

Global Breakthrough in PPP Technology: “RTK From the Sky”

RTK accuracy and instant convergence worldwide

Overview

Hexagon’s Autonomy & Positioning division is proud to present a breakthrough in precise point positioning (PPP): immediate, globally available, centimeter-level accuracy. The technology is the first of its kind and is expected to unlock a new era of PPP capabilities. This paper presents the first results, providing a glimpse of the future of PPP with RTK From the Sky.





Research from Hexagon's Autonomy & Positioning division has resulted in breakthrough innovations in precise point positioning (PPP).

Introducing the future of PPP – RTK From the Sky

GNSS positioning has become a fundamental technology in small and large scales across marine, land and autonomous industries. Satellite positioning is based on the complex interaction of a number of advanced technologies, including GNSS constellations, receivers, antennas and algorithms for correction generation and user positioning. Whereas additional sensors like inertial measurement units (IMUs) offset satellite positioning limitations, corrections maximize the quality of the GNSS position by compensating for GNSS errors. Corrections play an important part and have become a critical component of any application relying on precise GNSS.

Hexagon has invested in delivering a highly accurate, reliable and immediately available position to diverse users worldwide. With RTK From the Sky technology centimeter-level positioning is now achievable in less than a minute (95%) without regional constraints or additional

infrastructure. This performance level is achievable through advancements at every stage of our correction services ecosystem, and it will become the new reality for end-users when paired with Hexagon's high-quality GNSS receivers. Hexagon has the technology to deliver an industry-first PPP solution with the accuracy of RTK without the PPP convergence wait time.

Figure 1 illustrates the significance of this breakthrough. The green line shows the TerraStar-C PRO service, which has been used in land-based PPP applications like agriculture since Spring 2016 and now supports a wide variety of land and airborne industries worldwide.

The blue line shows the performance of RTK From the Sky. Improving the convergence time from 18 minutes to less than one minute is monumental. RTK From the Sky is the first technology to provide instant convergence globally.

Breakthroughs in Global PPP Technology

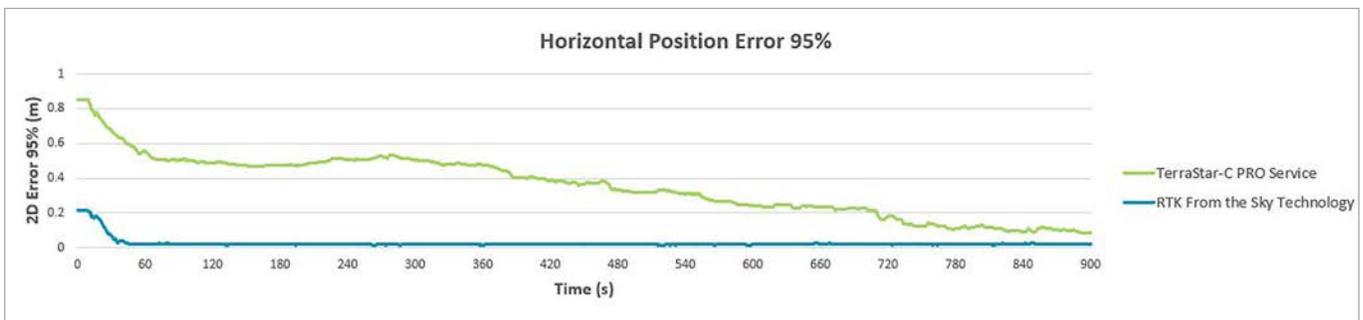


Figure 1: Horizontal position error (95%) for RTK From the Sky compared to existing TerraStar-C PRO service using four days of data in Calgary, Canada.

Evolution of Corrections

30 years of GNSS innovation

NovAtel, part of Hexagon's Autonomy & Positioning division, has pioneered GNSS and corrections technology since the early 1990s. The first corrections system was real-time kinematic (RTK) positioning that eliminated common errors between a base station and rover, improving GNSS position accuracy from several meters to centimeters. NovAtel's RTK solution was introduced in 1994 and delivered centimeter-level accuracy within a 10 kilometer baseline.

NovAtel was one of the few companies that mastered the tracking and use of semi-codeless L2P tracking. This innovation was essential to unlocking GPS dual-frequency capabilities needed for medium and eventually long baseline RTK. The accuracy provided by this early RTK was highly precise but very limited geographically as the user was tethered to a local base station. NovAtel continued to evolve RTK capabilities with the introduction of dual-frequency and multi-constellation RTK for more robust positioning and longer baseline support. Still, RTK is inherently reliant upon local base stations and therefore limited to a specific, regional coverage area.

While NovAtel developed RTK solutions, VERIPOS, another brand under Hexagon's Autonomy & Positioning division, spearheaded precise point positioning (PPP) corrections for marine applications. VERIPOS was supplying PPP correction services in 2005 and started using their stations for PPP correction processing in 2011. Marine applications cannot rely on additional infrastructure like base stations, so VERIPOS looked to PPP for globally available, geographically unlimited corrections. The technology provided decimeter accuracy regardless of user location, but it also identified a new problem: convergence time. RTK solutions are near-instantaneous, while PPP requires time to converge to the final accuracy. PPP solutions took nearly an hour for convergence and required a continuous, uninterrupted view of the sky, making the technology suitable for limited applications.

Over the last 10 years, PPP technology has continued to improve, making it more accessible to diverse applications. Current PPP correction service products from Hexagon include NovAtel's TerraStar-C PRO service and VERIPOS' Apex service. These services deliver accuracy of three centimeters (95% horizontal) with a convergence time of 15-30 minutes for land-based applications, like agriculture and offshore marine applications, respectively.

Moving into a new era of fast-converging PPP, NovAtel released its regional TerraStar-X service in August 2019, providing 2.5 centimeter (95% horizontal) accuracy and convergence under one minute. Hexagon continued research into technology that could deliver this level

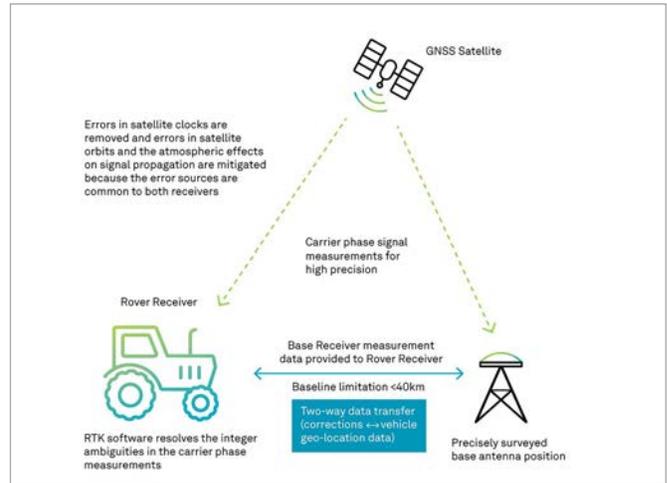


Figure 2: A diagram of a typical RTK system featuring a base receiver, a rover and GNSS satellite.

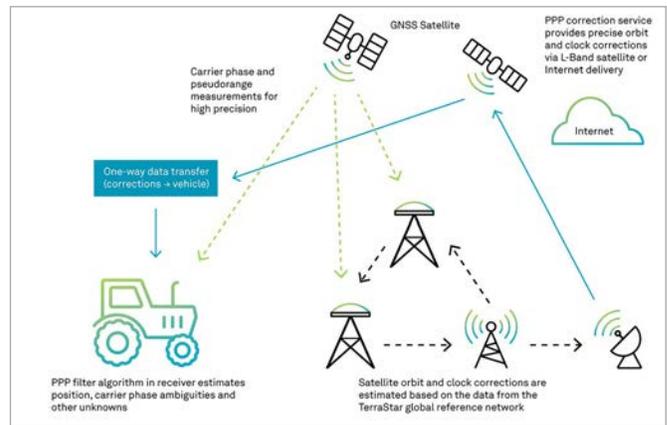


Figure 3: This diagram illustrates a typical PPP system, demonstrating how corrections are delivered without reliance on regional base stations.

of performance globally. Recent developments with GNSS constellations provided the catalyst, with three constellations supplying triple or quad frequency signals – BeiDou phase III, Galileo and modernized GPS. With Hexagon's expertise, the complex corrections system was optimized to harness the capabilities of these signals. As demonstrated in the following results, this breakthrough eliminates the choice between the ease and availability of global PPP and the regional performance of local RTK networks; RTK From the Sky is accessible anywhere, anytime.

Leveraging the entire GNSS ecosystem for globally available RTK From the Sky

Delivering RTK From the Sky performance in a production-ready global solution requires end-to-end excellence. This performance relies on technology advancements across Hexagon’s entire positioning architecture, which is shown in figure 4.

The first key to generating this globally applicable service is Hexagon’s worldwide reference station network. Each reference station site is surveyed for multipath and interference; only sites that meet strict performance standards contribute to the correction generation solution. In addition, network geometry has been designed to ensure redundancy and robustness for a highly available correction stream.

The network’s components – reference station antennas, receiver hardware and firmware – have been strategically fine-tuned for error elimination. In addition to tracking all frequencies broadcast from the GNSS constellations, the system includes advanced anti-spoofing, multipath mitigation and integrity monitoring algorithms. These additions provide clean and reliable data, essential for this breakthrough performance and functionally safe integrity systems.

High-quality measurements from the global network are then passed to the correction generation software. The

correction generation software efficiently transforms the multi-constellation and multi-frequency reference station data into a robust and reliable set of corrections valid for worldwide use.

Hexagon’s correction generation system delivers corrections quickly with low latency over both L-Band satellite and IP delivery to the user receivers.

The corrections arrive at the user’s receiver and positioning engine. NovAtel receivers and firmware are optimized to utilize the complete correction content from Hexagon services to converge quickly and accurately. This system is designed to support various applications and operations. The fast convergence and steady converged accuracy of this technology will enable users across many industries like agriculture, offshore surveying and construction to complete their jobs effectively and more efficiently than ever before.

To achieve these results, no error can be ignored. With precision, built-in redundancy and fine attention to detail, errors are estimated, catalogued and subsequently removed during processing. This end-to-end fine-tuning of measurement quality and error mitigation establishes the foundation for RTK From the Sky performance.

Hexagon’s PPP Ecosystem



Figure 4: Hexagon’s PPP ecosystem generates and delivers GNSS corrections across diverse positioning applications.

Global RTK From the Sky Results

For the first time, fast PPP convergence has been demonstrated worldwide without a dense reference station network to measure every deviation of the atmosphere. These results are achievable with a single set of globally valid correction data, meaning that corrections can be delivered without boundaries or geographic constraints. The data presented here was collected in static open sky conditions using quad-frequency measurements, exploiting the L1/E1/B1, L2, L5/E5/B2 and E6/B3 bands.

Figure 5 demonstrates that this performance is achievable worldwide, with rovers across six continents able to converge in less than a few minutes. Many reach two-centimeter accuracy in seconds over seven days. As discussed in the previous section, this performance is based on the complex interaction and optimization of Hexagon’s entire GNSS correction system to leverage the potential of quad-frequency signals. To get a more detailed view of what this performance looks like, figure 6 shows the convergence curves of six locations. This data, which represents the 95% horizontal position error of convergence performance over seven days, demonstrates the technology’s global consistency and performance.

This performance is consistent week-over-week, showing reliability and robustness to typical operational events such as atmospheric changes, internet disruptions and changes in satellite health. Such events have been well-considered and planned for to ensure that performance remains stable and consistent. This stability is evident in figure 7, which shows the variation of 21 stations worldwide over four weeks: nearly 90% of the data converges in less than one minute, with the remaining 10% converging in less than three minutes.

These results indicate that the global availability of PPP corrections with instantaneous convergence and centimeter-level accuracy is achievable. Not only is this performance ground-breaking, but it is also reliable, consistent and robust, establishing a promising future for applications that require uptime and optimal positioning performance.

Global Performance Using RTK From the Sky Technology



Figure 5: Convergence time for RTK From the Sky from sites around the world using one week of data reset every 10 minutes (over 1,000 resets).

Global Examples of Convergence Performance – Horizontal Position Error 95%

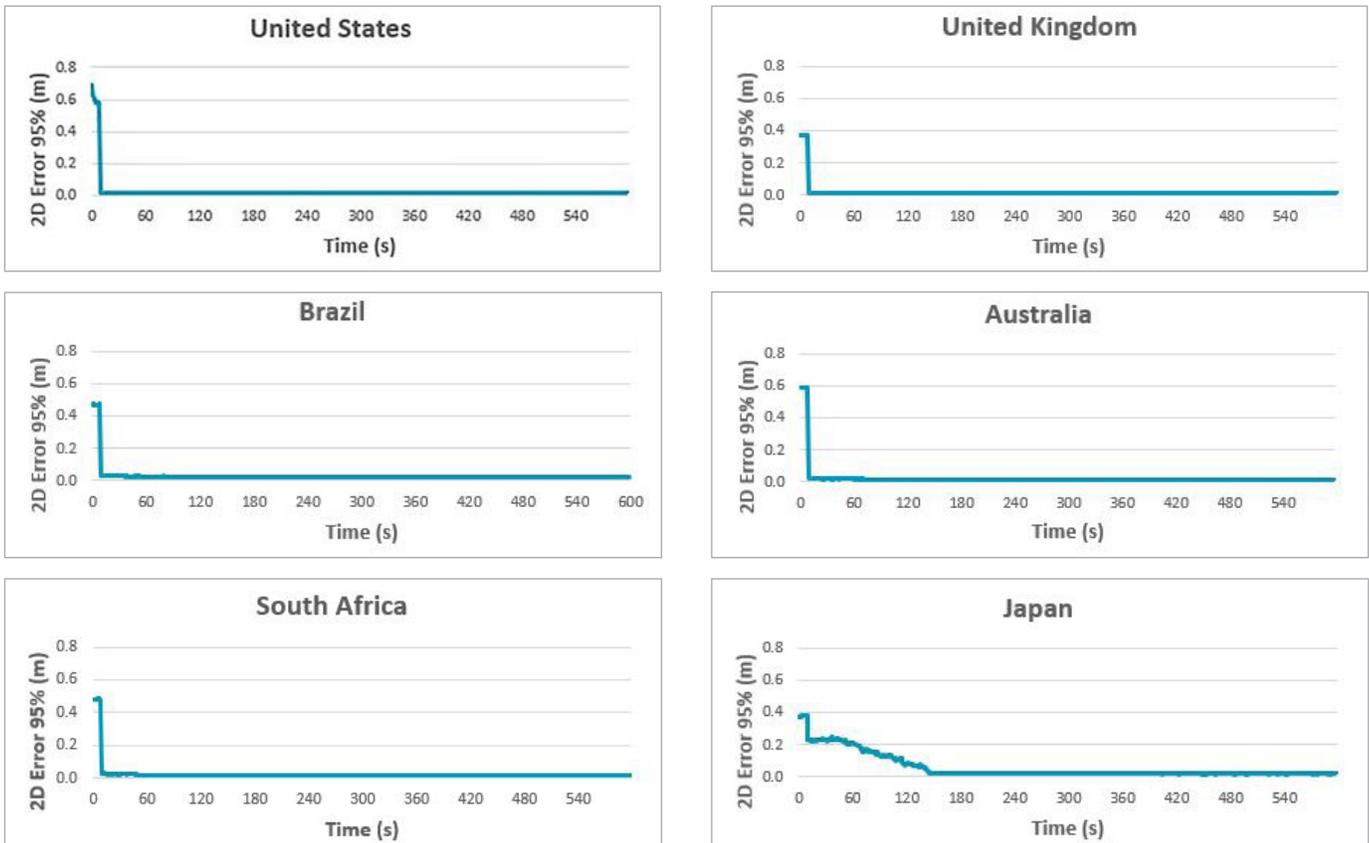


Figure 6: Horizontal position error (95%) after a PPP reset. Based on one week of data reset every 10 minutes (over 1,000 resets).

Consistency of Global Convergence Time Over 4 Weeks – Convergence Time 95%

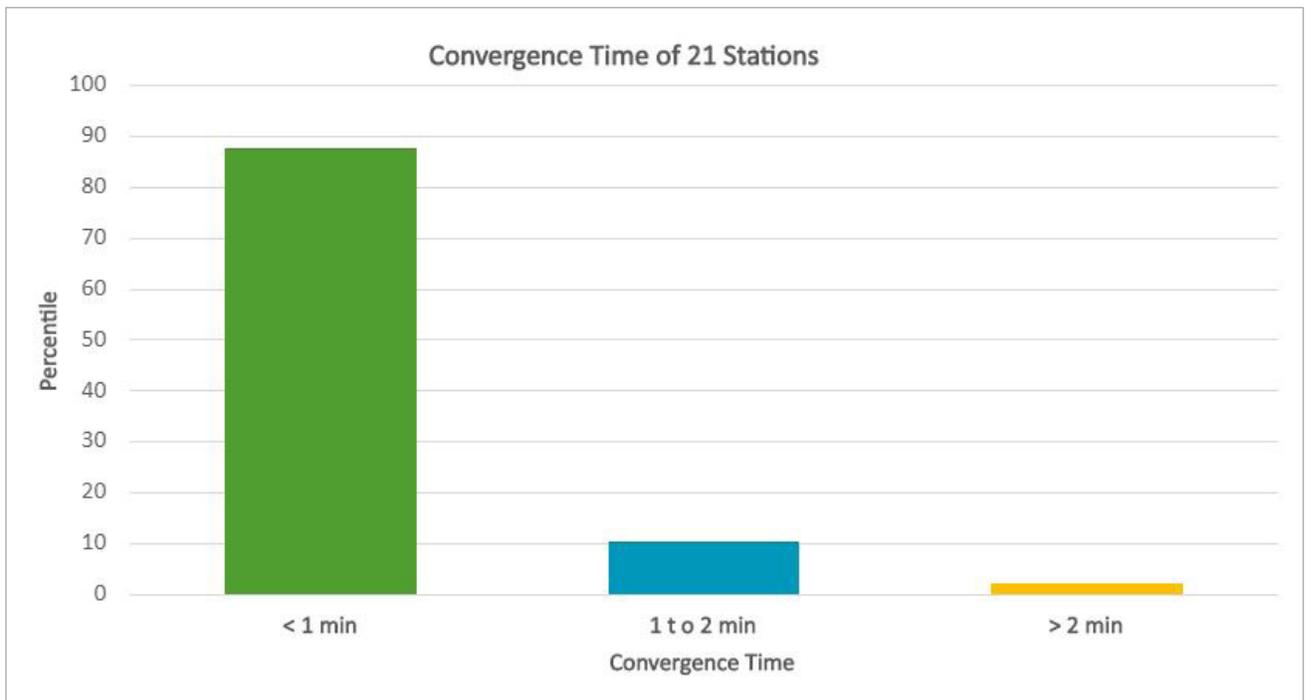


Figure 7: Distribution of convergence time for 21 stations distributed around the world over 4 weeks (84 days of data with over 1000 resets each).

Future possibilities with global RTK From the Sky

Hexagon's technology has pushed PPP into a new era of possibilities: PPP has become RTK. High accuracy and fast converging PPP is globally attainable, removing the barriers of regional solutions and dense network infrastructure. These innovations leverage the extensive experience of Hexagon's correction generation and GNSS receiver technology.

The complex interaction of this entire ecosystem enables this huge step forward in global performance. This advancement in PPP technology paves the way to worldwide high accuracy positioning, which is critical for assured positioning in marine, land and autonomous applications. RTK From the Sky technology will be incorporated into paid correction service offerings on most hardware products from Hexagon in the future.

Unlike other correction technologies and offerings, the RTK From the Sky breakthrough approach contains all multi-constellation and multi-frequency data in one feed, meaning that users can get the maximum performance benefit of modern satellite signals from a single source. With a valid worldwide solution, this technology also opens possibilities for users who have not previously been serviced by regional RTK solutions or who operate in widespread project areas. Not only will this technology provide a reliable and highly accurate position, but it will enable users to get this performance in minutes, with no time lost to setting up equipment or waiting for the solution to converge. Hexagon's innovative advancements in both correction generation and receiver design means that the future of positioning is much more accessible – and faster than ever.



Hexagon is a global leader in sensor, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications.

Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

[Hexagon's Autonomy & Positioning division](#) is a global technology leader, pioneering end-to-end solutions for assured positioning for land, sea, and air. Its solutions power intelligent positioning ecosystems in vital industries and safety-of-life applications, enabling the advancement of the Autonomous X (cars, UAVs, industrial vehicles, trains, vessels, and more). The division includes leading brands [NovAtel](#), [VERIPOS](#), and [AutonomousStuff](#).

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