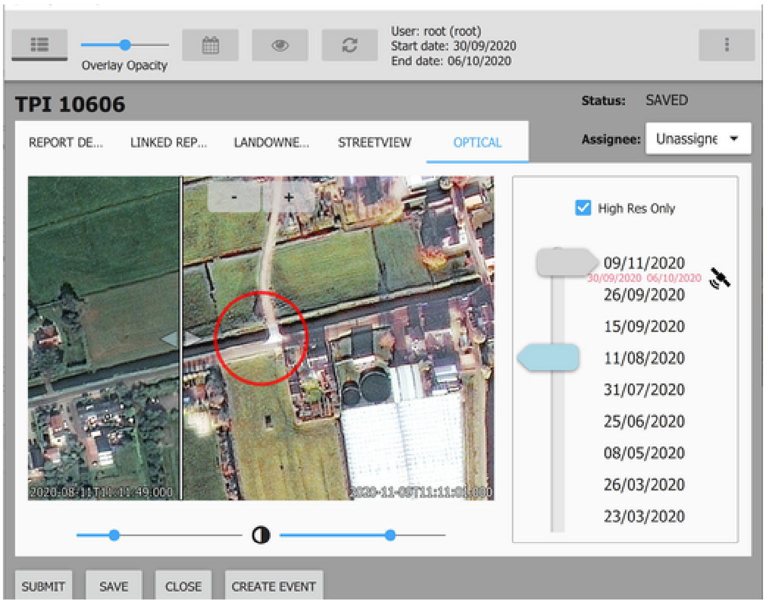
CoSMiC-EYE Multi-platform Application

This is a multiplatform, use-case tailored tool, assisting users to interpret all available information for the reported event, as well as supporting the workflows for (on-site) TPI follow-up.

In addition to radar data, CoSMiC-EYE can also integrate high resolution optical satellite data when available. Primarily, this imagery is served to CoSMiC-EYE users to allow visual verification of reported activities from the office,thus reducing the need for on-site follow-ups, but also serves as input to further enhance the selectivity of the monitoring solution itself.



←Figure 2a : Here, a Third-Part Interference (TPI) being reported in the CoSMiC-EYE Application. Showing the alert location with an orange placeholder, the change map overlay with changes remaining after filtering and the pipeline in green.



←Figure 2b: To the left, a TPI report screen is shown in which high-resolution optical data for that particular location can be compared over time, thus allowing visual interpretation of the ongoing activity by the user.

Only for those locations flagged as relevant by the radar analysis, high-resolution optical satellite data is sourced from satellite data archives or tasked directly through our data providers in a fully automated fashion.

This minimizes the amount of rather expensive commercial imagery that needs to be acquired, which keeps the solution commercially viable, while the user benefits from the advantages of high-resolution optical data (See Figure 2b).

Operational validation

In the past two years, CoSMiC-EYE has been validated in a number of operational pilots, assessing both the performance and the usability for field staff.
The outcomes of two of these validation campaigns are detailed below, benchmarking against ROW monitoring using helicopters with a human observer, as this is currently still considered the industry standard.

Validation pilot 1 - Germany, 2019

In this validation campaign, a detailed comparison was made between TPIs reported by helicopter inspections and those generated by CoSMiC-EYE for a period of 1 year and for a 33 km long section of pipeline crossing both rural and dense urban terrain in Western Germany.
The helicopter was flying on a bi-weekly interval, while CoSMiC-EYE was using satellite radar imagery acquired every 6 days. All activities detected were confirmed by ground truth, either by a photo taken from the helicopter or from a high-resolution satellite image in the case of CoSMiC-EYE.
For comparison purposes, all activities detected by either method were attributed to one of 4 categories based on size and duration. What results is the detection overview given in Figure 3. In total, 22 relevant TPI activities occurred during the pilot, of which 14 (64%) were reported by the aerial inspection and 16 (73%) were reported by CoSMiC-EYE.

This shows that CoSMiC-EYE is at least as good, if not better, as aerial-based inspection methods in detecting activities relevant in the context of RoW monitoring.

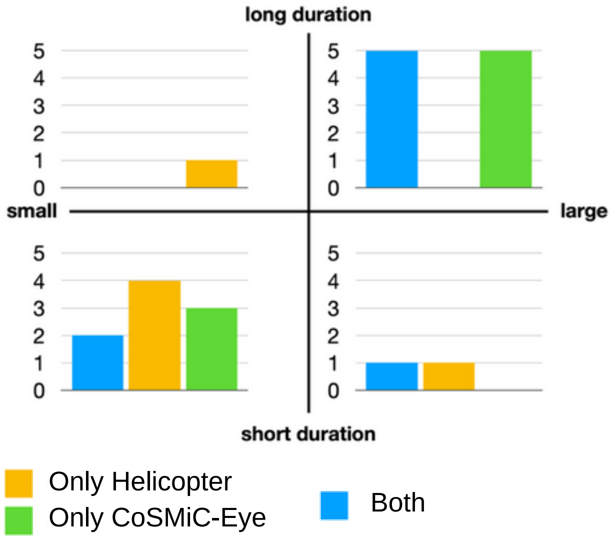


Figure 3: Overview of the number of TPI's detected by the helicopter and CoSMiC-EYE during the validation campaign 1. Activities are divided based on duration and extent, where activities of a few days or less are considered "short" and activities covering less than 50 km2 without heavy equipment are designated "small". Blue bars indicate the number of TPI's detected by both methods, yellow and green pertain to detection only by helicopter and CoSMiC-EYE, respectively.

Some further insights gained within this validation campaign are summarized in Table 1. For small short-duration events, the overall performance of both methods is similar. Helicopters are capable of detecting slightly smaller activities than CoSMiC-EYE, but this is compensated by CoSMiC-EYE' higher monitoring frequency and reliability, (Helicopter flights can get cancelled due to bad weather) lowering the chance of missing short-lived activities. For larger activities, typically having higher risk profiles, CoSMiC-EYE outperformed helicopters inspections.
Although remarkable, this can possibly be explained by the fact that large complex activities, that progress slowly over time, are hard to keep track of by human observers.

Most likely the observer did see the larger activity but did not notice the relevant TPI, within this larger activity.
This illustrates the advantage of machine-based change monitoring, comparing the current and previous observation of a site, instead of direct observations by an observer at a specific moment in time.

Finally, it may be noted that the early-warning performance of both methods was found to be very similar. Even though a helicopter can report quick after observation and CoSMiC-EYE' satellite-derived information can take up to a day after data acquisition to be delivered, the observed early-warning function (how soon after the activity starts is it reported) for both methods is similar, which can again be explained by the higher monitoring frequency of satellites.

While pilot 1 validated the detection capabilities and sensitivity of the CoSMiC-EYE technology, this second pilot was aimed more at validating the suitability of the solution for operational use.
One of the biggest concerns of the pipeline sector when it comes to using EO-technology for monitoring applications is the number of false alarms (FA), which are reported locations that proof to not have a relevant activity ongoing. Especially dense urban and industrial areas are prone to FA's as those areas are in constant flux.
In this pilot, CoSMiC-EYE was validated by a field follow-up and classification using the tablet version of the CoSMiC-EYE application for each activity detected based on the radar data analysis. On average the radar-based analysis produced 6.4 locations with activities per 12-day reporting cycle per 100 km pipeline.

	Performance	Comments
Detection of short and small events	Equal performance	- CoSMiC-EYE can monitor more frequent - Helicopter is able to detect smaller events
Detection of long and large events	CoSMiC-EYE performs better	- These events form the largest threats to damage pipelines
Early-Warning Performance	Equal performance	- Higher monitoring frequencies will improve the early-warning function

Table 1: Overview of the performance comparison between helicopter inspections and CoSMiC-EYE on some key indicators.

Validation pilot 2 - The Netherlands, 2020

A second 4-month validation project was executed in 2020 on a 130 km long pipeline section running through busy industrial and urban zones near Rotterdam and some of the more rural areas in the western part of the Netherlands.

Although this can be expected for such a busy area, these numbers are way too high to be manageable operationally.
This is where Orbital Eye's advanced filtering and classification technology comes into play. It could already discard almost 60% of detections as irrelevant based on additional analysis of the radar data and other open-source context information like cadastral information and land use.

This brings the number of possible TPI locations to be assessed each cycle down to 2.6 per 100km pipeline, which is a number that pipeline operations can cope with. The outcome of the validation campaign (see Figure 4) showed that of the remaining locations reported almost 75% were confirmed TPI's. This leaves about 25% false alarms, which is a number in the same ballpark as the false alarm fractions reported for helicopter reports by our in-sector partners.

The remaining 46 TPI's are classified as approximately 90% relevant, leaving around 10% of them to be false alarms. In addition, the percentage of missed events during the pilot was found to be around 20%, which is again similar to Helicopter inspections and in agreement with the findings of validation pilot 1 below.

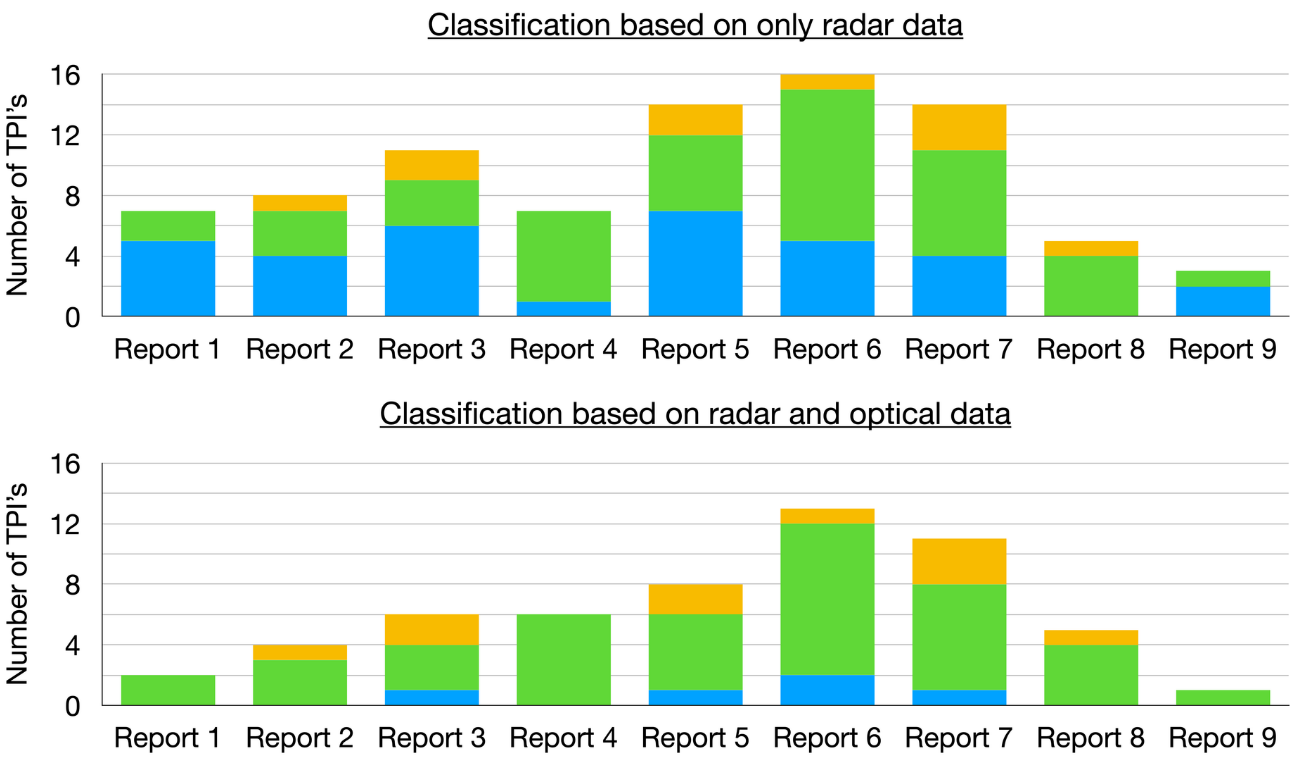


Figure 4: Summary of validation campaign 2 results. The top bar plot shows the number of activities considered for each cycle when filtering is applied without exploiting high-resolution optical data. The bottom bar plot shows the considered activities when high-resolution optical data is exploited. The bar colours, yellow, green and blue indicate the number of activities determined to be missed events, relevant activities and false alarms, respectively.

However, as already mentioned above, CoSMiC-EYE can be further enhanced by sourcing high-resolution optical data. Detailed analysis of the remaining TPI's showed that the availability of optical data would further reduce the false alarm fraction by another 16% (see bottom of Figure 4).

Conclusion

EO based monitoring solutions for the oil and gas sector are no longer a promise for the future but are here today to start to replace traditional monitoring methods that no longer align with the industry’s sustainability goals.

This article presents one of them, the RoW-monitoring solution CoSMiC-EYE, developed by Orbital Eye and validated over the past two years together with in-sector partners. These validation campaigns showed that CoSMiC-EYE at least equals, if not outperforms, monitoring with traditional aerial inspection methods.

In addition, CoSMiC-EYE is more sustainable, less costly and still has a lot of potential to further improve over the coming years. As AI technique, EO-data quality and availability further increase, it is safe to say that this solution is ready for widespread market introduction.

As of the beginning of 2021 the first large-scale operational deployments of CoSMiC-EYE are underway, with field personnel using the CoSMiC-EYE application in their daily work. This brings CoSMiC-EYE to its biggest challenge so far, which is not detecting relevant activities using sensors circling earth many hundreds of kilometres above our heads, but it is convincing those responsible for the safety of pipelines on a daily basis to embrace this new technology and leave their existing monitoring methods behind - in which they laid their trust for so many decades. This will not happen overnight, but the transition has started, and it cannot be stopped.

About the authors

Sven van Haver holds a Ph.D. in Applied Physics, with a specialization in electromagnetics.
Sven is the CTO of Orbital Eye since 2015, and has played a big role in the development and validation of CoSMiC-EYE. He is responsible for all technology and R&D related activities with Orbital Eye.

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He works within the development team of CoSMiC-EYE and has a leading role within Orbital Eye to verify the performance of CoSMiC-EYE.

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