LEVERAGING COLLABORATIVE EXPERTISE: iXBLUE INS AND DVL TIGHT COUPLING PERFORMANCE IMPROVEMENTS

iXblue, a global company that provides innovative solutions devoted to navigation, positioning and underwater imaging for the Offshore Energies market, has partnered with Nortek and Teledyne RD Instruments to characterize their DVL behavior during a subsea mission in order to enhance the position performance of the INS & DVL solution.

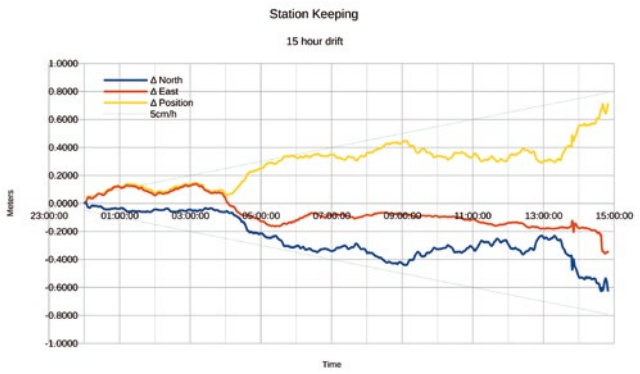
Indeed, while the best INS used on the Offshore market provide very accurate short-term characteristics, the longer term characteristics will eventually drift causing a position and velocity error that can compromise the whole operation. It is to correct these limitations that iXblue has partnered with DVL manufacturers to offer its customers a solution with enhanced performance, through the use of aiding data.

Courtesy of iXblue

INCREASED PERFORMANCE FOR SUBSEA OPERATIONS

Coupling an INS to a DVL will indeed change a system that might drift at a rate of up to half a nautical mile an hour, to one which is able to hold position for many hours. An INS aided with a DVL is thus effectively able to stay on station for many hours without significant error in position.

Instead of a drift that builds up over time, the error is then mostly related to the distance from the original start point.



INS&DVL drift over 15 hours < 5cm per hour (Courtesy of iXblue)

In recent years and months, significant developments in subsea DVL have been driven by some key patents expiring and a number of alternative devices were introduced on the market. Innovation-driven, iXblue, has partnered with major DVL manufacturers to test and characterise the performance of those new devices and their positive impact on the INS/DVL combined performance.

Combining velocity sensors with differing characteristics with iXblue's inertial sensors now allows a vehicle's navigation system to be extremely flexible (e.g. using a 1Mhz sensor for high accuracy low altitude operations and switching over to a low frequency sensor for operations requiring extended altitude working).

The reliability of the position and speed provided by an INS depends on the characterization of internal and external sensors in terms of performance and behaviour during operation. A constant axis of development for iXblue research engineers. In order to bring more flexibility and reliability to this new coupled system, iXblue has worked on both the physical relationship between the velocity sensor and the INS, and the technical characteristics of the data provided.

Mechanical integration

When it comes to the physical relationship between a DVL and an INS, there are two main integration approaches: integrated and non-integrated.

In the integrated approach the DVL sensor is integrated in the same housing as the INS. Once the offset between the INS and the velocity sensor has been measured in the factory the unit has the advantage of being considered calibration free. However, in case of damage to the acoustic elements or electrical failure of either the INS or DVL, the whole unit must be replaced.

The non-integrated approach involves rigidly attaching the INS and DVL by means of a mechanical mounting system (interface plate or bracket). Calibration will however be required after any changes made to the system, but through the use of built-in calibration routines, will allow the user to change the DVL or INS at will. The INS and DVL may individually be placed anywhere on the vehicle and in any convenient orientation.

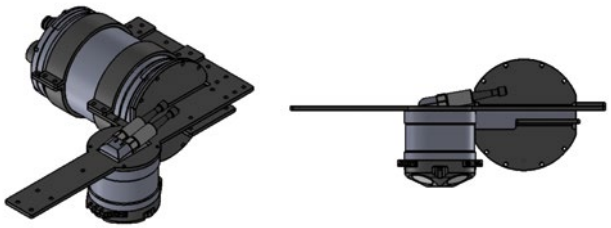


Figure 1 Rovins NANO & 1MHz Nortek custom mount to fit observation class ROV skid. (Courtesy of iXblue)

Tight coupling

Beyond the physical integration of the INS and the DVL, the algorithmic integration is the primary aspect affecting performance. When it comes to the algorithmic interfacing of external sensors to an INS there are two main approaches: loose coupling or tight coupling.

One might be confused by the term tight coupling into believing it is related to the physical interface between one device and another, when it in fact refers to the algorithmic connection.

In a loosely coupled system, the external sensor system calculates its results and passes those results to the INS. The INS then takes those results at face value and uses them to aid its internal calculation. While in a tightly coupled system, the sensor motion (as measured by the INS) is used to assist in the calculation of the results.

INS ERROR MODELS: A CRUCIAL KNOWLEDGE

Once a subsea vehicle is deployed, absolute position information such as a GNSS, USBL or LBL may remain unavailable for a while. This is why iXblue has set up a strategy to reduce its INS short-term position drift. Indeed, over a longer period, the position computed by the stand-alone INS (pure inertial mode) will start to drift if no external aiding remains unavailable. This drift is mainly due to a build-up of errors in the calculated velocity, and using an external speed sensor such as a DVL will limit the build-up for error and hence greatly reduce the position drift.

In order to achieve the best coupling solution possible, it is crucial to have a good knowledge of internal and external sensor characteristics. This will indeed allow to define an error model reflecting sensor behavior during various operational conditions.

SOURCES OF DVL ERRORS: BIAS, FACTOR, HEADING & SYNCHRONIZATION

Bias

The DVL bias error corresponds to a constant speed offset when the system doesn't move or when external conditions remain the same. DVL manufacturers aim to reduce the bias as much as possible and consequently most of the DVL specifications do not mention this information. Nevertheless in dynamic conditions at constant speed and external conditions, the scale factor error residual can be interpreted as a bias that can affect the INS if it is not correctly minimized by the calibration process or by the internal error model.

Scale factor

In contrast to the static bias, the scale factor error is more difficult to observe and requires another external speed reference which must be more precise than the DVL measurement. The INS coupled with a GPS can provide this speed and position references (respectively 1mm.s-1 & 3mm) and iXblue post-processing software DelphINS completes this robust benchmark.

Heading error

In addition, the composite heading error (INS heading error + INS & DVL assembly misalignment) is another source of error and needs to be adressed whether the INS and the DVL are integrated in a separate or single housing. The composite heading error will generate a wrong earth frame projection of the speed sensor used into the INS kalman filter and affect the accross track navigation.

Whereas the INS heading error can be minimized by the use of iXblue high grade INS, the DVL heading error is mechanical and depends on how the beam(s) have been calibrated together in factory and how the DVL is oriented compared to the INS.

Synchronization

The synchronization mechanism between the INS and the external sensor is also another source of error. It affects the INS solution even more if either the external conditions are rough (dynamic movements inducing quick attitude changes).

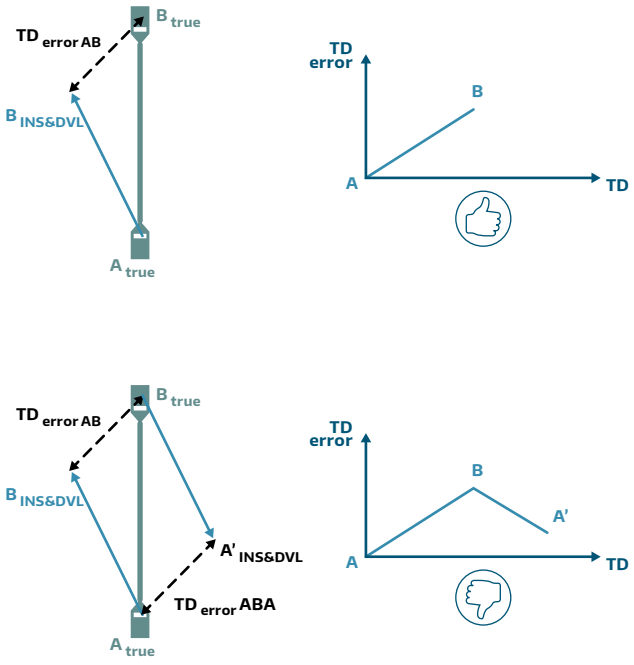
Without time compensation a nonlinear response is seen by the INS algorithm. The combination of subsea vehicle dynamic and the DVL accuracy interpreted by the INS may produce two scenarios:

- BEST CASE SCENARIO: The DVL observation is rejected by the Kalman filter when the discrepancy with the inertial sensors in not acceptable for the INS
- WORST CASE SCENARIO: The DVL observation is accepted by the kalman filter and corrupts the INS position solution

It is therefore essential for the INS to be able to associate a speed observation by a DVL and to compare it to its own internal sensors speed observation at the same time.

IXBLUE'S INS & DVL TIGHT COUPLING PERFORMANCE

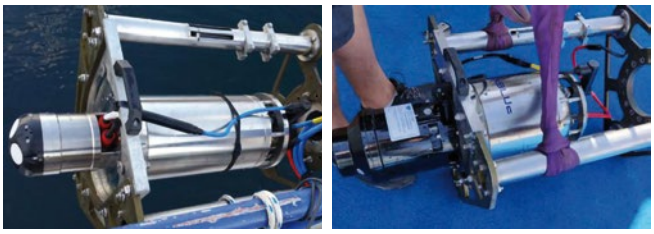
Evaluating an INS/DVL solution performance is done through a one straight line navigation. To sail back to the starting point will partially cancel the INS/DVL error.



Evaluate INS&DVL tight coupling solution shall be done over a one way navigation line (Courtesy of iXblue)

SUCCESSFUL SEA TRIALS FOR IXBLUE INS/DVL COUPLING

Back in May and June 2018, sea trials were conducted at La Ciotat (France) in order to qualify at sea the characteristics of these products and confirm the latest algorithm developments. A survey vessel from iXblue fleet was first mobilized with Nortek experts to assess the Rovins + Nortek 1Mhz performance. A second test was then conducted with Teledyne experts to assess Phins 6000 with phased array Pioneer 600Khz DVL.



On the left iXblue Rovins and Nortek DVL 1Mhz, on the right iXblue Phins 6000 and Teledyne RDI phased array DVL Pioneer 600Mhz (Courtesy of iXblue)

Following the sea trials, iXblue, Teledyne RD Instruments and Nortek were very pleased with the performance observed.

Through strict quality process of its INS firmware package qualification and from a conservative perspective, iXblue was able to review its INS performance specification to increase the position performance by a factor 2:

- Rovins Nano or Phins Compact C3 tight coupled with DVL: **0,2%TD**
- Rovins or Phins Compact C5 tight coupled with DVL: **0,1%TD**
- Phins 6000 or Phins Compact C7 tight coupled with DVL: **0,05%TD**

iXblue experts feedback on sea trials with Teledyne RD instruments and Nortek DVL (Courtesy of iXblue)

iXblue will continue to improve its reliable inertial navigation solution and will take further the level of autonomy of the subsea vehicles thanks to INS coupling with sonar, LIDAR and camera.