PRECISE POSITIONING CROSS-EUROPE DRIVE

Abstract

The market for precise positioning is experiencing an inflection point, driven by the need for autonomy, automation, navigation, tracking, and mapping in a wide range of industries including automotive, robotics, mobile devices, Internet of Things (IoT), and Geographic Information System (GIS). Swift Navigation and Deutsche Telekom offer centimeter level precise positioning to unlock the next generation of mass market location-based products.

While other solutions for high precision GNSS rely on local deployments and expensive equipment, Swift's Skylark™ Precise Positioning Service is built for scale. It is interoperable with popular receivers, guarantees uniform performance across entire countries, and is trusted by industry leaders in the auto and IoT space.

Swift's carrier-grade, continent-wide coverage is enabled by partnerships with mobile network operators (MNOs) across the globe. In Europe, Deutsche Telekom (DT) deploys and operates the network of Continuously Operating Reference Stations (CORS) which Skylark uses to model corrections in the cloud and deliver high accuracy positioning with seamless availability across the continent.

Swift and Deutsche Telekom collaborated to conduct an ambitious 2,000 km drive test across five countries: Germany, Switzerland, France, Italy, and Spain. The drive test compared GNSS positioning with and without Skylark corrections and included a variety of challenging environments to test the limits of the precise positioning solution. In all test environments, the Swift and DT solution delivered impressive results, significantly beating out the control configuration.

Highlighted Environments

Urban Canyons

Underground Tunnels

Multi-Lane Roads

Mountainous Areas

While these environments are particularly relevant for automotive, navigation, and fleet management use cases, Swift and DT's Precise Positioning solution is available in a variety of configurations to deliver against the accuracy, availability, and coverage requirements of a wide range of industries and use cases.

If you are interested in learning more about Swift's Precise Positioning, visit www.swiftnav.com. To learn more about how Deutsche Telekom brings it to life, visit iot.telekom.com/en/solutions/precise-positioning

Precise Positioning for Automotive

Advances in the technology supporting connected and autonomous vehicles are moving at a rapid pace, unlocking new possibilities for the automotive industry to enhance mobility and optimize logistics for commercial fleets. The next generation of vehicles will offer immersive navigation, crowdsource maps in real-time, communicate with other vehicles and infrastructure, and provide higher levels of autonomy.

To enable these applications, cars and trucks are equipped with an advanced suite of sensors, including radar, camera, LiDAR, inertial, and GNSS. While early innovations in advanced driver assistance systems (ADAS) relied heavily on perception-based sensors and relative positioning, as the industry moves toward more advanced use cases and eventually full autonomy, the absolute positioning provided by GNSS has become critical. Today, high accuracy, high availability precise positioning is crucial to ensuring safe, reliable assisted and autonomous operations.

Legacy GNSS positioning solutions are not suited for today's automotive requirements. Modern vehicles need centimeter-accurate positioning that just works–everywhere, always. Positioning solutions must deliver:

- **Reliable accuracy** - lane-level precision, fast convergence, uniform coverage, and carrier-grade operations are non-negotiable for delivering the required performance
- **Guaranteed safety** - compliance with ASIL standards for safety and integrity is necessary to imbue trust in the autonomous system and satisfy regulatory requirements
- **Flexible design** - interoperability with mass market hardware, automotive-grade antennas, and both legacy and modern compute architectures will enable OEMs to harness precise positioning without impacting budgets or design cycles

Mobile and Industrial Applications

Precise positioning extends far beyond the automotive realm, offering a multitude of advantages across various verticals, each with unique use cases and customer benefits. Whether in mobile devices or industrial applications, precise positioning revolutionizes outdoor localization, accuracy, and safety, enhancing the efficiency and functionality of these industries. This technology serves as the backbone for a multitude of applications, fostering innovation and improved operations for both businesses and individuals. The following table only summarizes a subset of existing use cases and benefits.

	Vertical	Use Cases	Customer Benefits
MOBILE		High precision outdoor localization on mobile devices such as smartphones, wearables, navigation devices, fitness trackers, or safety beacons	• Improvement of outdoor positioning accuracy to <1m • Increased navigation quality, especially turn-by-turn navigation • Reliable accuracy for safety critical applications
ROBOTICS		Autonomous outdoor robots such as lawnmowers and precise agriculture robots	• Geofence creation and adherence • Systematic, efficient, and precise operations
LOGISTICS		Delivery vehicle and asset tracking	• Deliver packages to the right doorstep • Easily manage fleets of vehicles down to the exact parking space
GIS		Surveying and mapping in construction, maintenance or planning	• Centimeter-level accuracy without the need for expensive total stations and theodolites • Easy access to GNSS corrections without having to deploy own reference stations
DRONES		Last-mile delivery drones and professional UAV applications such as GIS	• Precise pickup from/delivery to small and tight sites • Absolute location accuracy for GIS
RAIL		Positive Train Control and Hi-rail equipment tracking	• Precise geofencing for worker safety • Disaster avoidance

Precise Positioning Cross-Europe Drive

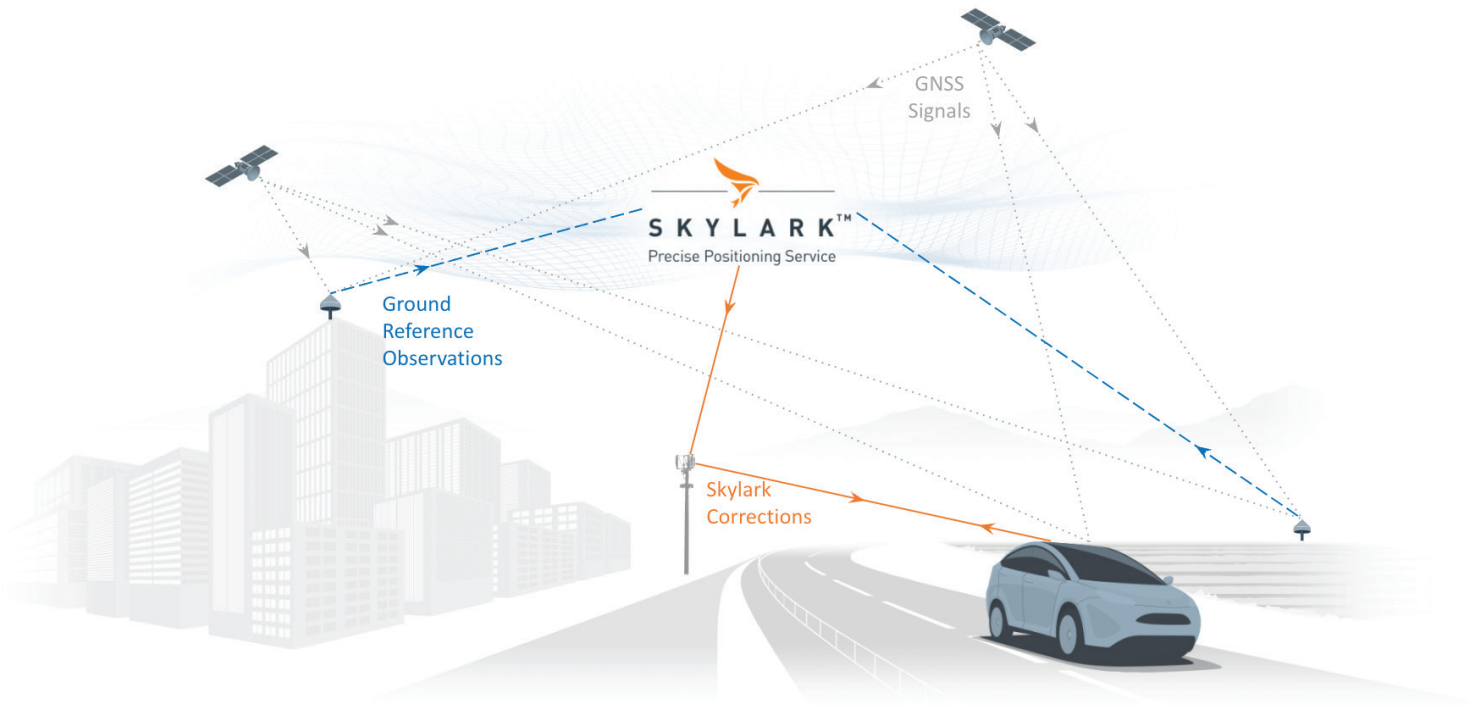
Swift Navigation Precise Positioning

Swift Navigation offers universal precise positioning to enable centimeter accurate mapping, tracking, navigation, and autonomy, unlocking digital innovation across industries globally.

Designed to meet the stringent requirements of automotive deployments, Swift's solution includes Skylark™ Precise Positioning Service, a cloud-based GNSS corrections service, and Starling® Positioning Engine, a high precision and hardware agnostic positioning engine. Skylark leverages advanced corrections models and carrier-grade networks deployed and operated in partnership with MNOs around the world to deliver GNSS corrections. Starling leverages GNSS and dead reckoning sensor fusion to deliver an absolute position, velocity, and time (PVT) compliant with ASIL-B safety standards.

Swift's Precise Positioning solution provides accurate and reliable location in even the most challenging environments, such as urban canyons, underpasses, access roads, complex intersections, remote locations, inclement weather, and more.

Today, over 7,000 customers – including more than 20 automotive OEMs and suppliers, multiple market-leading handset manufacturers, logistics companies, industrial equipment manufacturers, and others – are collectively launching more than 5 million vehicles and devices enabled by Swift's technology in collaboration with Deutsche Telekom and other MNOs around the globe.



Test Drive Setup

Swift and Deutsche Telekom constantly test their joint solution as DT continues to deploy more ground reference stations across Europe and Swift launches new features. This particular drive test was designed to test both the precision of the solution in various environments as well as its availability across an entire continent, in real-world conditions.

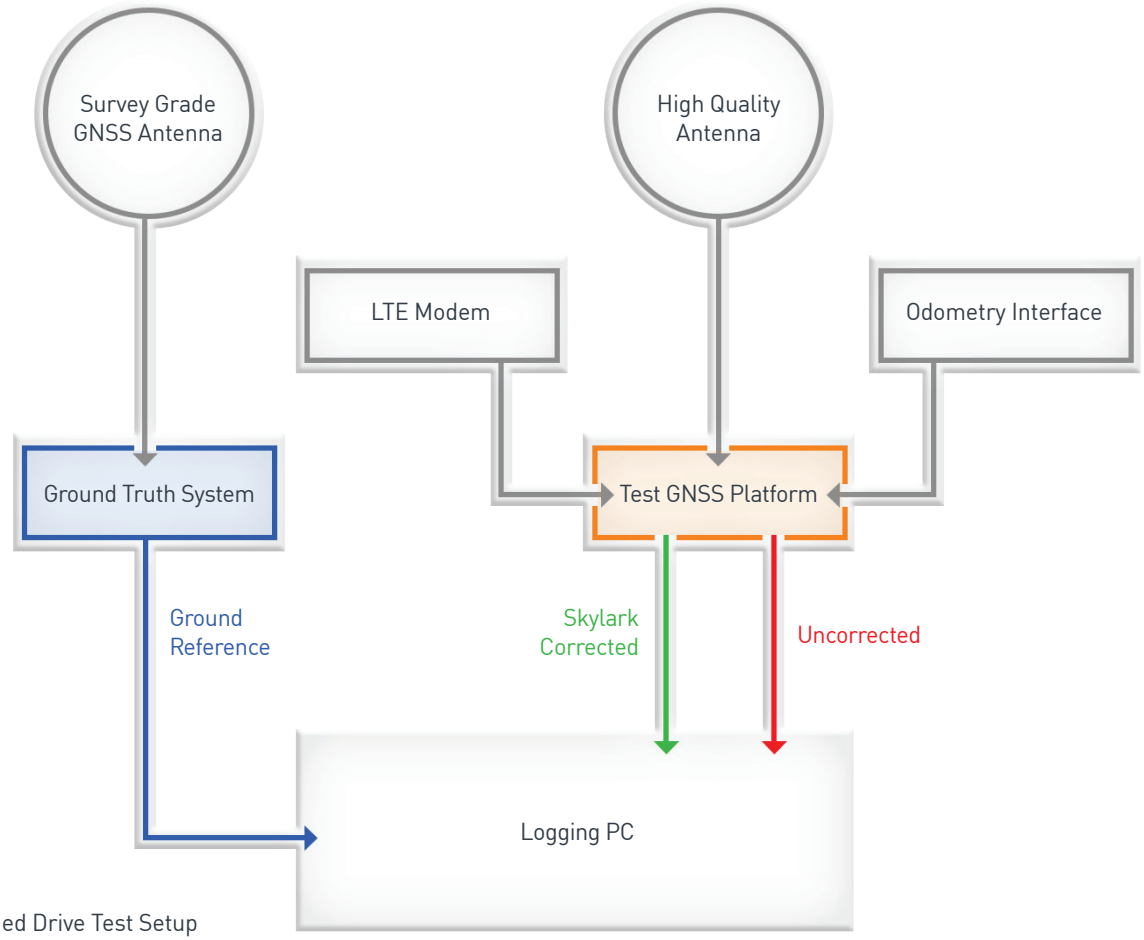
It took four days for the DT crew to navigate the 2,183 km separating Hanover, Germany and Barcelona, Spain. They drove through dense urban areas, tree-lined highways, the Alps and its network of tunnels, including the infamous Mont-Blanc and Gotthard ones.

Drive Test Route

The test vehicle, a regular sedan, was equipped with two parallel GNSS systems:

- A survey grade GNSS antenna connected to high-end reference system to act as the source of truth
- A automotive-grade dual-band GNSS platform capable of outputting both the Skylark-corrected location and the uncorrected one, both aided with an Inertial Measurement Unit and Wheel Odometry

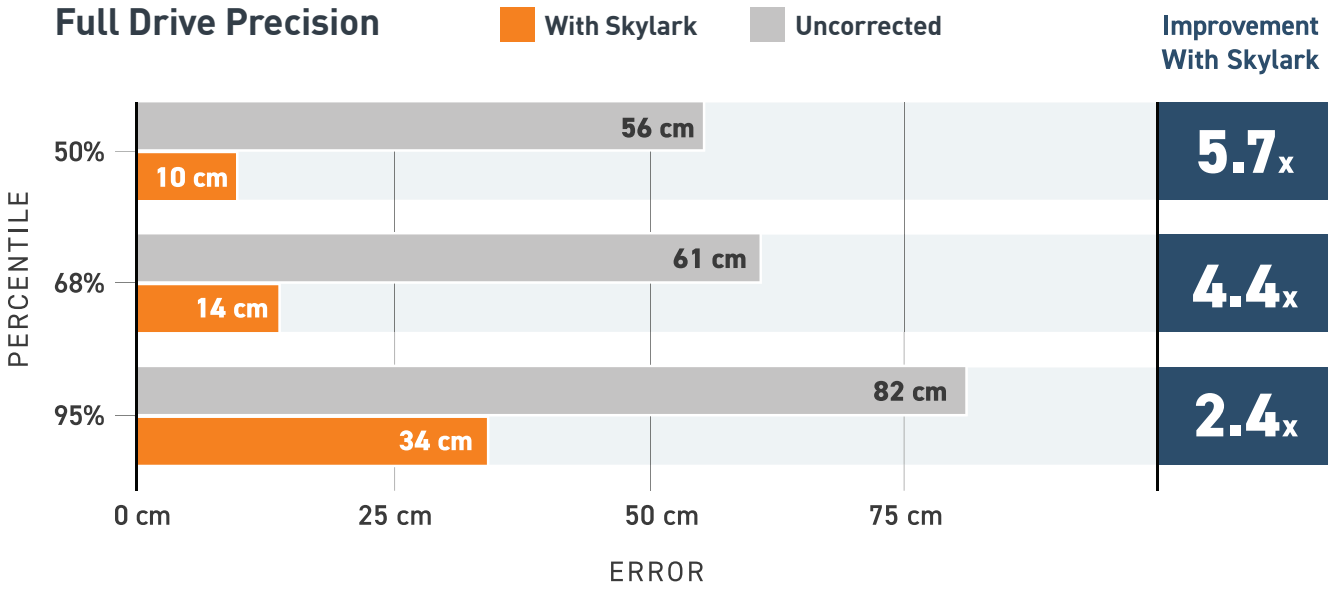
The reference platform established an internet connection by using an LTE router and a Deutsche Telekom IoT SIM card, enabling it to link up with the Skylark servers.



Simplified Drive Test Setup

Key Takeaways

Test results show that Swift and DT's precise positioning solution achieved an accuracy better than 10 cm for half of the entire 2,000 km drive, compared to 56 cm without corrections, a 5.7x improvement. At 2-sigma, or 95 percentile of the drive, corrections achieved 34 cm versus 82 cm without. Considering that a typical highway lane is 3.5 meters wide and a typical car is 2 meters wide, this accuracy enables safety-critical autonomous operation.

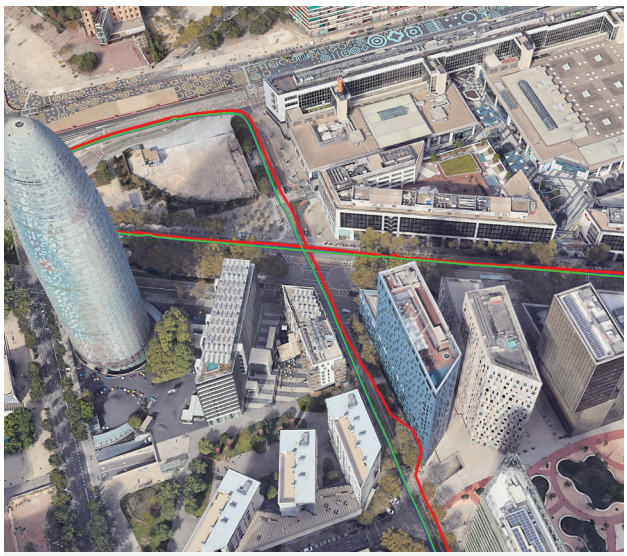


In the rest of the paper, we focus on particularly challenging environments where traditional GNSS typically becomes unreliable and loses precision.

Precise Positioning Cross-Europe Drive

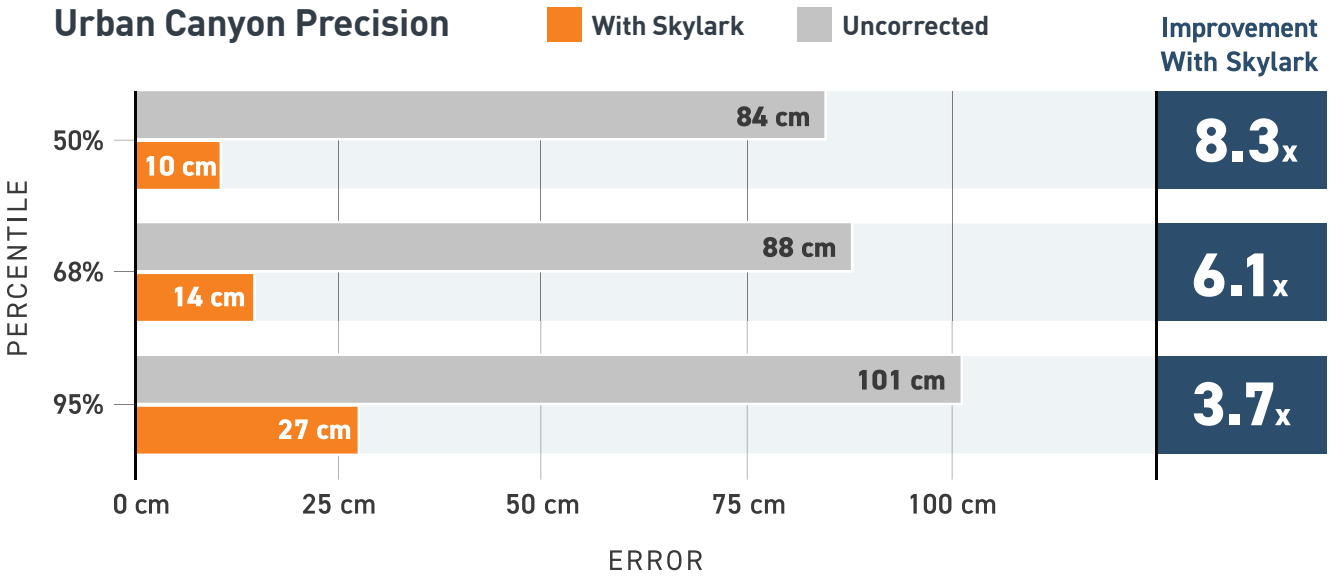
Environments

Urban Canyon



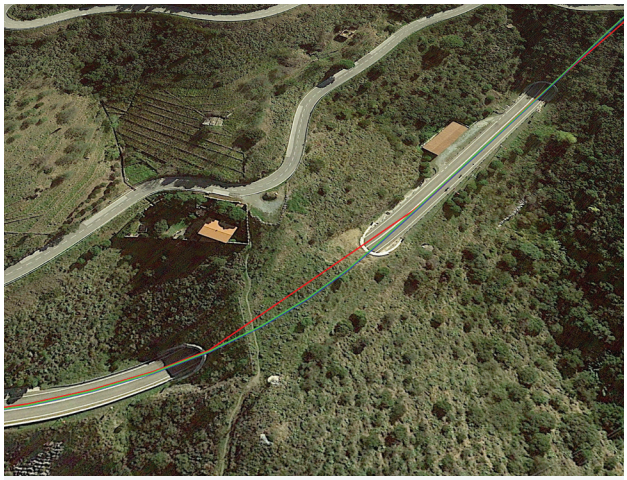
Uncorrected
Skylark Corrected
Ground Reference

Urban canyons refer to streets that are flanked by tall buildings on both sides, resembling a natural canyon. These environments pose significant challenges for satellite-based positioning systems like the Global Positioning System (GPS) due to the multipath effect, signal blockage, and signal reflection. By ingesting Skylark corrections, the test system showed an enhancement of nearly 4x at the 95 percentile, with precision improving from a meter to 27 cm. Not only that, using the Skylark stream, issues like position jumps can be a thing of the past. When used in conjunction with dead reckoning technology, the system ensures that the position can be relied on every single time. Beyond ADAS, this has a profound impact on consumers as well. You will now be able to set off on our journey without having to wait for your favorite maps application to show you the correct location. In urban canyons, GPS signals often bounce off buildings before they reach the receiver, leading to erroneous readings.



Precise Positioning Cross-Europe Drive

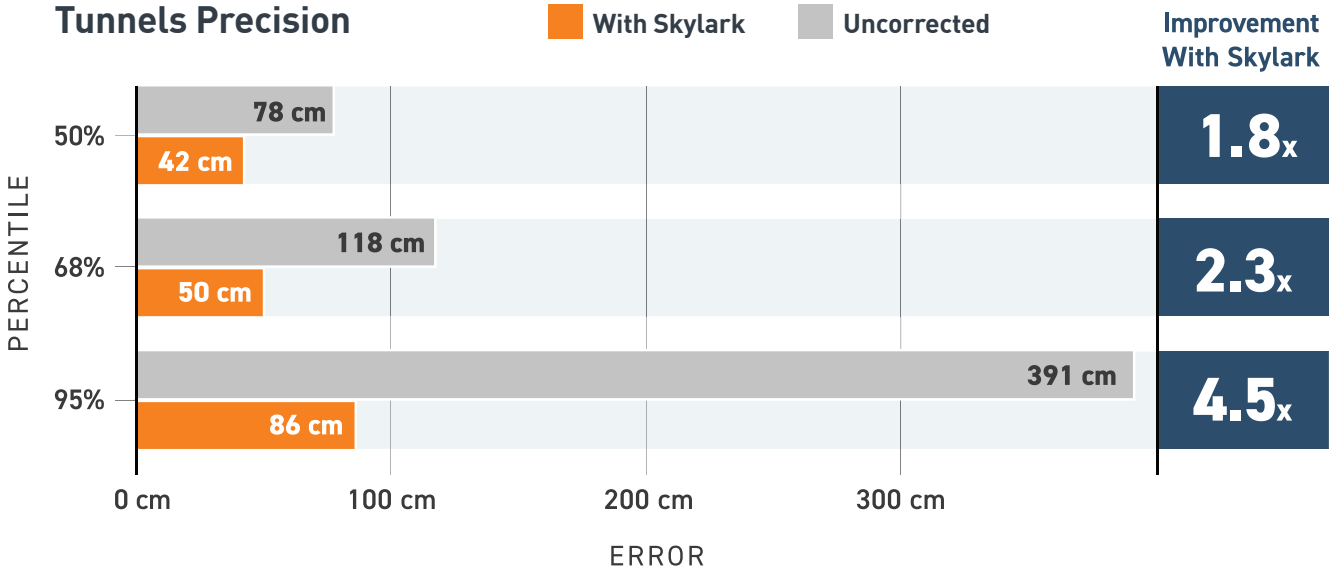
Tunnels



Uncorrected
Skylark Corrected
Ground Reference

As a vehicle enters a tunnel, it loses track of satellites and hence cannot provide a meaningful position estimate. This is the reason we sometimes see the position on our navigation system or phone not changing as we move through a tunnel. More sophisticated systems use a technology called dead reckoning which will continue to estimate a position based on inputs from other vehicle sensors. The challenge with these systems is that the error is accumulative and gets bigger as more distance is traversed in a GNSS-denied environment such as a tunnel. It is important to correct for this error as soon as the vehicle emerges out of the tunnel. This is where Skylark can greatly reduce the time taken to re-acquire a GNSS position. From our tests, thanks to fast re-convergence achieved with Skylark, precision improved from almost 4 meters to better than 86 cm at the 95th percentile.

Tunnels Precision



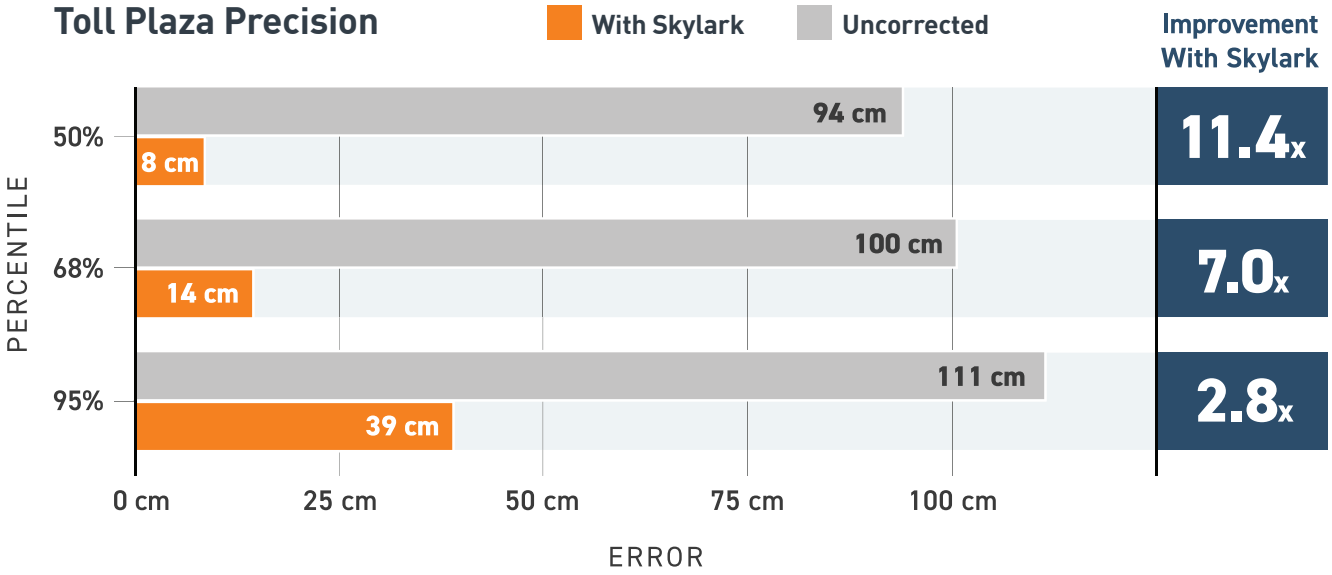
Precise Positioning Cross-Europe Drive

Multi-Lane Roads

Uncorrected
Skylark Corrected
Ground Reference

For a L2+ ADAS system, it is required to have a high level of precision while navigating city streets and suburban areas. For example, for advanced applications such as red light violation warning, the car needs to understand very precisely the lane it is in. This is due to the fact that the application uses precise maps to match itself to the lane and determine the traffic light status. Here, Skylark corrections improved precision from over 1.1 meter to just 39 cm at the 95th percentile. This is visible in the overhead snapshot of the toll plaza, where one could have mistaken the vehicle to be on the lane marked with the red line (uncorrected), while it was in fact on the adjacent one. The blue line for true position and green for Skylark-corrected are so close to each other that they look like a single line thanks to the high precision of the system.

Toll Plaza Precision



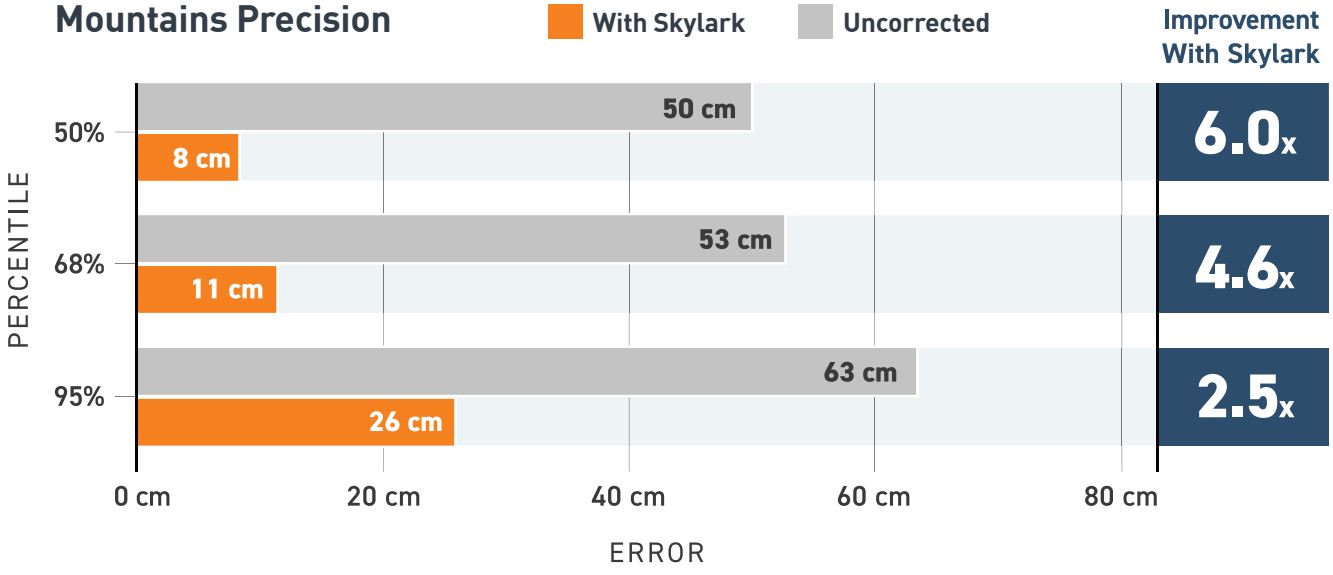
Precise Positioning Cross-Europe Drive

Mountains

Uncorrected
Skylark Corrected
Ground Reference

Mountains introduce several challenges to a GNSS system, such as reduced satellite visibility, localized atmospheric disturbances, and signal blockage. These regions also tend to have limited mobile coverage, as cellular signals encounter similar issues. Fortunately, Deutsche Telekom's IoT SIM cards rely on DT's extensive network and at least two roaming partner networks per country to ensure consistent cellular connectivity along the entire 355 km route through the valleys and tunnels of the Alps. This ensured that Skylark corrections could still be received even while crossing national borders, maintaining a high precision of 26 cm, a 2.5x improvement vs. uncorrected.

Mountains Precision



Conclusion

The extensive drive test conducted together by Deutsche Telekom and Swift Navigation evaluated the performance of their Precise Positioning solution in various challenging environments across more than 2,000 km and five countries. Notably, whether navigating urban canyons, tunnels, multi-lane roads, or mountainous areas, the system consistently outperformed traditional GNSS, achieving impressive levels of accuracy. These results underscore the importance of high-precision positioning in the rapidly evolving automotive industry, where safety, reliability, and compliance with standards are paramount.

Swift's technology is already on the road today, with more than 5 million vehicles and devices already deployed or launching. Beyond automotive, precise positioning technology is indispensable across diverse industries. In GIS, it enables accurate data collection for surveying and mapping. Drones benefit from it to know their way around complex environments and land in the right spot. Rail systems rely on precise positioning, especially for safety measures like positive train control. In robotics, it enhances precision agriculture, autonomous lawnmowers, or even street cleaning robots. The mobile industry uses it for location-based services, such as ride-sharing. Logistics companies optimize supply chains and reduce delivery delays through accurate vehicle and goods tracking.

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