

INERTIAL SENSE

Autonomous Navigation Solutions

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WHITE PAPER

Beyond Position

Why Modern Navigation Needs an IMU Alongside GNSS

Continuous, high-rate, full-state navigation depends on more than satellite positioning. This paper explains the limits of GNSS-only systems, what an inertial measurement unit contributes, and how the Inertial Sense IMX-6 fuses the two into a single, resilient navigation solution.

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Executive Summary

Global Navigation Satellite Systems (GNSS) answer a single, important question: where am I? But they answer it intermittently, only when the sky is visible, only as a position, and only at low rates. Autonomous vehicles, stabilized platforms, survey systems, and pointing applications need much more than that. They need orientation, not just position. They need an answer every millisecond, not a few times per second. And they need that answer to keep flowing when the satellites disappear behind a building, a bridge, a tree line, or a jammer.

An Inertial Measurement Unit (IMU) supplies exactly what GNSS cannot. It measures motion directly, at high rate, with no dependence on an external signal, and it reports attitude even when the system is standing still. On its own, an IMU drifts over time; on its own, GNSS drops out. Fused together in an Inertial Navigation System (INS), each sensor covers the other's weakness, and the combined output is continuous, high-rate, and drift-bounded.

The **Inertial Sense IMX-6** packages a tactical-grade IMU, magnetometer, and barometer with onboard AHRS and INS sensor fusion in a reflow-compatible module. Add a GNSS receiver and it delivers synchronized roll, pitch, heading, velocity, and position — with roughly 30% better navigation accuracy than the previous-generation IMX-5. The pages that follow make the engineering case for why an IMU belongs in any serious GNSS-based design.

1. Where GNSS Alone Falls Short

GNSS is remarkable: a few dollars of silicon can locate a receiver anywhere on Earth to within a meter, or to within centimeters with RTK corrections. But every GNSS-only design inherits a set of structural limitations that no amount of receiver quality can fully remove.

Coverage gaps are the rule, not the exception

Satellite signals are line-of-sight and extraordinarily weak by the time they reach the ground. Urban canyons, tunnels, parking structures, dense foliage, bridge underpasses, and indoor environments all block or degrade the signal. In these conditions a GNSS-only system does not degrade gracefully — it simply stops producing a trustworthy position until the sky reopens.

Update rates are too slow for control

Typical GNSS receivers output a solution between 1 and 20 times per second. A control loop steering a drone, stabilizing a camera, or guiding a ground vehicle needs state estimates an order of magnitude faster. Between fixes, a GNSS-only system is effectively flying blind.

Position is not orientation

A single-antenna GNSS receiver reports where the antenna is, and — only while moving — the direction of travel. It cannot tell you which way the vehicle is pointed, how it is rolling or pitching, or its heading at a standstill. For any platform that must aim, stabilize, or orient itself, position alone is insufficient.

Noise, multipath, and latency

Reflections off buildings and terrain introduce multipath error, individual fixes carry measurement noise, and the solution arrives with latency after the measurement instant. A position that is both noisy and late is a poor foundation for tight, dynamic control.

Interference, jamming, and spoofing

Because the received signal is so faint, GNSS is easy to overpower. Intentional jamming and spoofing have moved from the laboratory to everyday operational reality across many regions and industries. A navigation architecture that has no answer when the GNSS signal is denied or falsified is a liability.

2. What an IMU Brings to the System

An IMU measures the physical motion of the platform itself — angular rate from gyroscopes and specific force from accelerometers — without relying on anything external. This single architectural difference addresses each GNSS weakness in turn.

- **High-rate measurement.** Output at 1000 Hz on the IMX-6 IMU and 500 Hz for the fused INS solution — fast enough to close demanding control loops.
- **Direct attitude.** Roll, pitch, and heading are computed directly through onboard AHRS fusion of the gyros, accelerometers, and magnetometer — available at a standstill, independent of GNSS.
- **Dead reckoning through outages.** When GNSS drops out, the IMU propagates position and attitude from the last known state, letting the system coast through tunnels, garages, and urban canyons rather than failing outright.
- **Smoothing and bridging.** Between GNSS fixes the inertial solution fills the gaps, and it rejects momentary GNSS noise and multipath glitches instead of passing them straight through to the controller.
- **Self-contained and interference-immune.** There is no external signal to lose, block, or falsify, so the inertial solution remains trustworthy even when GNSS is jammed or spoofed.
- **Low latency.** Inertial estimates are available essentially instantaneously, eliminating the latency penalty of waiting on a GNSS fix.

3. Better Together: GNSS / Inertial Fusion

The decisive insight is that the strengths and weaknesses of the two sensors are complementary. An IMU is accurate in the short term but drifts as small measurement errors accumulate over time. GNSS is the opposite: it provides an absolute, drift-free reference, but only intermittently and at low rate. Fuse them and the partnership is self-correcting.

- **GNSS bounds the IMU's drift.** Each GNSS fix resets accumulated inertial error, keeping the long-term solution accurate.
- **The IMU bridges GNSS gaps.** During every gap between fixes — and through complete outages — the inertial solution carries the navigation state forward continuously.

Inertial Sense performs this fusion in an onboard Kalman filter that produces a single, continuous estimate of the full navigation state — position, velocity, and attitude — at inertial rates with GNSS-level accuracy. The filter also estimates and removes IMU biases online and accounts for the lever arm and alignment between the IMU and the GNSS antenna, so the solution stays consistent as conditions change.

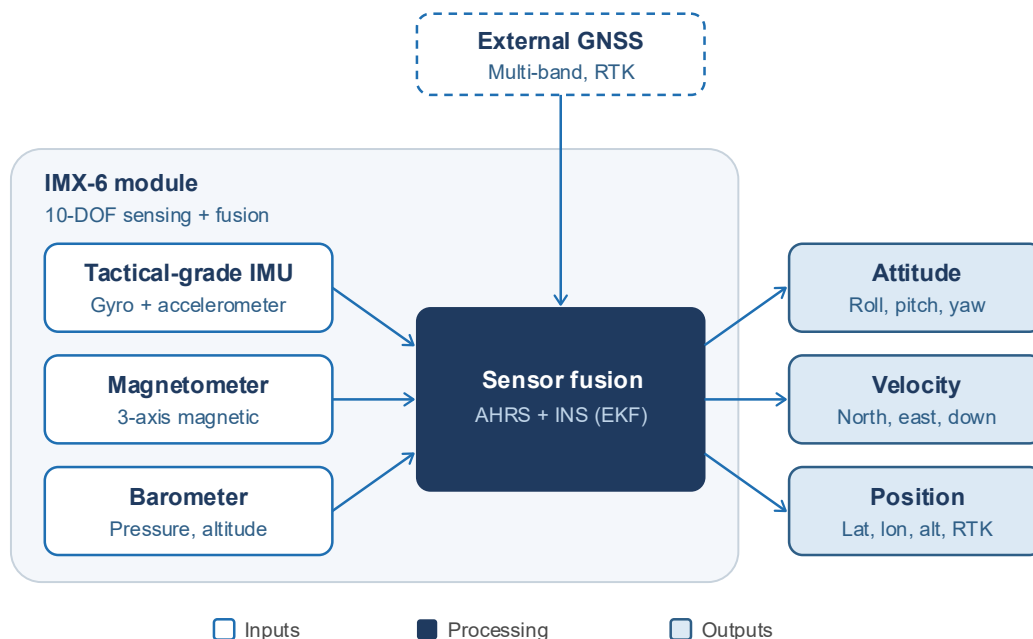


Figure 1. IMX-6 system architecture — onboard sensors and an external GNSS receiver feed the fusion engine, which outputs the full navigation state.

The practical payoff is graceful degradation. When GNSS is healthy, the system delivers bounded, absolute accuracy. When GNSS weakens or vanishes, performance does not fall off a cliff — it degrades slowly and predictably along the inertial solution, then snaps back the moment satellites are reacquired.

4. Why Sensor Grade Matters

During a GNSS outage, the only thing standing between the system and a growing position error is the quality of the IMU. How fast the dead-reckoned solution drifts is governed directly by the gyroscope's bias instability and angular random walk (ARW) and the accelerometer's bias instability and velocity random walk (VRW). Better sensors drift slower — and that difference is the difference between coasting cleanly through a long tunnel and losing the solution within seconds.

The IMX-6 uses a tactical-grade IMU, a class well above the consumer- and industrial-grade MEMS parts found in typical integrated receivers:

Performance parameter	IMX-6 specification
Gyro bias instability	1.3 °/hr
Gyro angular random walk (ARW)	0.11 °/√hr
Accel bias instability	3 µg
Accel velocity random walk (VRW)	0.012 m/s/√hr
Dynamic roll / pitch accuracy	0.03°
Dynamic heading accuracy	0.09°
IMU output rate	1000 Hz
INS (fused) output rate	500 Hz

Lower bias instability and random-walk figures translate directly into longer, more accurate dead reckoning. This is what allows a tactical-grade INS to ride out a meaningful GNSS outage while a consumer-grade integration would have already diverged.

5. The IMX-6 in the Real World

These advantages are not theoretical. In published testing of an IMX-based ground-vehicle integration, the system was driven into a parking structure and lost GNSS entirely. Over a 105-second outage and roughly 350 meters of travel, the dead-reckoned solution accumulated only about 6% drift — and recovered cleanly on regaining signal. In ground-vehicle mode, drift is governed more by distance traveled than by elapsed time, so slow, prolonged maneuvers in GNSS-denied areas remain well bounded.

In comparative testing, IMX systems have achieved results on par with established, higher-cost integrated solutions such as NovAtel SPAN. The IMX-6 itself represents roughly a 30% improvement in attitude and navigation accuracy over the IMX-5 it replaces.

Representative deployments

- **Satcom-on-the-move pointing.** A satellite-communications provider needed a fraction-of-a-degree orientation reference for antenna pointing on moving vessels, at a price point existing tactical systems could not meet. An IMX integration paired tactical inertial performance with low-SWaP GNSS to hit both the accuracy and the cost target.
- **Unmanned platforms.** An unmanned-systems developer required lower ARW and bias instability than the previous generation could deliver — precisely the envelope the IMX-6 was built to serve.
- **And more.** Drone navigation, ground and aerial survey, stabilized platforms, robotics, automotive navigation, and maritime systems all rely on the same continuous, full-state output.

6. Designed to Drop Into Your System

Performance only matters if it is easy to deploy. The IMX-6 is engineered for straightforward integration across the full range of programs, from a surface-mount module on a custom board to a rugged enclosure ready for the field.

- **Complete sensing.** A 10-DOF sensor module — tactical IMU, magnetometer, and barometer — with onboard AHRS and full INS sensor fusion built in.
- **Flexible GNSS.** Accepts multi-band external GNSS input, with a modular architecture supporting multiple receivers (including u-blox F9 and X20, with planned support for the Septentrio mosaic-G5).
- **Easy to manufacture.** A reflow-compatible PCB module available in cut tape and tape-and-reel, and pin-compatible with the IMX-5 for a true drop-in upgrade.
- **Open tooling.** An open-source SDK with data logger, math libraries, and interfaces for Linux, Windows, and embedded platforms, backed by published reference designs and evaluation hardware.
- **Field-ready options.** Rugged RUG-4 enclosure variants add RS-232, RS-485, and CAN bus, with options for RTK precision positioning and dual-antenna GNSS compass heading.

7. Conclusion

GNSS tells you where you were a moment ago — sometimes. An inertial navigation system tells you where you are, which way you are pointed, and how fast you are moving, continuously, right now, and keeps telling you when the satellites cannot. For autonomous vehicles, stabilized platforms, survey rigs, and pointing systems, that difference is not a luxury; it is the foundation of reliable operation.

The IMX-6 brings tactical-grade inertial performance, onboard fusion, and a clean integration path together in a single module. It is the answer to the gaps that every GNSS-only design eventually runs into — the tunnel, the parking garage, the tree line, the jammer, the moment a controller needs an orientation that GNSS simply cannot provide.

Ready to evaluate the IMX-6 for your application? Contact Inertial Sense — a Hexagon company — to request a datasheet, an evaluation kit, or an integration consultation at www.inertialsense.com.