Inertial Labs
Attitude is Everything

Improved Position, Navigation, and Timing Accuracy for GPS-Aided INS in GNSS Denied Environment

Understanding the Problem

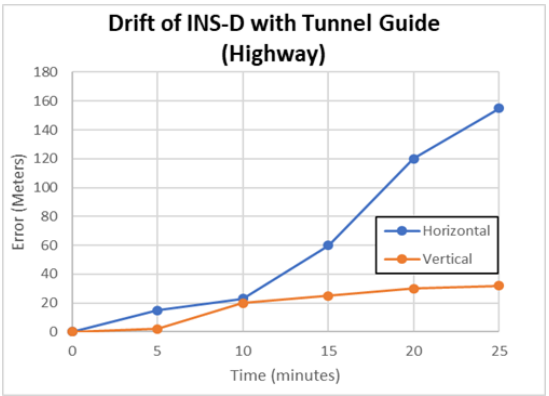
For years **Inertial Labs** has produced high accuracy Inertial Navigation Systems (INS) at the world's best price-performance ratio. An INS estimates the position, attitude, and velocity using the gyroscopes and accelerometers contained inside an inertial measurement unit (IMU). Position accuracy can be greatly improved when the INS is aided by Global Navigation Satellite System (GNSS). However, GNSS is not always available. Customer requirements demand for better performance of an INS during GNSS outage. Outages occur from natural environments like: tunnels, urban canyons, and roads under bridges; or from forced conditions like GNSS jamming or spoofing. During GNSS outage, position error growth is inevitable. Inertial navigation using any IMU will accumulate error due to integration and double integration of unknown accelerometer and gyroscope biases. Using GNSS allows the INS to estimate and correct these biases. However, when satellite communication is lost, bias instability and noise still cause drift. A typical INS using a MEMS-based position solution would drift by thousands of meters over 20 minutes of GNSS outage; a navigation-grade IMU INS, like Northrop Grumman LN-100G, which uses high accuracy ring laser gyros, claims to drift 120 meters after a 20-minute GNSS outage. Instruments like this are simply too large, too expensive, and too power hungry for most applications, especially for the emerging ones.

As a proven effective alternative, **Inertial Labs** developed the **Tunnel Guide** feature for the GPS-Aided INS: an advanced algorithm that implements continuous dynamic modeling for land vehicle motion. As a result, the INS can mitigate error and increase accuracy of its MEMS IMU during prolonged GNSS outage. Now the position error of a land vehicle remains low even in a GNSS outage area such as: a tunnel; a city with signal blocking buildings; or any area where satellite communication is being blocked, spoofed, or jammed.

The Tunnel Guide feature has proven to be an effective solution for military vehicles such as: Infantry Carrier Vehicles (ICV), Mobile Gun Systems (MGS) Anti-Tank Guided Missile Vehicles (ATGM), Anti-Drone Guided Missile Vehicles (ADGMV), NBC Reconnaissance Vehicles (NBCRV), Assault Amphibious Vehicles (AAV), and Light Armored Multipurpose Vehicles (LAMV).

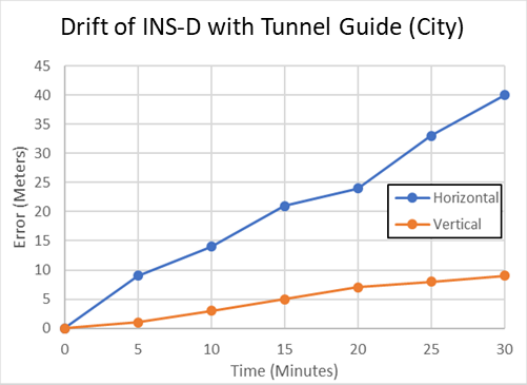
An Effective Solution

Sample data was gathered to demonstrate the effectiveness of **Tunnel Guide** for different application methods in purely inertial mode, only using inertial sensors together with sophisticated modeling of land vehicle motion. For both of the following sample sets, a driving test was conducted using an **Inertial Labs** INS-D with **Tunnel Guide** without any aiding data from a Distance Measurement Instrument (DMI). The first test was run on a highway driving at an average speed of 60 mph (96 km/h). The plot below shows accumulated drift of approximately 160 meters, with outage time of 25 minutes. This leads to an approximate drift rate calculation of 0.4% of Distance Travelled (DT) for a 25-minute outage. This is already comparable to a navigation-grade INS (120-meter drift over 20-minute outage), yet the size, weight, power, and cost are an order of magnitude lower.



For applications involving more frequent turns, **Tunnel Guide** will only improve in its accuracy.

A plot from another sample test was produced in a similar manner, but in this situation the vehicle was driven in a city environment. This sample set shows the effective nature of **Tunnel Guide** when vehicle dynamics allows better observability of the system state. This driving test was done at an average speed of 25 miles per hour (40 km/h) with frequent turns, and the GNSS outage lasted for 30 minutes. The plot below shows performance of the INS using Tunnel Guide with no aiding data from a DMI.



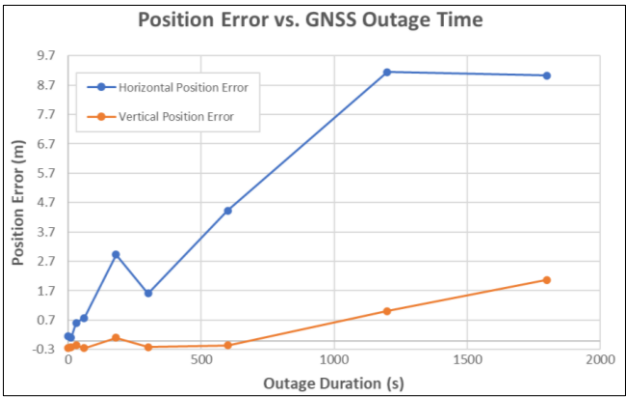
The average drift rate of the second sample set was calculated to be 0.2% DT over the course of the 30-minute outage with a peak drift of approximately 45 meters. These results show that **Tunnel Guide** significantly improves performance accuracy during GNSS outages, at a much lower cost.

Improved Accuracy with Aiding Data

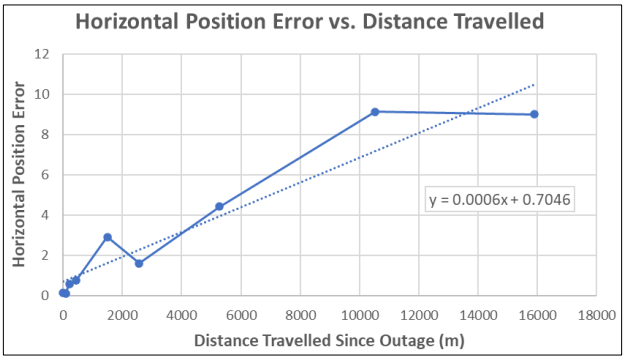
To test the filtered navigation solution while using aiding data directly from a vehicle's OBD-II port via CANbus, a drive test was performed in a similar manner to the previous test. The vehicle was driven at an average speed of roughly 20 miles per hour, and a GNSS-outage was simulated 15 minutes into the drive. After 30 more minutes of driving under GNSS-outage conditions, the device was given GNSS corrections again, and the solution converged. Above is an image of the test route that was driven.

Data was then processed in NovAtel Inertial Explorer. A post-processed solution utilized IMU data from the INS-B and the recorded GNSS data. This data was independent of the INS navigation solution and was used as reference data for comparing the results of the simulated GNSS-outage.

After the data was recorded and post-processed, Inertial Labs engineers derived a plot of position data as a function of GNSS outage time. The derived plot is shown below.



Additionally, a second plot was generated to show the trendline for horizontal position error as a function of distance travelled. This plot is useful because it is critical for land-based navigation systems that need to operate in a GPS-denied environment. This plot is shown below.



From these plots, it can be concluded that the usage of CANbus aiding data in the INS-D Kalman filter resulted in a horizontal position error of 0.056% DT, which is a significant improvement on the 0.2% found in the test mentioned earlier. Now users can be confident that even in an extended GPS-denied environment, systems can navigate autonomously with accuracy that outperforms any other comparable sensor in the industry.

In Summary

Regardless of your land vehicle application, keeping accuracy during a GNSS outage can be the deciding factor in meeting expectations of your project requirements. For **Inertial Labs**, the development of the **Tunnel Guide** feature is a solution that provides increased position accuracy without increasing the cost of our devices. The GPS-aided INS-D is **Inertial Labs'** dual antenna INS unit, but with it comes accuracy and advanced features that ensure that saving money doesn't mean cutting corners on performance.

What Do You Think?

Here at Inertial Labs, we care about our customers satisfaction and want to continuously be able to provide solutions that are specifically tailored to problems that are occurring today, while vigorously developing products to tackle the problems of tomorrow. Your opinion is always important to us! Whether you are a student, an entrepreneur, or an industry heavyweight. Share your thoughts on our products, recommendations you have, or just say hello at opinions@inertiallabs.com.

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GPS-Aided INS-D

Specifications	Accuracy (RMS)
Position with GNSS	1.5 m (SP) 0.6 m (SBAS) 0.4 m (DGPS) 0.01 m (RTK)
Position without GNSS	0.2% DT (w/o odometer input) 0.056% DT (w/ odometer input)
Pitch and Roll	0.05°
Heading/Yaw	0.08°
Velocity	0.03 m/sec
IMU	1°/hr (Gyroscopes drift) 5 µg (Accelerometers drift)
Fluxgate Compass	Optional
Aiding Data	Odometer, Encoder, Wheel Sensor, DMI
Weight	320 grams
Size	120 x 50 x 53 mm

About Inertial Labs Inc.

Established in 2001, Inertial Labs is a leader in position and orientation technologies for commercial, industrial, aerospace and defense applications. Inertial Labs has a worldwide distributor and representative network covering 20+ countries across 6 continents and a standard product line spanning from Inertial Measurement Units (IMU) to GPS-Aided Inertial Navigation Systems (INS). With application breadth on Land, Air, and Sea; Inertial Labs covers the gambit of inertial technologies and solutions.

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