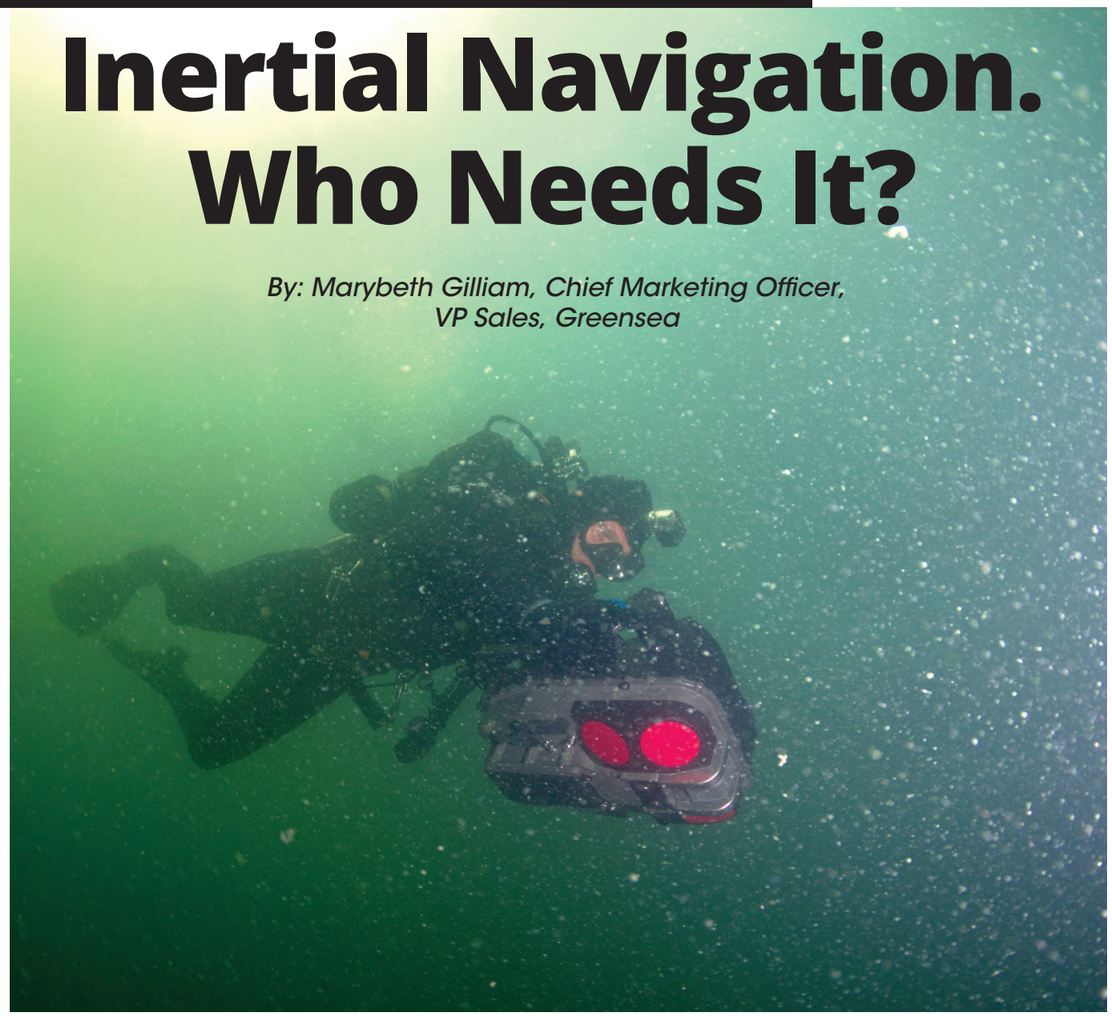
Inertial Navigation. Who Needs It?

By: Marybeth Gilliam, Chief Marketing Officer, VP Sales, Greensea



The Greensea INSpect GS4 inertial navigation system with DVL is fully-integrated into the STIDD RNAV2 Diver Navigation system.

Underwater navigation is difficult. Unlike land and air, there is no Global Positioning System (GPS) to identify a subsea vehicle's location and position. Instead, the industry uses a variety of sensors to approximate position. An Ultra Short Base Line (USBL) and Doppler Velocity Log (DVL) are popular navigation sensors but they are not a complete solution and work best when used as navigation-aiding sensors contributing data to an inertial navigation system (INS).

Inertial navigation relies on a combination of navigation-aiding sensor data (such as DVL, USBL, GPS, depth, etc.) and high-level math algorithms to calculate a vehicle's orientation and its location in the world. With an INS, an operator has a complete, optimized navigation solution, including heading, depth, pitch, roll, and latitude/longitude.

Doesn't a USBL provide a vehicle's position?

A USBL is frequently used to approximate a vehicle's position and can be an important contributor to a navigation system. Using a transceiver mounted on a pole and placed underwater, the USBL transmits an acoustic pulse to a transponder located on the subsea vehicle that replies with its own acoustic pulse. The direction (angle) and time passed of pulse transmission is mathematically converted into a position estimate for the vehicle.

While this information is helpful, a USBL can only transmit its data through water at a very low rate. Common position update rates provided by USBL manufacturers are between 0.5 and 10 seconds. The variability in performance is associated with water conditions such as depth, temperature, and salinity. Although the USBL does provide vehicle position, at these update rates a USBL cannot provide the accuracy required for many important or complex subsea jobs, including anything requiring closed-loop control or supervised autonomy.

Can a DVL be a single-source solution for navigation?

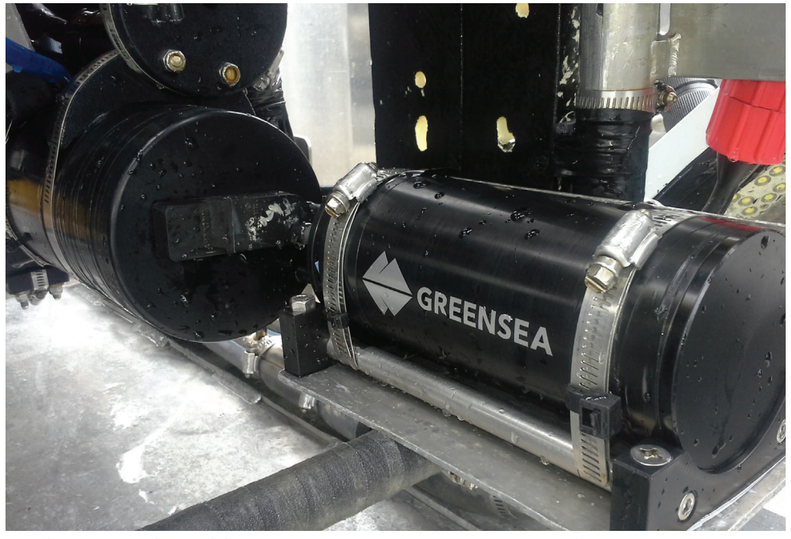
A DVL is another acoustic navigation device. By transmitting acoustic beams down to the seafloor and measuring frequency shift (Doppler shift), it can calculate a vehicle's velocity in three directions (x,y,z) relative to the bottom—but this information alone won't provide a vehicle's position. It is a very important navigation sensor, but it is designed to be one of multiple inputs for a navigation solution.

As an acoustic device, the DVL also struggles to provide sufficient update rates, although the maximum updates are generally better than a USBL with manufacturer published rates as high as 0.125 seconds. In addition, DVLs are challenged with maintaining bottom lock. The acoustic beams must maintain contact with the seafloor. This can be a particular challenge if the seafloor is uneven or at an angle greater than about 20 degrees. It is also challenged with maintaining bottom lock if it is too close the seafloor, too far from the seafloor, or if it becomes occluded by nearby equipment or infrastructures.

An inertial navigation system acts like an analyst, monitoring navigation data inputs and deciding which ones are reliable.

An INS is designed to capture a wide-range of navigational inputs and fuse them together into an optimized multi-state position for the vehicle. An INS considers the sensors contributing to its solution and makes real-time decisions about the accuracy of the information it is provided. For example, if the DVL loses bottom lock, it puts more emphasis on alternative data sources until it is once again receiving quality DVL data. Likewise, if USBL data become erratic, the INS can smooth the data and mitigate the noise in the system. An INS helps maintain an accurate heading and position, even in tough environments, by pulling all the information together to provide a more meaningful, accurate, and stable solution. Without an INS, navigation sensors are acting as independent, bolted-on devices providing discrete data points.

In addition, the INS provides navigation updates to the vehicle at a very high rate (upwards of 50 Hz or 0.02 seconds). The significantly higher frequency of communications to the vehicle increases the accuracy and stability of the overall navigational estimate.



The Greensea INSpect GS3 inertial navigation system is designed for small inspection-class vehicles.

An Inertial Navigation System is essential for advanced vehicle control.

With the optimized inertial solution, a vehicle is ready for meaningful work and complex tasks. It can execute advanced vehicle control functions such as station keeping, "GO TO" position, target reacquisition, and supervised autonomy for intervention tasks. Missions can be planned and executed with high-level commands to the vehicle. Pipeline inspections, riser inspections, and explosive ordnance inspections can all be automated for reliability and repeatability.

Next month's column will focus on how inertial navigation systems are being optimized for size, weight, power, and cost (SWaP-C) to support supervised autonomy on small vehicles.