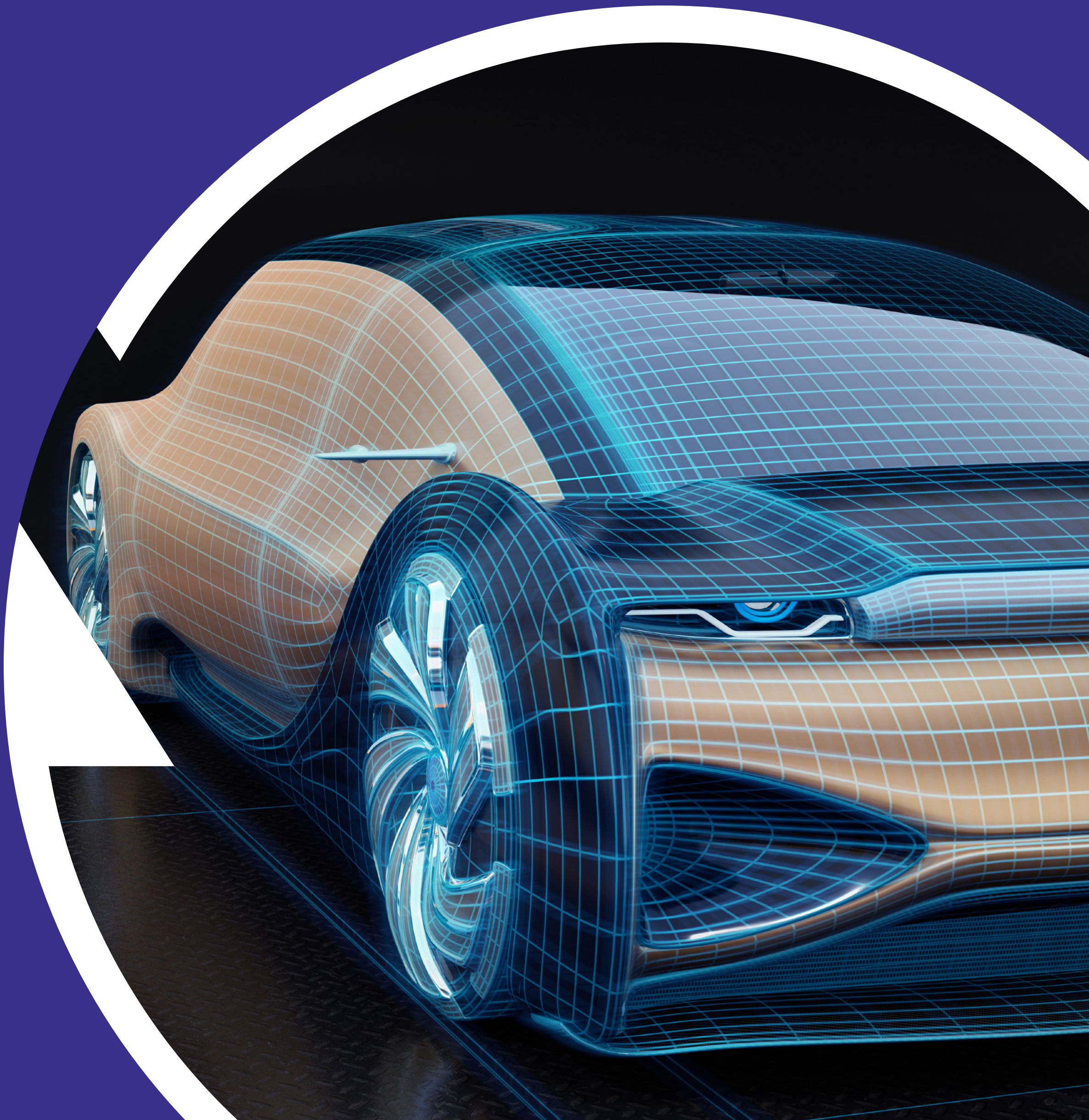
A SPIRENT EBOOK

Enabling reliable GNSS performance for autonomous urban driving

Navigate safely in urban and built-up areas with GNSS forecasting for Level 2 to Level 5 vehicles



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The automotive world is moving towards a future in which more vehicles operate more autonomously more of the time. That promises many benefits: from improved road safety to lower carbon emissions, and new mobility options for millions of people.

One technology that can make a significant contribution to vehicle autonomy is global navigation satellite systems (GNSS) like GPS, GLONASS, Galileo and BeiDou.

Almost all automated and autonomous vehicles are equipped with a GNSS receiver for positioning, navigation and timing (PNT). However, GNSS is often deprioritised in favour of more complex and expensive sensors because of one critical issue: its unpredictable reliability in urban and built-up areas due to intermittent signal obscuration.

In this eBook: Bringing "anyplace, anytime" autonomous driving closer to reality

If there was a way of making GNSS coverage more predictable in built-up areas, it would open up many new possibilities for developers, users and operators of [SAE Autonomy Level 2 to Level 5] automated vehicles.

In this eBook, we'll look at what causes the problem, and why existing solutions designed to improve GNSS performance don't fully address it. We'll then introduce an innovative new solution that addresses the reliability issue, bringing "anyplace, anytime" autonomous driving one step closer to reality.

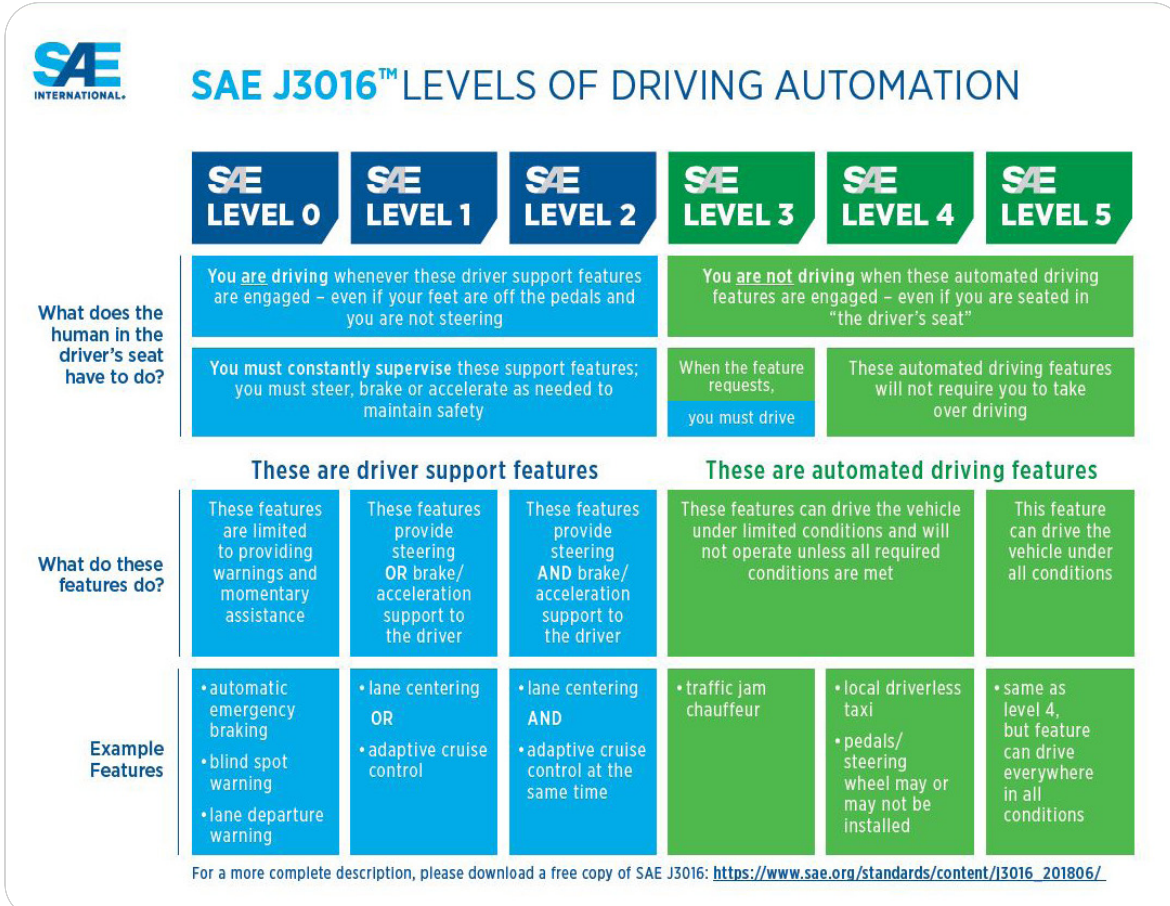


Figure 1: SAE Autonomy Levels
https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

The challenge of signal obscuration for GNSS reliability

GNSS is one of the most ubiquitous and proven PNT technologies. Almost every vehicle – ground, air, or water based – now includes a GNSS receiver that can receive and process satellite signals almost anywhere to resolve an absolute position on earth.

Receiver sophistication has increased over the years, as has the number of fully operational GNSS constellations. Since 2011, GPS has been joined by Russia's GLONASS, Europe's Galileo and China's BeiDou. Today, there are over 100 orbiting GNSS satellites providing near-ubiquitous PNT services to receivers capable of processing their signals. Added to this, augmentation services like Real-Time Kinematics (RTK) or Precise Point Positioning (PPP) are frequently used, and can refine the positioning accuracy of those signals to much less than 100cm.

But while GNSS signals are freely available and highly effective almost everywhere and almost all of the time, they can be intermittently obscured by buildings and landscape features – creating patches of degraded coverage that can affect navigation performance.

Line of sight to four satellites is a minimum requirement for reliable GNSS performance

To calculate an accurate position, a vehicle's GNSS antenna must have clear line of sight (LOS) to at least four satellites. But in built-up areas, GNSS signals are often blocked by buildings and other solid structures that the signal – which is only as powerful as a 40W lightbulb – can't penetrate.

This means that, particularly in urban environments, the view of the open sky can be too narrow for the receiver to see four LOS satellites at once. When that happens, GNSS signal reception can be degraded, and a receiver may temporarily lose its ability to calculate or report its true position.

It's very common in built-up areas for the receiver to see reflections of signals as they bounce off buildings (an effect known as multipath). But as those signals are non-line of sight (NLOS) to the satellite, they can cause the receiver to calculate and report a position that is inaccurate.

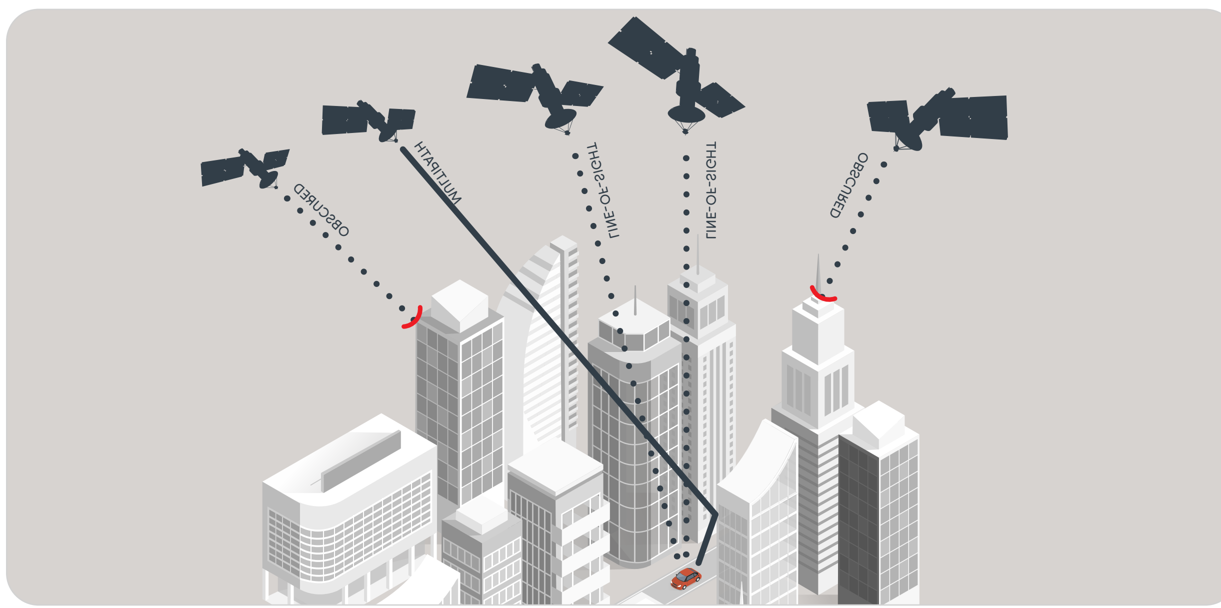


Figure 2: Satellite signals can be blocked or multipathed by buildings, creating patches of degraded GNSS coverage

Signal dynamics are constantly changing

What's more, as satellites constantly move in and out of view as they orbit the Earth, obscuration patterns are always changing – making it difficult to accurately predict exactly where and when signal obscuration might occur.

A street corner that offers good coverage at 3pm may not do so just a few minutes later, for example. This variability has made signal obscuration one of the big unsolved issues standing in the way of autonomous urban navigation using GNSS.

Existing GNSS enhancement solutions don't address the reliability issue

While several solutions have been developed to maximise GNSS performance, none truly address the issue of reliability. Those existing solutions include:

- **Multi-GNSS receivers:** The more satellite constellations the receiver is capable of processing, the more likely it is to have LOS to four or more signals at any one time. Figure 4 shows a heatmap of an area of downtown Indianapolis with GNSS coverage ranging from green (good) to red (poor). The heatmap reveals that a multi-GNSS receiver can be used for navigation in most of this urban area. However, without access to a heatmap like this, the receiver does not have the situational awareness to know exactly when and where signals will be usable.
- **Additional sensors:** An autonomous vehicle needs to know both where it is on the Earth's surface (absolute position), and where it is in relation to objects in its environment (relative position). Positioning engines typically use a combination of GNSS, IMUs, wheel speed sensors, LIDAR and camera vision to calculate position, with all inputs combined using sensor fusion to ensure the safe operation of the vehicle. LIDAR and camera vision both offer potential for absolute positioning, but there are critical limitations in both practicality and reliability, meaning the issue of obscuration for GNSS is not overcome.

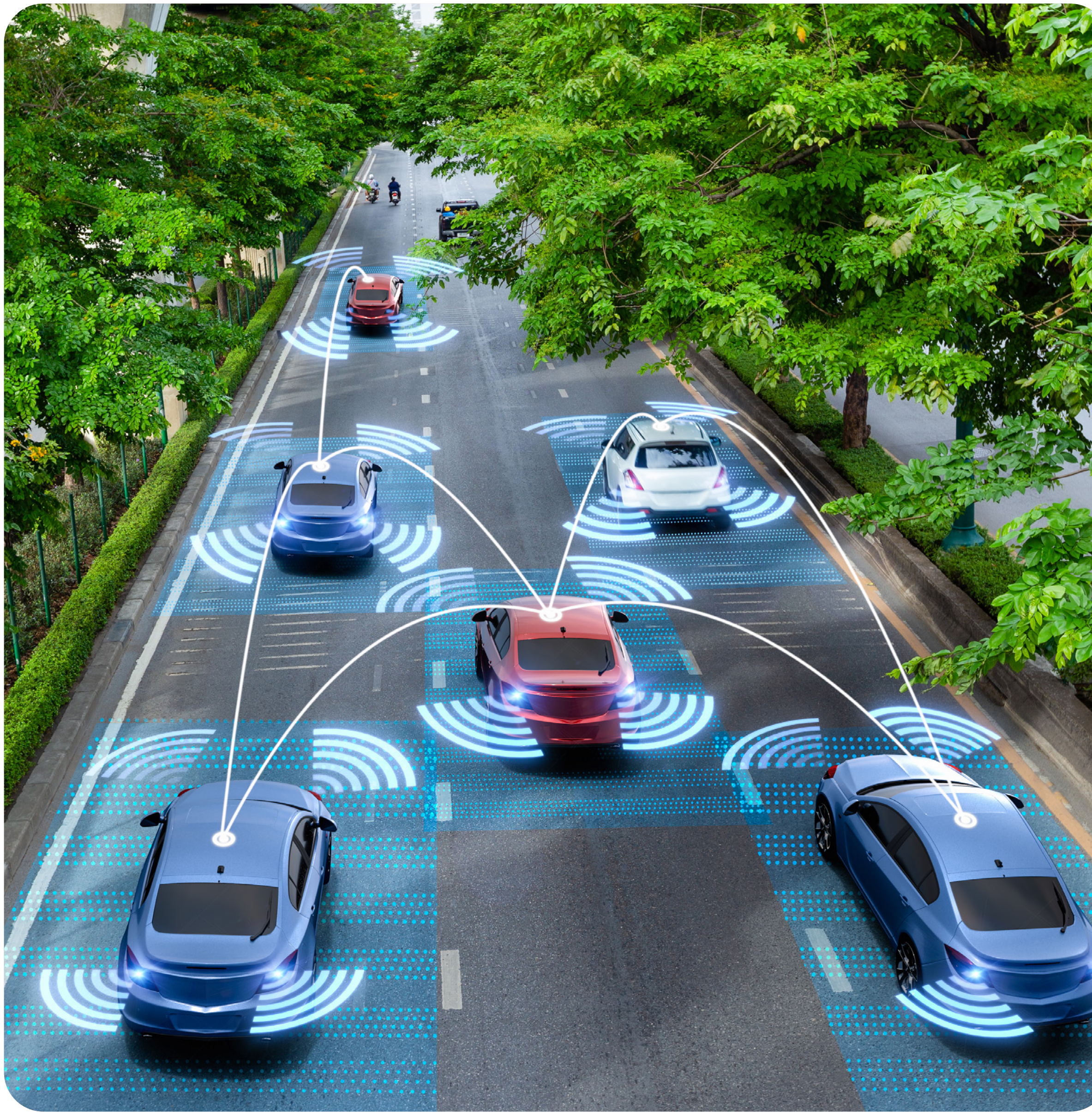
Figure 3: Signal coverage in downtown Indianapolis for a multi-GNSS receiver

- **Improved antenna design:** Advanced antennas can maximise reception of available signals, but they can be expensive and can't help in situations where signals are fully obscured.

- **GNSS augmentation services:** GNSS signals alone typically don't provide the sub-100cm accuracy needed for lane-keeping and other precision driving operations. Navigation systems for automated and autonomous vehicles tend to incorporate GNSS augmentation services such as RTK and PPP, which use ground-based stations to measure and correct for atmospheric errors that degrade the accuracy of GNSS signals.

  While RTK and PPP can correct for errors that degrade signal accuracy, the accuracy derived from them depends on the same LOS signals reaching the vehicle as the non-augmented GNSS engine. As such, they improve precision, but don't alleviate reliability concerns introduced by obscuration in any area of operation.

- **Avoiding autonomous driving in built-up areas:** One solution – used by some autonomous delivery companies today – is simply not to use automated driving capabilities in areas where signal obscuration might impact safe navigation. This either means a safety driver must be constantly present, or it means avoiding urban and built-up areas altogether – making routes longer and preventing autonomous driving in exactly the areas where it is most wanted and needed.



The missing capability: Knowing where and when GNSS will be reliable

What's missing from the above solutions is a means of knowing where and when GNSS will be reliable. If that were known, both in real time and in advance, it would unlock a host of possibilities:

- **Route planning and optimisation:** Operators of autonomous delivery fleets could use any route where GNSS coverage will be reliable – or at least sufficiently reliable that IMUs or other sensors could safely take over for short periods of signal obscuration before handing back to GNSS.
- **Real-time decision making:** If an autonomous vehicle's navigation system could receive a warning of poor GNSS coverage ahead, it could make an informed decision to prioritise other sensors and revert to GNSS when good coverage returns. Alternatively, new routes could be planned and followed on-the-fly.
- **Improved driver experience:** Avoiding areas with poor coverage would minimise disengagement of autonomous driving features, and offer more reliable feature availability in more areas including rural, suburban, urban, and deep urban environments.
- **Lower-cost navigation systems:** The more a navigation system can rely on GNSS for accurate and continuous positioning, the less need it has for expensive arrays of optical sensors. Extracting more performance from the vehicle's existing GNSS receiver could significantly reduce the cost of mass-producing a fit-for-purpose autonomous navigation system.
- **Improved performance:** Adding geospatial awareness gives a GNSS receiver the capability to prioritise LOS satellites, reject strong multipath signals, and reject spoofed signals. In the time domain, it can also enable a receiver to know in advance which satellites are known to remain LOS for longer sections of a journey, reducing the need for changes to tracking.

However, until now, no service has been available to forecast when and where GNSS will be reliable. That's due to the significant technical challenges involved in building and delivering such a service, as listed below:

- **Predicting satellite motion:** The 100+ global navigation satellites are in continuous motion, orbiting the Earth at a rate of around one degree per minute. This means the angle of arrival of their signals is constantly changing. While the orbits are generally predictable, predicting exactly where and when signals will come in and out of view is a significant challenge.
- **Mapping real-world locations:** Every location in the world is unique, with buildings, structures and landscape features of differing height, width, and depth. These streetscapes and terrains must be accurately mapped in 3D for a GNSS forecasting solution to be reliable.
- **Generating dynamic forecasts:** The 3D maps must be correlated with predicted satellite signal patterns to generate dynamic forecasts of where and when GNSS signals are likely to be degraded through full or partial obscuration.
- **Enabling ease of access and use:** Forecasts must be made available for easy consumption and distribution throughout the value chain – for example, by providers who currently supply RTK and PPP services – or via fast and reliable cloud access. Appropriate data compression and distribution technologies are needed to handle the massive volume of prediction data generated for every location and time.

Introducing Spirent GNSS Foresight

Drawing on our 35-year heritage in GNSS signal modelling and simulation, Spirent has met these challenges to develop a robust and easy-to-use GNSS reliability forecasting solution.

Spirent GNSS Foresight is a cloud-based forecasting service that uses 3D maps and precise orbital information to predict exactly where and when GNSS will be reliable, allowing users to plan routes, optimise navigation performance in challenging environments, and assure reliable operation.

It works by ray-tracing each GNSS satellite's line of sight for every square meter of terrain, every second, using high-definition 3D maps and precision orbital models. The Foresight engine calculates with a high degree of accuracy the times and locations at which each satellite will be obscured by buildings or other impediments, reliably predicting satellite availability and associated positioning performance. The heatmap shown in Figure 3 was generated by a visualisation application that uses the Spirent Foresight API, indicating the quality and granularity of the data it can provide.

Spirent's Foresight solutions are provided in two ways: as a detailed risk analysis report for a certain route or area, or as an ongoing, cloud-delivered forecast service:

- **GNSS Foresight Risk Analysis:** Provides a best- and worst-case analysis – or periodic updates over time – for a given route or geographical area. The analysis shows where good GNSS coverage is always available, never available, or sometimes available, and when and how it differs over time. Areas with high coverage variability may require the Forecast Service (see below).
- **GNSS Foresight Forecast Service:** Enables second-by-second predictions to allow routes with reliable coverage to be identified in advance, and early warning of likely disengagements to be provided to the driver, operator, or positioning engine in real time, thus maximising the utility of GNSS in the vehicle's sensor fusion engine. The Forecast Service is available as an annual subscription by service area.

Why use Spirent GNSS Foresight?

Spirent's unique GNSS forecasting solutions offer significant benefits to developers of vehicle positioning and navigations systems; providers of RTK, PPP and related services; automotive OEMs; and operators of autonomous vehicle fleets.

Key benefits

For vehicle positioning and navigation system developers

- Extract maximum value and use from GNSS as an absolute positioning sensor
- Use GNSS Foresight data to optimise navigation decision algorithms
- Improve performance through receiver optimisations based on geospatial awareness

For providers of RTK, PPP and related services

- Understand where and when RTK/PPP provision may be compromised (as Spirent GNSS Foresight can also predict obscuration patterns for error correction satellites)
- Provide assurance or service level agreements (SLAs) around RTK and PPP, as these services rely on good GNSS coverage in a given area
- Offer GNSS reliability forecasting as an additional revenue stream

For automotive OEMs

- Improve the driver experience by minimising disengagement of autonomous driving features and providing route change suggestions based on feature availability
- Remove the need to rely solely on simultaneous localisation and mapping (SLAM) for autonomous positioning and navigation
- Optimise the overall cost of onboard sensors

For autonomous fleet operators

- Maximise the market opportunity by opening up many more efficient driving routes
- Improve planning and resourcing by knowing where and when safety drivers may be needed
- Move with confidence towards fully autonomous operations

Unlock the future of autonomous driving with GNSS reliability forecasting

As the automotive world moves towards greater autonomy, the reliability of GNSS signal coverage, particularly in built-up areas, is a key issue to address. Spirent GNSS Foresight offers an innovative solution, predicting where and when GNSS is available for up to three days in advance, in any location around the world.

With accurate knowledge of where and when GNSS will be reliable, the automotive industry can move towards 'anytime, anyplace' autonomous driving, paving the way for the full potential of self-driving vehicles to be unlocked faster and more cost effectively.

TALK TO A SPIRENT EXPERT TODAY

Spirent GNSS Foresight is available today for developers of automotive positioning and navigation systems, providers of automotive navigation services, and any party with an interest in GNSS forecasting and assurance. To find out more about this innovative technology, contact Spirent at www.spirent.com/contact
or visit the website.

About Spirent Communications

Spirent Communications (LSE: SPT) is a global leader with deep expertise and decades of experience in testing, assurance, analytics and security, serving developers, service providers, and enterprise networks. We help bring clarity to increasingly complex technological and business challenges. Spirent's customers have made a promise to their customers to deliver superior performance. Spirent assures that those promises are fulfilled. For more information visit: www.spirent.com

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