NAVENTIK POSITIONING SOLUTIONS FOR VEHICLE AUTONOMY

NAVENTIK PATHFINDER
Product Summary

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PATHFINDER is NAVENTIK's technology for demanding and safety-critical localization tasks.

PATHFINDER GNSS

PATHFINDER FUSION

Precise Positioning for Automotive Safety Applications

In era of connected and automated transport use cases beyond human navigation require a new level of localisation performance - accurate, robust, highly available and functional safety compliant at lowest cost. PATHFINDER is a scalable platform that combines satellite navigation with information from vehicle sensors and modern augmentation services to meet these requirements.

NAVENTIK PATHFINDER
Features

Quality GNSS Software Receiver
Due to the seamless embedding into the cluster computing architectures of ADAS, our flexible software based GNSS sensor can now substitute expensive legacy hardware components to achieve mass market readiness and high performance levels – ready for safety critical applications!

High Accuracy and Integrity
PATHFINDER reliably estimates the vehicle system state including the accurate position, velocity and heading as well as their associated integrity values (measures of trust). Combined with next generation correction services these data dimensions are the basis for a safety critical GNSS integration into ADAS and AV use cases that require lane-level positioning.

Safety Compliance
PATHFINDER is designed according the highest quality standards of the automotive industry. We are working towards ISO26262 and ASIL B compliance for our PATHFINDER localization solution for safety critical vehicle applications.

Integrated Sensor Fusion
The deeply coupled combination of GNSS and motion data leads to an extremely robust and high-performance GNSS/INS positioning. Furthermore it is possible to extend fusion of GNSS with additional vehicle onboard sensors e.g. odometers or vision based navigation systems, tailored to specialized use cases.

Advanced Multipath Mitigation Models
Multipath and non-line-of-sight (NLOS) effects strongly degrade GNSS positioning performance. PATHFINDER uses advanced probabilistic multipath mitigation algorithms to detect the type of pseudorange measurement to adjust the protection level of the state estimate.

In-Field Software Upgrades
Keep PATHFINDER up to date within the product lifecycle. Current and future GNSS features such as new constellations or argumentation services are provided by a simple update process.

Highly Portable
PATHFINDER is written in C++ and can be ported to your platform of choice. For easy integration into prototyping and evaluation frameworks, PATHFINDER supports common middlewares and has been tested on various ADAS platforms.

Low Cost Serial Production
The use of PATHFINDER drastically lowers the cost factor compared to a conventional hardware GNSS solution. The integration of PATHFINDER into your vehicle systems reduces the hardware overhead and enables a simplified and centralized architecture.

Post Processing
PATHFINDER‘s powerful and highly configurable post-processing engine maximizes the performance of the localization solution using all available GNSS and INS data.

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Technology

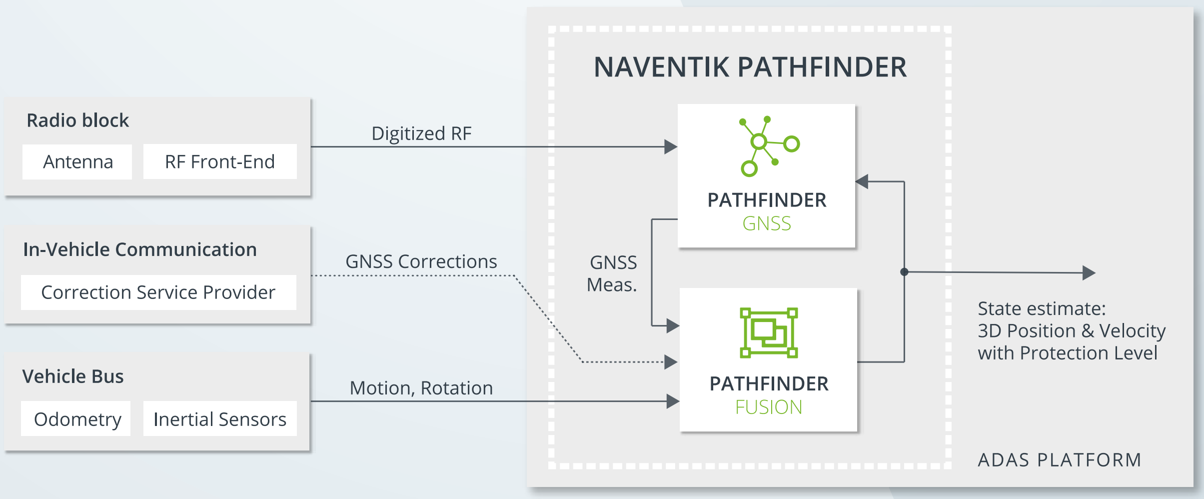
PATHFINDER GNSS is NAVENTIK's unique Software Defined GNSS sensor (SDR) that fully substitutes your existing hardware receiver by a flexible and scalable ECU embedded software. PATHFINDER GNSS provides highly accurate multi-band and multi-frequency raw measurements including integrity data. Real-time confidence estimation of GNSS input data is the key to seamless and safety-compliant deep-coupled sensor fusion. With the software approach, our sensor is highly portable and always up-to-date.

PATHFINDER FUSION is NAVENTIK's advanced positioning engine that exploits the synergies of GNSS measurements and data from additional vehicle sensors. Starting from inertial system (INS) integration, we provide algorithms that combine odometry or vision-based motion data with measurements from any GNSS receiver, taking into account the vehicle model. In doing so, we also take advantage of modern GNSS augmentation services, which enable a safe positioning with low convergence time. PATHFINDER FUSION creates the most robust and accurate navigation solution using all available information.

PATHFINDER GNSS

PATHFINDER FUSION

The joint use of PATHFINDER GNSS & FUSION enables an end-to-end integrity concept, as both the GNSS sensor and the positioning engine are implemented as software without having a „black box" within the system architecture. Integration with additional sensor and correction services is seamless and cost-effective. Furthermore, both modules together interact with each other in deeply coupled sensor fusion mode for extremely robust and uninterrupted high-performance GNSS/INS positioning. Unlike conventional tightly- or loosely-coupled GNSS/INS systems, deeply coupled systems not only combine autonomously generated GNSS and INS solutions. Motion data is used to support and stabilise the satellite tracking of the GNSS receiver in difficult environments or after a loss of the satellite signal. In addition, GNSS measurements from as few as two satellites can be used to compensate for the sensor drift of the intertial unit.



PATHFINDER GNSS+FUSION architecture

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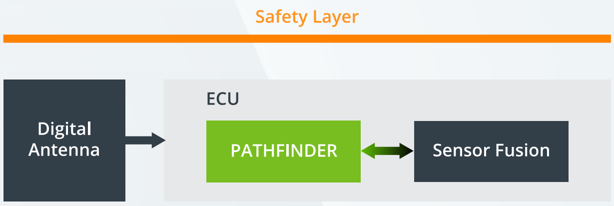
Safety

Navigation for highly automated driving requires an integrated safety concept for GNSS signal processing.

Exact vehicle positioning is a major challenge for advanced driver assistance systems (ADAS) and autonomous vehicles. Future safety-critical driving functions also require functional safety down to the sensor layer. NAVENTIK PATHFINDER enables both - a more robust localization even in urban environments and the implementation of functional safety concepts through transparency of the signal pre-processing within the receiver framework.

Traditional Setup. A dedicated hardware GNSS receiver plus antenna results in a complex system architecture. An integrated supervision of the receiver performance is not possible.



PATHFINDER is seamless integrated into the central sensor fusion platform. This approach leads to a simplified architecture and enables an integrated safety concept.

Safety Lifecycle. In order to implement a security concept for GNSS position data, the entire processing chain from the GNSS ground segment via satellites in space to the final position in a digital environmental model must be covered. This includes the explicit modeling and mitigation of all known sources of error. Some of the influences are related to signal propagation disturbances, others to errors inherent in the system. Most of them can be monitored by external service providers and integrity information must be evaluated in real time in the receiver.

> *In short, PATHFINDER integrates all safety-relevant aspects of vehicle localization. All steps of signal processing are carefully reviewed so as not to lose or falsify any information relevant for the estimating a valid error budget. The PATHFINDER modules will be interfaced by an API tailored to your needs and requirements. As we aim to implement on your ECU or ADAS processor, we carefully develop according to automotive standards and will also comply with ISO 26262.*

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Frequently asked questions

1) Why have you developed your own software GNSS receiver when there are good and cheap hardware receivers out there?

Powerful GPU-based compute platforms for ADAS and Autonomy (e.g. NVIDIA DRIVE) are available at suitable cost levels for mass market & series deployment end enable our solution to scalable and cost-effective replace a legacy hardware receiver with the latest functional safety oriented positioning algorithms. Unlike a black box solution, the software approach gives us full control over the entire signal processing chain, starting with the digitized antenna signal. This is the basic requirement for generating GNSS measurements with high integrity for functionally safe integration into the sensor fusion environment. In contrast to an integrated circuit the software approach enables seamless interfacing to the sensor fusion environment. Our software can easily be tailored to specific use cases and allows deeply coupled sensor fusion. Since PATHFINDER is written in C++ according to strictly controlled coding standards, it runs on all ADAS platforms with GPU's and is compatible with the most common middlewares. Our software can be quickly upgraded to future signals and services (e.g. Galileo HAS or other modern GNNS argumentation services like SPACORDA).

2) How many position candidates and confidence pairs come from PATHFINDER?

That currently depends on the receiver mode (single point positioning, D-GPS, RTK) and is ultimately depending on both the environment and receiver configuration. For example, under open-sky reception conditions a single candidate is usually enough to approximate the probability density of the position estimation well enough. Only under multipath and/or non-line-of-sight conditions ambiguities arise, which may be further increased by the ambiguity problem RTK has to resolve anyhow. In this case, 2-5 candidates are usually a fair enough representation.

3) How do you handle multi-path & NLOS situations?

Our GNSS receiver employs probabilistic models within the signal tracking itself to assess and mitigate the presence of multi-path and non-line-of-sight conditions. This leads to a reliable confidence estimation for the receiver measurements and increases its resistance to localization biases caused by such effects (especially during short-term signal disturbance).

4) Is there an indicator of the current integrity of the localization?

Confidence is expressed using average Normalized Estimation Error Squared (A-NEES). PATHFINDER confidence estimate maximum in deeply coupled mode is A-NEES < 10.

5) PATHFINDER uses IMU data internally, so it can output position candidates even though fewer than four satellites are in sight, right? And a low-cost IMU can meet the PATHFINDER requirements? What's the IMU model in your reference board?

PATHFINDER itself does not require an IMU to function, although such additional input can highly increase its performance depending on the chosen data fusion scheme. If PATHFINDER is to be integrated into a larger data-fusion based localization engine that already uses such an inertial sensor, then IMU data shall only be used to tune its signal tracking dynamics. This would still improve its tracking performance without violating the data-fusion systems presumptions (fusing a sensor twice is usually not a sound approach, especially if the caused correlations are ignored). If this is not the case, then PATHFINDER can deeply integrate IMU sensor data on its own to fully exploit its usefulness. It is designed to work with arbitrary IMU models if the noise/drift parameters of that IMU can be adequately determined. We usually do not supply an IMU on our own, PATHFINDER is software, although we can point out models we used so far. As a last note: As most modern GNSS receivers, PATHFINDER can update its position estimation using a single satellite in sight as well. The four satellites requirement is true for trivial single positioning algorithms only, that need to solve the position and clock bias estimation at each update step. Using more sophisticated assumptions on the receiver dynamics softens this requirement. However, this is only suitable to bridge short term signal interruptions like at an underpass. Understandably, precision will suffer over time (but slower with an IMU) and confidence estimation will disclose this.

6) In case of cold booting – when will PATHFINDER be "alive" again?

As described at the previous question, this depends on the information the receiver can still rely upon. If it leaves a GNSS denied area, it will regain position estimates within few seconds, typically between 5s and 15s. That's usually called the warm or normal time-to-first-fix (TTFF). There is also a "cold TTFF" describing the time to the first position if the receiver has no valid information at all. In this case it needs to find available satellites and retrieve the required information from them. In traditional, unassisted operation, this tends to take around 40s to 60s.

7) In case of a long tunnel the IMU will take over the positioning. In most cases the performance will not be sufficient because of the drift. How can the NAVENTIK Technology cover this kind of a worst case scenario?

By principle, long term operation in a GNSS denied environment leaves the scope of our technology. Depending on its performance, this allows bridging signal gaps from several seconds up to few minutes, with ever increasing covariance estimations. PATHFINDER is precisely designed for integration into a large-scale positioning data fusion system, maximizing the use of GNSS. ADAS needs precise and reliable positioning during a broad range of conditions, something no single sensor can achieve. Optical systems like camera and Lidar based visual odometry can be helpful to reduce the drift, but can fail due to poor lighting conditions, map and feature based approaches fail in unmapped areas or if the surrounding lacks notable features and GNSS fails under poor radio reception conditions. To solve this, many different sensors and a lot of know-how must be combined to function under all conditions sufficiently, with NAVENTIK covering the GNSS part and integration support.

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NAVENTIK PATHFINDER
Specifications

Sensor characteristics

GNSS Constellations & Frequencies	GPS L1/L1C, L2/L2C, L5 Galileo E1, Galileo E5a/E5b
SBAS	WAAS, EGNOS, MSAS, GAGAN according DO-229E_SBAS_VTU592S7
Number of Channels	platform specific [1] e.g. 32 channels @ 3% GPU NIVIDA PX2
Multipath Mitigation	Several advanced algorithms
Signal Tracking	Shared State Vector
GNSS Front-End	Reference multiband HW with high precision clock
Interfaces	SW interface, platform specific[1] HW interfaces
Sensor Fusion	All kind of odometry, motion and rotation data
Corrections	RTCM 3.x over NTRIP, SAPCORDA (Q2 2021)
Navigation Output	GPX, GeoJSON, KML, NMEA 0183, RTCM 3.x, RINEX, LCM, MQTT

Performance [2]

GNSS only (Standalone mode)	1.2 m (RMSE)
SBAS	0.8 m (RMSE)
DGPS	0.4 m (RMSE)
GNSS/INS (deeply coupled)	Improved continuity, availability and precision [3]
RTK	0.02 m (RMSE)
PPP-RTK	0.10 m (RMSE) with high integrity data
Post processing (deeply coupled)	0.01 m (RMSE)
Time to first fix (TTFF) [4]	COLD < 40 s Reacquisition < 1 s HOT (aided start) < 9 s
Data rates	25 Hz, up to 100 Hz using sensor fusion
Confidence estimate	maximum NEES [5] 10
Initialization Reliability	> 99%
Solution latency	< 40 ms

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[1] Highly scalable depending on available resources of the processing platform

[2] Positioning performance depends on atmospheric conditions signal multipath, satellite geometry as well as available corrections and their quality. A minimum of 5 satellites is assumed. All accuracies apply to Horizontal Position accuracies.

[3] Accuracy similar to GNSS standalone mode, but increased robustness (bridging GNSS signal losses) and localization performance in high dynamic scenarios.

[4] TTFF times apply in open sky and strong signals conditions. Hot Start is the time taken by the receiver to achieve a standard position fix after a brief outage between 30 and 50 seconds, Re-acquisition between between 1 and 5 second, cold start after a prolonged outage.

[5] Normalized Error Estimation Squared