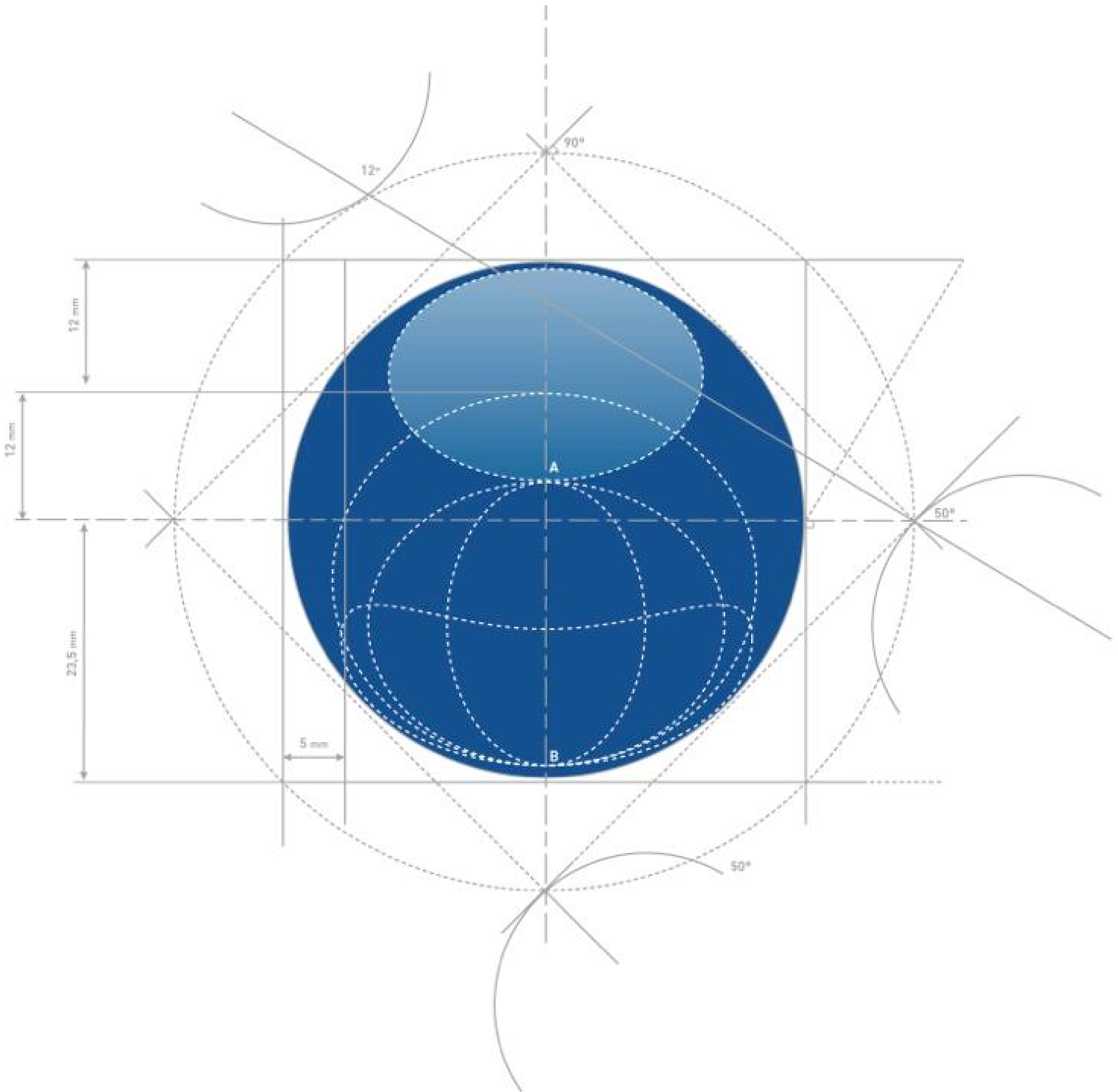
iXBlue Positioning Solutions

your data deserves the best positioning

August 2014



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1. IXBLUE Brief Corporate Description

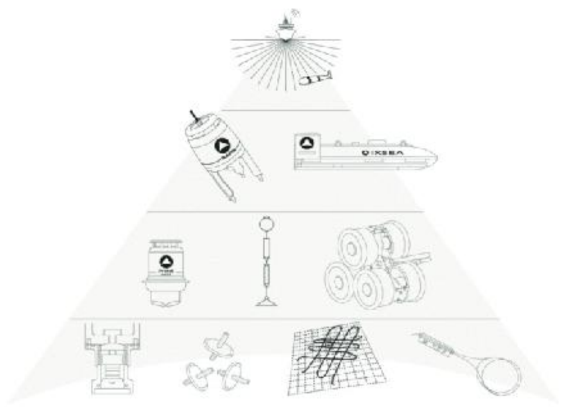
iXBlue is a privately owned French technology company incorporating a wide range of capabilities to deliver world leading solutions to the marine, land, air and space markets.

Formed in 2010 by the merging of a number of companies within the IXCORE group including IXSEA, SODENA, IXMOTION, IXWAVES, H2X, IXELEK, IXFIBER and IXSURVEY, iXBlue combines the proprietary technologies of these companies to deliver integrated solutions to meet the challenging requirements of today's world with innovation, flare and efficiency.

iXBlue comprises three main business areas: equipment and systems, components, services and platforms. Currently IXBLUE is headed by Mr Philippe Debaillon Vesque (ENST Paris) who is the President and CEO of the company. Mr. Debaillon Vesque is formerly vice-president of the "surface vessel sonar and torpedoes" Business Unit of the Thales Group. iXBlue employs more than 500 people worldwide and in 2011 had a turnover in excess of $100m.

1.1. Business Model

Our approach is based on leading-edge technology, product development and proposing integrated solutions to our customers.



Organised into eight (8) business areas, iXBlue is an independent group able to combine its unique technologies, products, systems and services from across its subsidiaries to provide unique solutions that fully satisfy customer's business requirements. Customer strategic outcomes are met quickly, efficiently and with best value.

iXBlue technologies, equipment and systems assure customers of a superior solution in all environments, navigating from the depth of the ocean to the reaches of outer space.

iXBlue consists of eight divisions in the following fields, with mainly IPD, APD and SOD (see below) divisions directly involved in the underwater acoustic and or inertial positioning :

IPD: Inertial products (gyroscopes, accelerometers, INS)
APD: Acoustic products (underwater navigation & positioning, beacons, pingers etc):
SOD: Sea operations (survey)
MSD: Motion systems (turrets)
ISD: Integrated solutions (Intergrated Bridge,cartography)
SSD: Sonar systems (sonars, seismic imaging systems)
ACD: Advanced components (optical fibre)
MWD: Marine works (ship building and refit)

1.2. iXBlue products development strategy

From day one and company incorporation iXBlue is having development guidelines which helped to design attractive and innovative products and solutions.

1.2.1. iXBlue owns / masters the technologies

One of the principle guideline at iXBlue while developing its products and systems since its creation. In order to maintain full control of key / critical components used in its products iXBlue develops and manufactures its own components, sensors, systems in house, starting from specialist optical fibers and accelerometers for Inertial products, or transducers for acoustic system for example.

This strategy is having very positive consequences:

- All critical components are manufactured in house and the company does not depend on third party suppliers or foreign export control regulation.
  As a consequence export of most products is easier and possible to most destinations, depends on local rules only, and turnaround time in case of maintenance or support is significantly improved.
- The whole technology know-how is within the company, detailed understanding of it allows better performance to be achieved and close coupling for ultimate results
- Reactivity is not depending on third party supplier. We can manufacture, maintain, support and deliver on short notice. Customized configuration is simplified and possible.
- Full product range can be offered based on a common design / technology. (lower grade INS to ultimate performance INS using QUADRANS to MARINS for instance)

1.2.2. iXBlue develops innovative solutions

New-comer in this industry iXBlue had to develop innovative products and solutions to catch the interest of its customers and grow its business. This tradition of innovation is a characteristic of iXBlue company with all products and solutions featuring unique characteristics and new ways to address today's navigation and positioning challenges.

- iXBlue first introduced FOG (Fiber Optic Gyroscopes) technology in its HARS (Heading and Attitude Reference Sensor) and INS (Inertial Navigation Sensors)
  Compacts, reliable, fully static and high performance solutions are provided, some of them became de-facto standard like OCTANS, or even created new market like PHINS on surface / subsea vehicles.
- iXBlue developed the longest range USBL (Ultra Short Base Line) positioning system with POSIDONIA, still unrivalled.

GAPS, the first system combining acoustics, Inertial and GPS in a single pre-calibrated solution was a revolution in this activity thanks to its featuers and performance (pre-calibrated, compact and small, able to operate in all and most difficult conditions)
- RAMSES, latest building block in iXBlue positioning system is the first Synthetic Acoustic Baseline positioning system, to replace ageing LBL (Long Base Line) solutions with no compromise on performance and ease of operation.

1.2.3. iXBlue equipment interfaces to other third-party systems

"Keep the complexity inside the instrument" is one of the concerns of iXBlue R&D teams.
All products are including standard input/output communication ports, mostly serial and Ethernet, fully configurable by the operator so that connection of external sensors or peripheral is made very simple with no need for further hardware or software development.
The internal electronics and firmware are powerful enough to calculate in real time the data they are designed to deliver with no need of external computer for most of them.
The use of external sensors when available is simply achieved by connecting them to the iXBlue sensor or system with predefined or industry-standard communication protocols.
Most of iXBlue sensors and systems are positioning building blocks that can be used alone or connect together or to external third-party sensors to form a positioning solution.

- Standard communication ports are available, serial (RS232, RS422) or Ethernet, or both.
- Industry standard communication protocols are available within the instrument to easily connect to pheripheral and/or use external sensors information
- Some facts:
  - ✓ iXBlue INS uses any modern GPS, DVL, and can use third party acoustic positioning systems
  - ✓ GAPS-NG pre-calibrated USBL positioning system or RAMSES (MF range) can operate from a selection of third party transponders
  - ✓ OCTANS emulates most industry standard HARS communication protocol

1.2.4. Simple, unified interface

Progressively all iXBlue products fitted with Ethernet communication are using a common look&feel MMI (Man Machine Interface). GAPS-NG recently joined the family early 2013.
With a simple standard WEB-browser software running on any terminal (Windows, IOS, portable device) and the unique IP address allocated to each iXBlue product programming of the instrument and data recovery can be simply achieved.
The same user friendly and intuitive MMI software is deployed across the full product range, learning phase is significantly reduced for customers operating various iXBlue products.
The modular positioning building block concept allows the use of single or multiple sensors / subsystems depending on the performance and features to be obtained.
A powerful post-processing software is available to refine real-time positioning results.

- No iXBlue software to install on computer to run MMI
- Standard interface and communication protocols for simple and time effective mobilization
- Standard and unified iXBlue WEB-based MMI across the whole range:

1.2.5. Performance

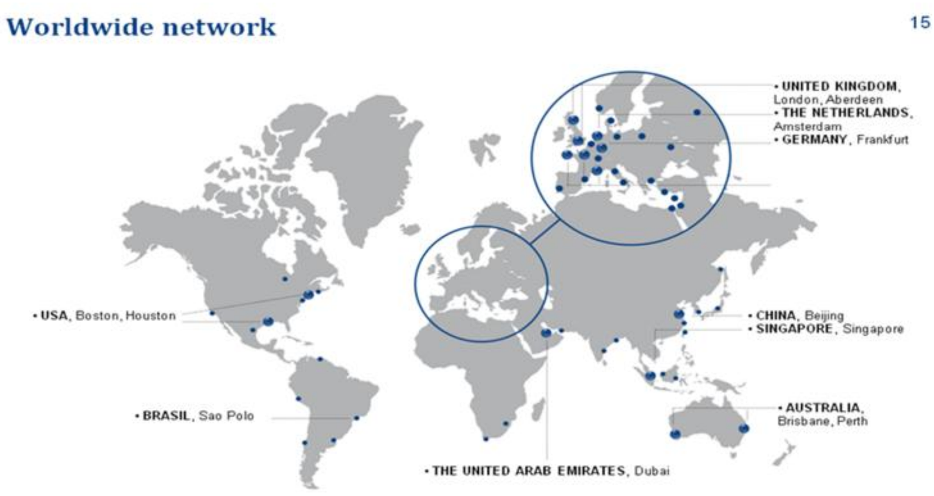
With core technology owned by the company and a large accumulated experience in navigation and positioning system design and manufacturing iXBlue offers flexibility, modularity, and performance to his customers.
iXBlue pioneered the development of FOG based system with sophisticated and high performance data fusion algorithm (OCTANS, PHINS, MARINS etc) and is a leader in combined inertial and acoustic technologies solutions which are the only solutions able to provide robustness, redundancy and ultimate performance.
The positioning building block principle allows the user to adapt his positioning solution to his projects requirements.

A long history of achievement and records:

- POSIDONIA II USBL acoustic positioning system tracking up to 10km
- GAPS pre-calibrated system working in mostadversed conditions
- PHINS, a market standard, operating up to 85deg lat North
- ComMet metrology solution providing 5cm accuracy and fastest operation time
- More than 3,000 OCTANS on the market become a generic name for Gyroscope

1.3. Global Locations

iXBlue operate globally through a specialist network of offices and agents. Through this network, iXBlue enjoy the capability to manage all client, commercial, technical and operational support requirements efficiently and effectively.
All of the iXBlue group products and services are supported through our iXBlue regional offices to ensure that all iXBlue customers receive the highest level of service within a minimum response time.



2. Scope of the document

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3. Underwater positioning general considerations

3.1. Forewords: existing positioning technologies, their benefits and limits

Positioning on the surface at sea has found its reference technology in GPS, a system that offers a straightforward and inexpensive solution which has readily found a place in the daily routines of hydrographers, marine surveyors and in maritime work in general.
Unfortunately, solutions to the problem of subsea positioning are complicated by the fact that GPS radio signals do not penetrate water.

In the subsea environment, the available solutions are to use a positioning system based on the triangulation of acoustic signals, (LBL, USBL, range measurement) or the use of Inertial Navigation Systems. All solutions have interest… and limitations:

a/ LBL positioning system (Long Base Line)

Mature (old?) technology which can lead to very high performance (operating frequency depending), LBL system is however long to mobilise and deploy since its principle is based on the acoustic communication between a surface/embarked transceiver and an array of transponders (3 min) that must be deployed and carefully calibrated.
Moreover acoustic propagation depends on a number of external parameters (noise, maximum range, ray bending) that can affect or in some extent prevent normal operations

b/ Conventional USBL positioning system (Ultra Short Base Line)

More recent on the market thanks to availability of powerful electronics and modern signal modulation and processing technics, USBL uses pure acoustic as well and the system correctly addresses some of the LBL limitations, …but brings some new drawbacks.
Installation of USBL system is still a complex and time consuming task but it has to be done once only. Then one transponder on the target is required which makes the system quicker to deploy and with no restriction on the tracking area.
The expected performance is lower than LBL systems, and in all circumstances USBL faces the same challenges as LBL concerning acoustic propagation.

c/ Inertial Navigation Systems (INS)

One of the core business at iXBlue is about Inertial Systems based on proprietary FOG (Fiber Optic Gyroscope). Using its internal sensors that monitor in real time motion and acceleration in three axis, an INS is able to update its initial position consequently and provide consistent position together with all attitude information (heading, pitch, roll, heave, speed, etc…)
One can think we have here the ideal solution, but unfortunately and despite high performance / sophisticated software algorithm all INS drift along time and the calculated position will ultimately diverge from the real one after a period of time. (Depending on the grade of the INS, from 1.3Nm/hour for ROVINS to 1Nm/24h for MARINS, a military grade INS)

The table below summarises the above facts:

	Range	Accuracy	Coverage	Update rate	Calibration	Drift	comment
GPS	unlimited but surface	DGPS: 5m RTK:<1m	unlimited	high	no	no	Surface positioning only
Inertial	unlimited	Very high (short term)	unlimited	high	initial alignment	yes	ext. aiding required
LBL	6 to 10 km	<1m	array of X'ponders	low	yes	no	Acoustics, SNR, range, topograp
USBL	8km posidonia	0.3% x range	unlimited	low	Yes (once)	no	Acoustics, SNR, range

3.2. Data Fusion and technologies combination

iXBlue is having a real expertise in all of these above solutions and manufactures "conventional" positioning solutions with the same limitations. By combining all of them and with dedicated data fusion techniques the goal here is to overcome these known limits and offer new solutions which are robust to temporary acoustic communication hazards, extremely accurate, without drift, and with the highest data rate.
With iXBlue manufacturing and mastering all of its internal sensors (FOG – Fiber Optic Gyroscopes, Acoustics) the company capitalises on a detailed lowest-level understanding of their characteristics and therefore is able to take all of the benefit of each technology to reach the higher performance and innovative features.

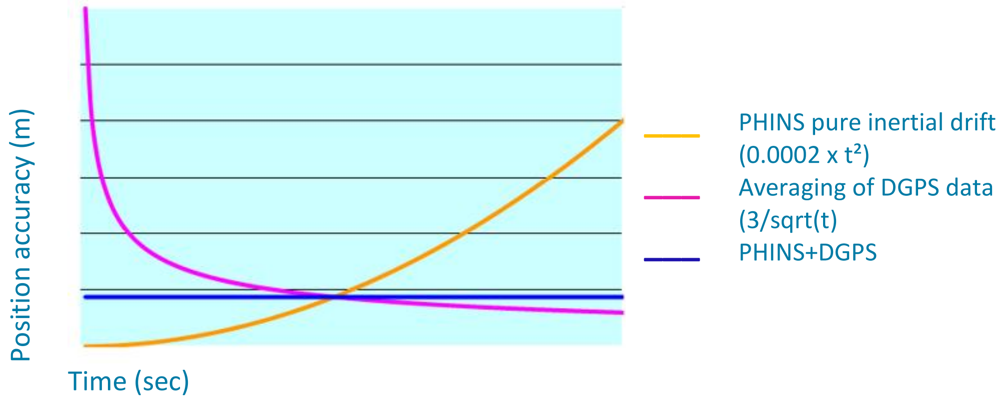
3.2.1. General principles

Combination of sensors improves performance by allowing new computations to be made. For instance, a pure inertial navigation system is based on the combination of FOG and accelerometers. The FOG alone or the accelerometers alone are not sufficient to compute either position or orientation; with the FOG alone only the instantaneous rotation and hence the north-south earth axe direction can be computed, with the accelerometers alone only the instantaneous accelerations and hence the attitude can be computed. With the combination of FOG and accelerometers, not only can the attitude and heading be computed, but also the whole position of the system. Hence, combination offers new possibilities.

Fusion of sensors providing similar data improves performance by allowing to cross-correlate data. In general, fusion of sensors providing similar data gives much better performance than simple combination. Two examples are given to illustrate this principle.

3.2.2. Examples 1: INS + GPS

The GPS provides an absolute position. The GPS is an external aiding sensor for the INS. It prevents the INS drifting by providing a geo-referenced position and at the same time, the INS filters positions when the GPS is not stable and increases the data rate for output (position, speed, heave, pitch, roll and heading).



3.2.3. Examples 2: INS + DVL, 4 hours survey

The trajectory below demonstrates the obtained performances using INS + DVL during a 4 hour survey. INS position is compared to an independent reference (RTK GPS). A single USBL input is simulated after the dive phase from a GPS data.

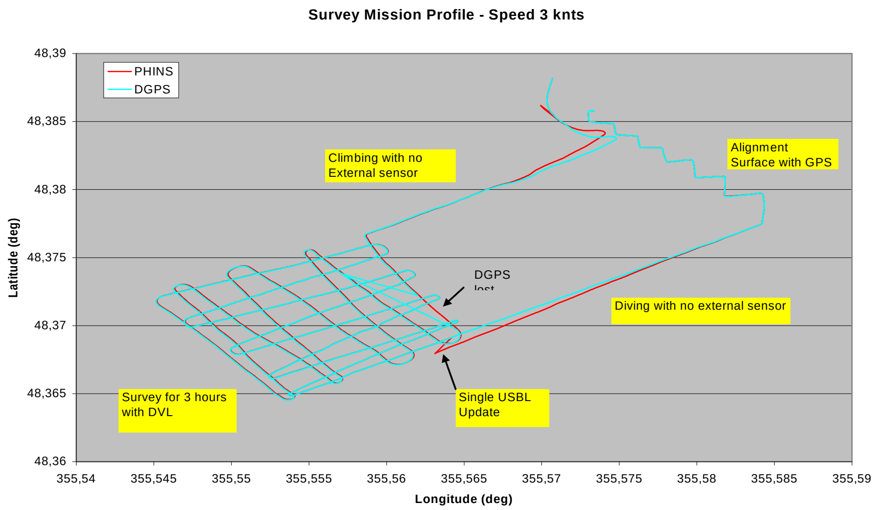
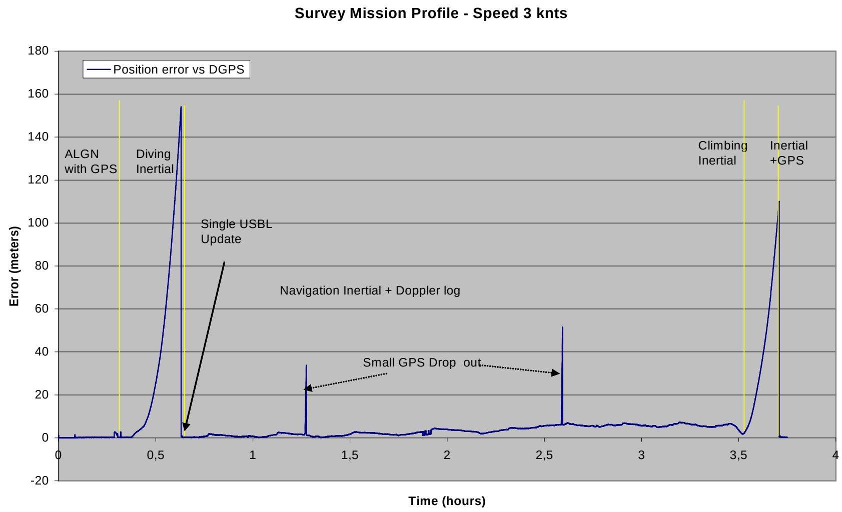
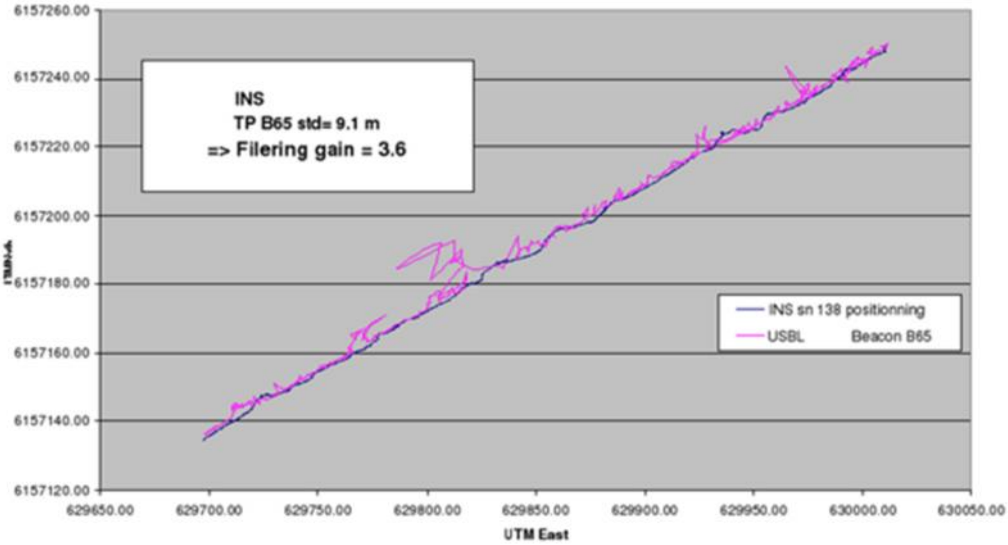


Figure below shows pure inertial drift versus INS + DVL drift. The constant measurement of speed by the DVL minimises the drift experienced by the INS. When the GPS signal returns, the system immediately takes into account the GPS information to provide a positioning solution with the highest degree of certainty



3.2.4. Examples 3: INS + USBL

Comparison of the positioning performance of a subsea vehicle using INS + USBL and USBL only. As shown in the following figure, the INS reduces the noise on USBL positions. The accuracy improvement is around a factor 3.5.



3.3. The "building blocks" concept

The iXBlue underwater positioning solution is a practical application of the previously described technics (individual positioning sensors, data fusion, and combination of sensors) using some or all of the iXBlue sensors – "building blocks" with additional third party components as required (DVL, pressure sensors, etc), the configuration of the system being adapted to the job itself

A tailored configuration must be considered, combining USBL, LBL and INS technologies, to reach or pass standard performances with robustness to acoustics, improved accuracy, and high positioning refresh rate

Positioning solutions offered by iXBlue are more than a standard LBL, USBL or INS system: they form a modular system based on a set of many building blocks (proprietary unique technologies) that can be combined in various ways, depending on the requirements of a specific application, thanks to data fusion.

This approach is the key for up-to-date subsea positioning systems. The advantages of such an approach are of 3 types:

- Only the advantages of each individual technologies is kept,
- It does provide redundancy, thus robustness
- It enables a modular approach, where the system architecture can be set to meet the specific needs of one given application.

a/ Inertial Systems

iXBlue' s range of inertial products is based upon IXSEA branded FOG (Fibre Optic Gyroscope) technology, which has been developed and significantly enhanced by iXBlue's own teams over the past 30 years. Unlike its competitors, iXBlue designs, develops and manufactures all its products from its own Fibres, IOCs (Integrated Optical Circuits), Electronics and Software. This allows iXBlue to control and maintain exacting quality standards in the production of each and every inertial product.
iXBlue's product catalogue includes gyrocompasses, Attitude and Heading Reference Systems (AHRS), Inertial Measurement Units (IMU), and Inertial Navigation Systems (INS) for use in a wide variety of applications, and providing our customers with the lowest life cycle cost of the market.

b/ Acoustic Systems

The Acoustic Products Division (APD) delivers high quality turn-key products for underwater positioning and oceanographic activities.
By combining inertial and underwater acoustic technologies fully mastered by IXSEA, APD has developed a unique range of innovative and technically advanced positioning systems, which deliver outstanding performance in the most demanding conditions.
APD also offers a wide range of reliable and affordable oceanographic acoustic releases, pingers and transponders.

3.4. Typical system configuration

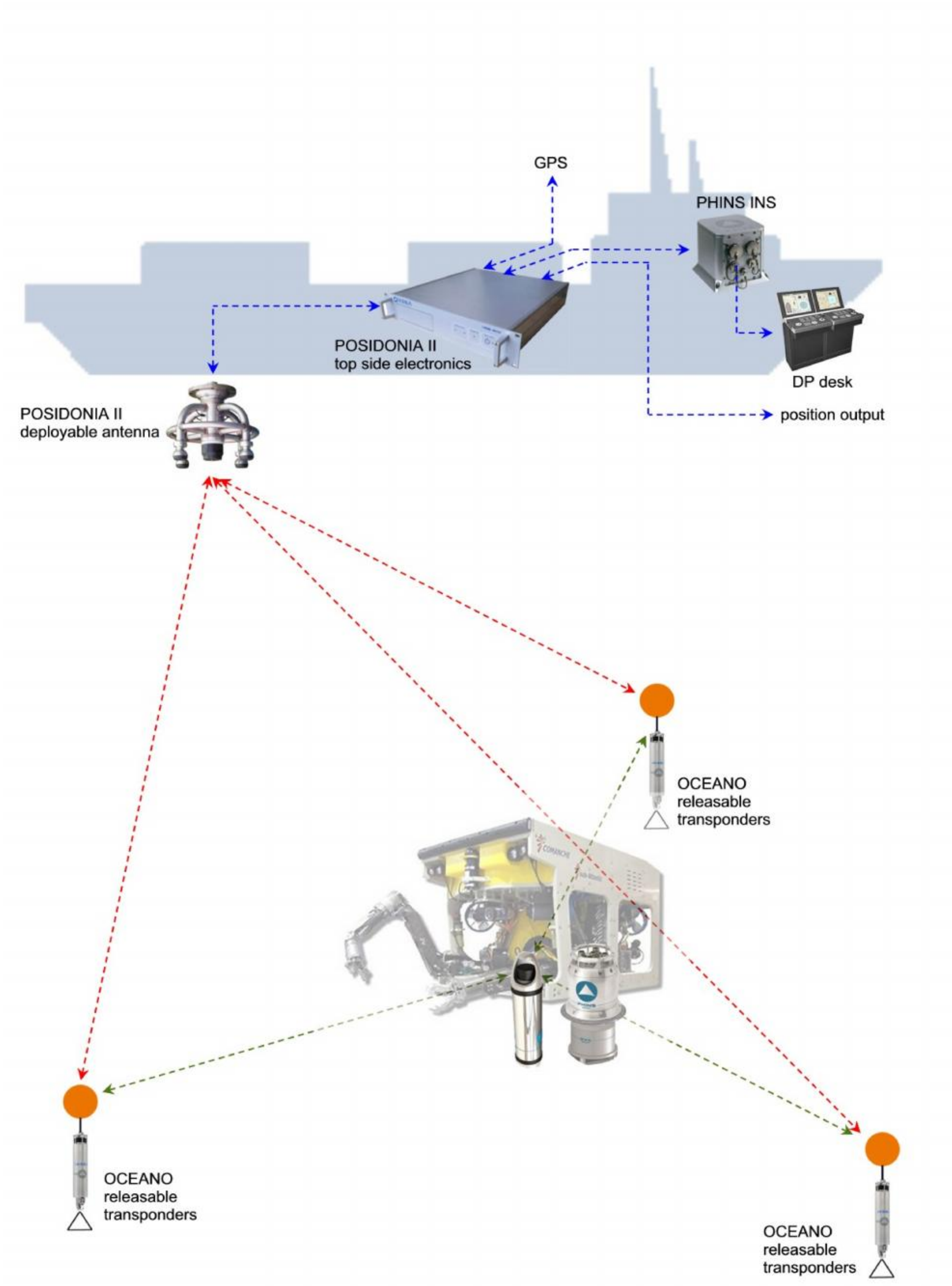
Although POSIDONIA Low Frequency/long range and PHINS are displayed below, alternative solutions using GAPS (medium frequency pre-calibrated USBL) and ROVINS can be considered as an option.
Additional and optional sensors are also offered in order to further improve the performance of the global system.

The proposed solutions aims at providing:

- Up to LBL-grade positioning performance with only a few transponder deployed on sea bed
- Self calibration of the seabed transponders (SLAM algorithm) while deploying the array and USBL (POSIDONIAII, or GAPS) / INS (PHINS or ROVINS)
- Sparse array capability, i.e. capacity to navigate with only a few reference beacons
- Robust “station keeping” mode with L/USBL capability to interface to DP desk
- Long range and robust positioning with Low Frequency POSIDONIA II system

The core of such navigation system is the INS (PHINS or ROVINS) installed on the tracked vehicle. In order to contain the natural drift of the INS, external sensors are connected to it, each one having a specific advantage:

- Pressure sensor
  INS is not as good in estimating its depth compared to horizontal position (X, Y). USBL is providing an estimate of the position with a 0.2% x range accuracy, which might not be sufficient. High quality pressure sensor (Digiquartz or equivalent) will provide sub metric rough accuracy (0.01% x water depth) further improved after being processed by the INS Kalman filter
- DVL
  A Doppler Velocity log in bottom tracking mode (from 300 to 1200kHz) provides an accurate estimate of speed to the INS Kalman filter which is used to drastically reduce the INS drift.
  Compared to 0.6nM drift in free inertial mode (PHINS), the drift will be limited to 0.1% x travelled distance with a well calibrated PHINS/DVL assembly.
  With a PHINS/DVL in bottom tracking mode a vehicule can navigate with less than 3m deviation / hour when travelling at 2knots in straight line.
- RAMSES
  With slant distance to seabed transponder measured with a submetric – non-drifting – accuracy RAMSES is providing to PHINS a valuable reference to contain the system drift to almost zero. Ideally 2 beacons are to be preferred so that PHINS/RAMSES will have a high quality reference along the two horizontal axis.
  The correction will be applied every time beacons are in acoustic range to the vehicle, any residual drift accumulated can be compensated for.
- USBL (POSIDONIA II or GAPS)
  The USBL provides an additional layer of redundancy by directly positioning the vehicle itself, and contains the INS drift during the dive while DVL is not locked on sea bed yet, and seabed transponders not fully calibrated (SLAM algorithm in progress)


GPS
PHINS INS
POSIDONIA II
top side electronics
DP desk
position output
POSIDONIA II
deployable antenna
OCEANO
releasable
transponders
OCEANO
releasable
transponders
OCEANO
releasable
transponders

3.5. USBL: Low frequency vs. medium frequency

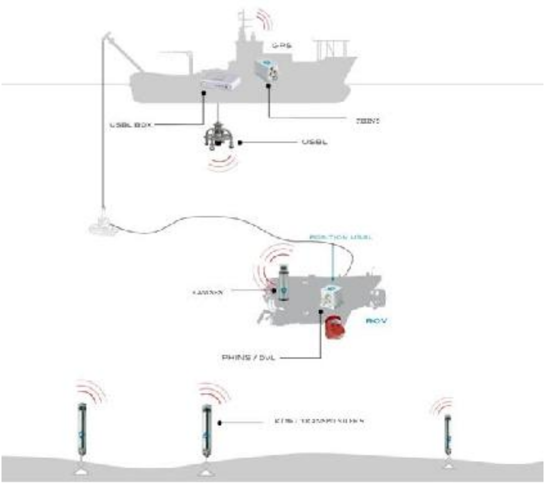
The operating frequency for an acoustic positioning system (USBL) is a delicate compromise between maximum range to reach, the size of the receiving antenna and transducers, the accuracy of the position. Each parameter is having a consequence on the others as explained below:

- Lower the frequency
  The lower the frequency, the lower the attenuation, and the longer the range (with a constant emission level). This is one of the main reason why POSIDONIA is “better” than GAPS in terms of range, and (almost) unique on the market.
  With the same radiated power at both end and identical environmental conditions, the range of POSIDONIA II (operating between 15~20 kHz approx.) is twice as much than the range of GAPS (operating between 20~30 kHz approx.)
  However lowering the frequency will decrease the accuracy of the position, unless the path between receiving hydrophones is larger (i.e. antenna larger) and/or signal bandwidth is increased.

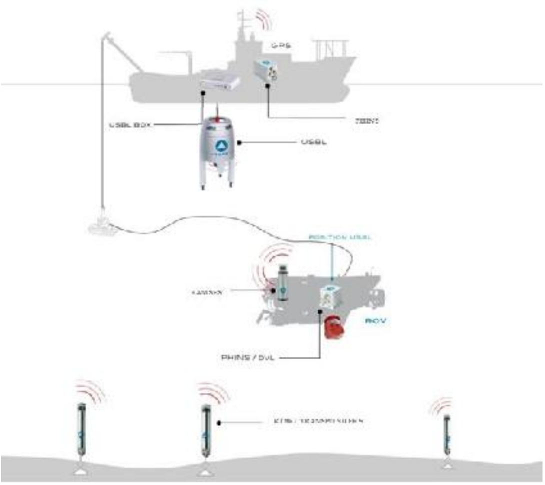
- Increase transmission power
  This looks to be an attractive way to reach longer distances without having to lower the frequency. However if it is fairly easy on surface where power supply is not limited, the power consumption on the remote vehicle transponder will increase, and the autonomy decrease.

- Use directional transducers
  iXBlue transponders normally use omnidirectional transducers, which allows the system to be tracked within a wider navigation sector. The use of directional transducers with a radiated beam pattern of +/-30 or 60deg will focus the energy within a reduced area and improve the maximum tracking range by 2,000m approx. Although this is an option offered by iXBlue for its systems, this solution makes transponders larger, heavier, more expensive, and tracking area will be reduced significantly.

iXBlue offers two (2) distinct product families to serve the various requirements in the academic, offshore O&G, and defense applications. Both systems are very similar in terms of functionalities and performances, POSIDONIA operating in LF (low frequency) band for long range application, and GAPS operating in medium frequency range for most application in offshore O&G and shallow water projects.
In order to offer the same functionalities for both systems, the Synthetic Acoustic Positioning system RAMSES operated with INS is also coming in two different frequency bands.



Typical configuration using Low Frequency band acoustic tracking systems:
POSIDONIA II and RAMSES 6000



Typical configuration using Medium Frequency band acoustic tracking systems:
GAPS-NG and RAMSES

4. A review of iXBlue main positioning “building blocks”

The following pages comprise a brief introduction of the main iXBlue positioning building blocks and their characteristics when used as such. A separate technical description is available for each one on request, and the combination of several or all of them into a global positioning solution is described in following chapters.

4.1. PHINS 6000 INS Inertial Navigation System

PHINS 6000 is the subsea version of the PHINS family.
PHINS is an Inertial Navigation System (INS) which provides true-heading, attitude, speed and position. It can be aided by external sensors, such as DGPS, DVL or USBL. The PHINS 6000 is rated for 6000 m immersion. The PHINS is the smallest INS in the world.

4.1.1. Positioning method

The core of PHINS is the inertial measurement unit (IMU) composed of three Fiber Optic Gyroscopes (FOG) and three accelerometers mounted on orthogonal axis. The FOGs provide the instantaneous rotation of the system and the accelerometers provide the instantaneous acceleration of the system.

From those internal sensors, an algorithm computes both the attitude and the position. Those data enters a Kalman filter especially developed for marine applications. This Kalman filter also receives the data of external sensors like GPS, DVL and USBL. The Kalman performs data fusion, and also estimates the sensor errors. The PHINS does then provide an optimized position and attitude of the PHINS

4.1.2. PHINS DVL Ready option

PHINS 6000 can be provided with (or upgraded to) a DVL: this set is PHINS DVL ready. The advantage of using a DVL is that it provides system robustness and redundancy into the system, and that it reduces the drastically the drift of the PHINS when there is no regular position input. Notably, this PHINS+DVL coupling is the state-of-the-art solution for AUV navigation.
Another specific advantage of the PHINS DVL ready is that the set is calibration free, so it avoids the difficult and costly alignment procedure that users have to perform each time they install an INS and a DVL on a platform.

4.1.3. PHINS general specifications

a/ Gyrocompass and motion sensor

Mode	Pure inertial	GPS aiding	USBL/LBL/DVL
Heading x secant latitude (1)(2)	0.05 deg	0.01 deg	0.02 deg
Roll/Pitch (2) dynamic accuracy	0.01 deg	0.01 deg	0.01 deg
Range		Heading: 0 to 360° Roll: -180° to +180° Pitch: -90° to +90°	
Heave, Surge, Sway	5 cm or 5%, whichever is higher	5 cm or 5%, whichever is higher	5 cm or 5%, whichever is higher

(1) *Secant latitude = 1 / cosine latitude*
(2) *RMS values. 68% of the data is within this value of confidence*

b/ Inertial Navigation

Mode	Pure inertial	With GPS	With USBL/LBL/DVL
Position (3)	0.8 m after 1 mn 3.2 m after 2 mn 0.6nm in 1h	3 times better than aiding system (4)	3 times better than aiding system (4) 0.1% of travelled distance

(3) *CEP: Circular Error Probability. 50% of the data is within this value of confidence*
(4) *Absolute position accuracy is dependent on aiding position sensor accuracy (i.e : GPS, USBL, LBL): PHINS 6000 will typically improve accuracy by a factor 3 and reject position spikes to provide a smooth and high data rate navigation.*

c/ Mechanical

	PHINS 6000	PHINS 6000 DVL Ready
Dimensions (l x w x h)	255 mm x 288 mm	298 mm x 543 mm (WHN300/600) 298 mm x 542 mm (WHN1200)
Weight air / water	23 kg / 13 kg	48.5 kg / 28.5 kg (WHN300/600K6) 41.5 kg / 23.7 kg (WHN300/600K3) 43.7 kg / 27 kg (WHN1200K6) 38.1 kg / 21 kg (WHN1200K3)
Construction	Titanium	Titanium
Mounting **Erreur ! Source du renvoi introuvable.**	6 Φ 6.5 holes	6 Φ 11 holes

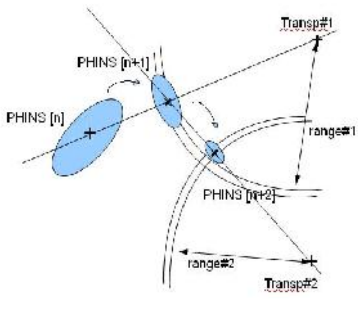
(5) *Two alignment pin holes are provided under the base plate for accurate assembly/removal of PHINS 6000*

4.2. RAMSES – Synthetic Acoustic BaseLine Positoning System

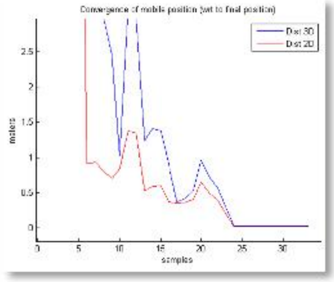
RAMSES is a fully portable synthetic baseline positioning system, including a rangemeter combined with embedded electronics and processing algorithms. In addition to its state-of-the-art distance measurements (full Wideband acoustics), RAMSES is capable of an autonomous array calibration and synthetic positioning, when coupled with an external positioning reference such as iXBlue INS, GPS, or even LBL/USBL systems.
Sparse array capabilities are then unlocked, as well as INS position referencing, thanks to sub-metric acoustic accuracy and built-in SLAM algorithm. In this case, inertial navigation precision is indifferent to time, initial positioning accuracy being sustained for the time of the job.
RAMSES is available in two different frequency bands, LF (Low Frequency RAMSES 6000) to operate with POSIDONIA and common transponders, or MF (Medium Frequency, RAMSES) when operated with GAPS and its transponders or compatible transponders.

4.2.1. Sparse array navigation

Provided it is coupled with an iXBlue INS (PHINS or ROVINS), RAMSES can autonomously provide full position information within a sparse array setup, starting with only one transponder. The accuracy of the navigation is maintained during the whole survey, as long as RAMSES is within the range of the beacon. Beyond beacon range navigation is still possible, full navigation accuracy being restored when the ROV is back in range. In this configuration, increasing the number of beacons enhances the positioning accuracy, but no more than three beacons are needed to maximise the system accuracy.



4.2.2. On-the-fly calibration



The positioning accuracy of the transponders can be furthermore improved during the navigation, if needed, starting from a completely unknown position. RAMSES is indeed capable of estimating the relative position of the different transponders, and will adjust imperfect (or unknown) initial parameters to the best possible result, according to the range measurements. This ability starts with one beacon, but can be applied simultaneously over a set of beacon within range. Setting up this function is automatic, and does not need separated calibration / navigation operations: one just need to provide a standard deviation relative to the beacon calibration accuracy, describing confidence the system can have into this initial placement, the idea being that the system is capable of using whatever information is available.

4.2.3. Using already calibrated reference beacons

RAMSES can be used within an array of pre-calibrated beacons, in which case the positioning calculus will be done fully autonomously within the device. The number of beacons needed in this configuration starts with two, in case a DVL is present, but a number of three beacons can be preferred for a better accuracy and resilience to acoustic dropouts.
In this case, the beacon calibration can be obtained using a surface USBL (POSIDONIA for instance), or via a calibration procedure involving a RAMSES and a GPS from a surface vessel. The coupling with an INS is still advised, providing a high-rate full positioning (including attitudes) of the device, without any timed restrictions.

4.2.4. RAMSES construction:

In a single reduced size waterproof container RAMSES integrates all the electronics required to interrogate seabed transponder(s), interface to external sensors (DVL, sound velocity probe, pressure sensor) to proceed to internal data fusion (Kalman filter) for better performances, and directly calculates a position available for the operator.
RAMSES does not require any additional hardware to operate (no deckset surface computer) and can be easily installed on the tracked vehicle itself (ROV, AUV) or from the surface ship as required.

RAMSES is built from iXBlue latest electronics PCB’s used with our most sophisticated products such as GAPS (calibration free USBL), SHADOWS (SAS synthetic aperture sonar) and all expertise in software development and data fusion algorithms.

4.2.5. RAMSES general specifications:

a/ Positioning

Mode	RAMSES 6000	RAMSES
frequency narrow band	8 ~16 kHz	19.5 ~30.5 kHz
wide band	14.5 ~17.5 kHz	21.7 ~30.5 kHz
Number of channels	Up to 10 simultaneous	Up to 10 simultaneous
Range resolution (*)	15 cm	<5 cm
Position accuracy (*)	From 1m	From 0.2m
Maximum range	Up to 8,000m	Up to 4,000m

(*) performance depends on acoustic propagation conditions, environment and sound velocity compensation.

b/ Mechanical

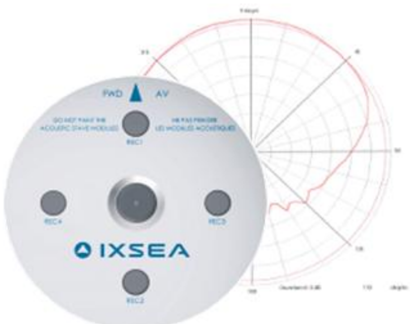
	RAMSES 6000	RAMSES
Construction	Titanium	Duplex stainless steel
Overall dimension integral	560 x 126 OD mm	560 x 126 OD mm
Remote transducer head	505 x 126 OD mm + X'ducer	505 x 126 OD mm + X'ducer
Bottom plate connector	Seacon 26 pins	Subconn 21 pins
Depth rating	6,000m	6,000m
Weight in air/water	18/12kg	11/5.5kg

4.3. POSIDONIA II extreme long range USBL system

POSIDONIA is the long range / high accuracy USBL system designed to track subsea vehicles down to 6,000m water depth and range in excess of 10,000m (depending on noise/environment conditions).
It is based on USBL technology (Ultra Short BaseLine) and advanced acoustic modulation and digital signal processing technology.
Since its first release on the market POSIDONIA has been installed on numerous vessels throughout the world for long range tracking operations (deep tow, deep sea vehicles) and is the only market proven solution available today.
Recently modernised with a new topside electronic incorporating all iXBlue development in terms of underwater acoustic technology (better sensitivity, immediate acquisition of the tracked vehicle, unified WEB-like man machine interface, etc…) POSIDONIA II features even better performances and can operate in deeper/longer ranges or … in more difficult / adverse propagation and noise conditions.

4.3.1. POSIDONIA Acoustic Array (Antenna)

Two different antenna versions are available.
Each acoustic array is composed of a central emission transducer and four reception hydrophones. The task devoted to the acoustic unit is to interrogate subsea transponder(s) and receive the acoustic signals transmitted back from transponder(s). After filtering and amplification, the signals are transferred to the Main Processing Unit for digital signal processing.



a/ The «flush» (mounted) acoustic array.

On a strict electronic and acoustic stand point both versions are identical and offer the same output power and receiving sensitivity.
In order for the FLUSH version to operate in good condition

despite its close proximity with the ship’s hull a baffling and mechanical decoupling is provided, which in turn makes the antenna a little bit less directional.
The flush antenna was initially designed for iXBlue customers operating in polar conditions in order for the ships’s hull to remain flush, i.e. with no protruding parts that could be damaged by ice otherwise.
With its flat face and mode of installation turbulences are also reduced to almost none, which make it operable at higher speed compared to the deployable acoustic array.
A flush antenna is installed and calibrated once for all, does not require any additional deployment machine or mechanical handling system, and is operable at any time without having to recalibrate the system as long as it is not dismantled or damaged.
The antenna can be installed from the outside of the ship, which will require dry dock at any maintenante operation.
Alternatively some of our customers are installing the antenna from the inside, which allows full maintenance or replacement without dry-docking after a closing gate (typically hemispherical clutch) has been installed by divers to grant water tightness.

Some examples:

Flush antenna installed on R/V Sarmiento do Gamboa, CSIC Spain. The antenna is on a sliding gondola deployed on request

Flush antenna installed on R/V Polarstern / AWI Germany a window can protect the antenna in very icy conditions

Flush antenna installed on R/V Meteor, Geomar Germany

Flush antenna installed on R/V Beautemps Beaupré (French Navy)

b/ The «deployable» acoustic array.

Designed to be deployed through an existing moon pool + deployment machine or on a side pole, this version is offered for vessel of opportunity and can easily be transferred from one vessel to the other.
USBL principle (relying on range + angle measurements) requires a perfect monitoring of the antenna during the tracking operation. An

initial calibration is performed during system installation which will remain valid until the "deployable" antenna is moved to a different place or ship.
In order to keep a calibration valid during system lifetime, the use of a deployment machine is recommended (iXBlue deployment machine HISYS here after).
In case of a pole mount installation the use of an iXBlue OCTANS heading and motion sensor right above this antenna is the right solution.
Simple pole mount will require a full calibration before every operation, i.e. 4 to 8 hours vessel time depending on water depth and operators skills.
iXBlue does not normally supply the pole mount hardware (if this option is selected) which is particular to every single ship, nor hull work on the ship should it be necessary.

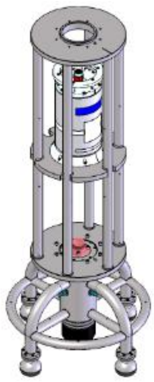
b1/ Pole mount examples.

The pictures hereafter are examples of installation designed and manufactured by iXBlue customers. They are provided here for information purpose only.

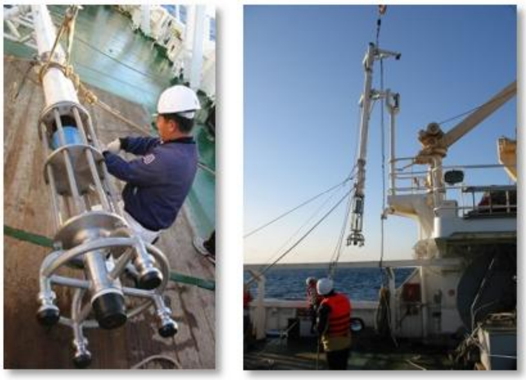
Deployable antenna installed on hydrographic vessel Sumner (US Navy)

Deployage antenna on pole onbaord Svitzer Mercator, UK

b2/ "pre-calibrated" installation with HARS in line on pole.



In order to keep an accurate monitoring of the antenna attitude when it is operated whatever the mode of deployment it is possible to have a HARS (Heading and Attitude Reference Sensor) rigidly installed close to the antenna. The subsystem so formed will be calibrated at sea once for all and calibration remain valid as long as both antenna and HARS are kept together.
The use of iXBlue OCTANS providing the Heading, Pitch and Roll information is recommended for this mode of installation, iXBlue can provide a mechanical frame for both as well as initial sea calibration on request.
See picture on right .



Deployable antenna and OCTANS on R/V Jeoje / KOREA

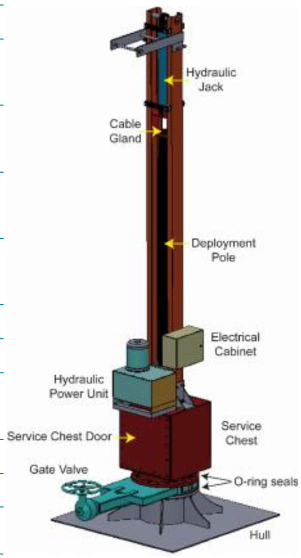
Deployable antenna and OCTANS

b3/ HISYS Deployment machine for POSIDONIA II deployable antenna

The HISYS system (Hoisting System or Deployment Machine) is a through-hull USBL acoustic array deployment machine which consists of an hydro-electrically operated pole, and a sealed bearing section providing required position accuracy and repeatability.
A sea chest service section, with inspection door is provided together with a gate valve (optional delivery), allowing easy maintenance of the acoustic antenna without having to dry-dock the ship.
The whole system is to be installed on the flange of a through hull penetration pipe.

Each vessel is unique and the ideal deployment length as well as position under the hull has to be carefully considered. A delicate compromise between long deployed lengths, subject to vibrations, and short deployed length (closer to acoustic noise sources) must be found, as a general rule a length of 1.5 meter (distance between acoustic transducers and ship hull) is considered to be acceptable. The HISYS systems can be tailored to any particular condition however, after receipt of installation specifications.
Operation speed of up to 6 knots with no performance loss in the acoustic positioning can be achieved, and 10 knots transit during short period of time.
The machine can be controlled locally at the machine. A bridge control is also available.

Mechanical	
footprint (mm)	940 x 1081 (with hydraulic command cabinet installed)
Height (mm)	6,040 (from top to sea chest lower flange)
Deployment length	2,000 (below sea chest lower flange)
Sea chest size	800 x 800 x 800 (internal, approx.)
Moon pool diameter	605
Electrical cabinet size	400 x 500
Total Weight (kg in air)	1,800 (gate valve excluded)
Electrical	
Power supply	400~440Vac – 3 phases, 50~60Hz



4.3.2. Main processing & command / control unit:

The whole electronics is integrated in a compact 19’’ rackmount topside, integrating all required hardware and software to smoothly interface to external sensors (antenna, HARS, GPS, data output, synchro, etc) and computing power for calculating the final position of the tracked subsea vehicles.

Features and characteristics:

- Longest range, improved accuracy, wider antenna aperture
- Full wideband modulation on all channels, interrogation and reception with up to 8 beacons in the field and processed during the same interrogation cycle
- Improved multipath rejection algorithms to enable operation in challenging conditions (noise, multipath, high elevation targets)
- Adaptive gain control with real time monitoring of ambient noise
- External sensor direct interface (heading/pitch/roll, GPS, etc) through Ethernet local network or serial fully configurable communication ports
- Kalman filter on position output (can be disabled) to increase position output rate
- Immediate acquisition of the target even at long distance
- Multiple data output port (Ethernet, serial) with choice of different communication protocols for data distribution and interconnection to various peripherals I
- iXBlue new WEB-based interface for easy configuration and control of the system

4.3.3. POSIDONIA II general specifications

a/ Positioning

Positioning accuracy (1)	0.2% x slant range
Measurement repeatability	+/-3m
Operating range (1)	10,000m
Operating frequency	16kHz (central frequency) +/-4kHz bandwidth
Position refresh rate	2 second min (acoustic, depends on range) 10 Hz with predictive filter
Communication protocol	Serial communication link NMEA proprietary GAPS protocol Multiple other NMEA or binary data telegrams Native compatibility with iXBlue products

(1) *Range and accuracy of the system depend on ambient acoustic propagation conditions, water depth and signal to noise ratio (SNR) and GPS grade.*
The accuracy and range are nominal with the following conditions:
- sea state 5 maximum, ship noise < 60dB at 16kHz
- vessel speed 3 knots in operation
- target below the antenna +/-30deg
- Heading / Pitch / Roll : 0.15 deg

- Sound Velocity Profile ideally compensated
- System calibrated (antenna v.s. HARS aligned)

b/ POSIDONIA acoustic array

Reception		
sensitivity (OCV)	-195dB Vrms/µPa +/-3dB	-195dB Vrms/µPa +/-3dB
frequency	16kHz +/- 3kHz bandwidth	16kHz +/- 3kHz bandwidth
Beam aperture / channel ($2\Theta_{-3dB}$)	-3dB: 65deg +/-5deg -10dB: 140deg	-3dB: 120deg +/-5deg -10dB: 140deg
Acoustic accuracy (1 sig)	60 deg cone: +/-0.3deg	60 deg cone: +/-0.3deg
Transmission		
Acoustic power	188dB ref 1µPa @ 1m	185dB ref 1µPa @ 1m
frequency	8kHz to 16kHz (-3dB)	8kHz to 16kHz (-3dB)
Beam aperture	200deg @ 3dB	200deg @ 3dB
Mechanical		
Diameter (mm)	580	800
Height (mm)	410	245
Weight (kg in air)	34	180
Weight (kg in water)	25	150
Electrical		
Mating socket	Burton	Jupiter (right angle)
Main cable		
length	50m	50m
diameter (mm)	26 +/-0.5	26 +/-0.5
Plug diameter	63mm	63mm
Plug length	305mm	305mm
Min bending radius	156mm	156mm

4.4. GAPS, combined INS+USBL pre-calibrated USBL system

Taking advantage of its unique expertise in acoustic positioning and inertial sensors, iXBlue developed GAPS, the only acoustic + inertial integrated positioning system for marine subsea applications.

It is an **all-in-one** system which can provide at the same time the position of a surface vessel and of several subsea vehicles or divers. It also provides a very accurate heading and attitude for the surface vessel with the highest accuracy (comparable to existing systems on the market) and unrivalled performances in shallow or extreme shallow water depth.

GAPS is a portable system (light weight and reduced size), does not require any complicated installation (all-in-one calibration free system), features very high performance thanks to data fusion of Acoustic, inertial and GPS technologies and finally has no limit in terms of operation area (shallow and deep water, horizontal and vertical channel, short or long range).

4.4.1. GAPS compared to standard USBL

Thanks to the fusion of INS and USBL subsystems GAPS is providing ultimate performances together with innovative features:

- Calibration free:
  the alignment between USBL and internal heading and motion sensors is achieved once for all in factory and tested at sea. GAPS is fully pre-calibrated upon delivery and can be deployed and operated in a short period of time with no sophisticated / expensive deployment machine.
- Unique 3-D acoustic array:
  The receiving hydrophones are forming a 3D receiving array which enables GAPS to operate within the full hemisphere below the antenna itself. Together with powerful acoustic algorithm, the 3-D antenna

makes GAPS able to work from extreme shallow water / high elevation tracking to deep sea / vertical tracking.

- All-in-one system:
  all components required for positioning are included in the system. This turn-key configuration allows quick mobilization and operation with no loss of time in interfacing ancillary sensors used with conventional USBL. (GPS, heading, pitch/roll sensors, computer)
- High accuracy:
  motion compensation is directly taken into account in the instrument itself with high performances INS (PHINS grade, 0.01deg H/P/R).
  Sophisticated signal processing and wideband efficient modulation allows a stunning 0.2% x slant range absolute accuracy, all errors included.
- User friendly. The integral system just need initial setting (offset, transponders information) and will start working immediately after powering on.
  The new iXBlue WEB-based unified Man Machine Interface is now available with GAPS-NG

An alien in the USBL world when first released, GAPS proved its performance and features with customers worldwide / all market application since then. GAPS-NG latest product generation now in production is again pushing the limits of acoustic subsea positioning.

4.4.2. GAPS-NG new product generation

With the experience accumulated over the last 4 to 5 years and customers' feedback GAPS has been recently upgraded and fitted with new features which open the scope of application of the product, and a potential to progressively add further functionalities.

Standard GAPS-NG is now coming with the following base configuration:

- Range, accuracy: 4,000m range and 0.2% x slant range (with nominal propagation, noise and environmental conditions
- Ethernet communication link (4 virtual ports) and serial RS232/RS422 communication port. All user configurable
- Standard iXBlue unified WEB-based Man Machine Interface
- Full access to internal INS data (PHINS-like) wth all PHINS communication protocols and data rate
- Full wide-band modulation capability (interrogation + reply) to operate with ETA / RTA iXBlue transponders
- Delph RoadMap display software
- New optional features and functionalities to be progressively added to the product:
  - Compatibility with some other manufacturers' transponders. (please apply to the factory for detailed available compatibility modes)
  - Enhanced DP modes (L/USBL, station keeping)
  - Telemetry

4.4.3. GAPS-NG example of installation

The few pictures here after demonstrate the flexibility of the GAPS system in terms of operation. These installation examples all provided by our customers are possible thanks to the internal INS installed in the instrument (pre-calibrated feature) together with the compactness and extreme integration of the system. (reduces size and weight, all integrated system)

a/ Pole mount examples

b/ Deployment machine examples

c/ Cable deployment, buoy or remote platform examples

4.4.4. GAPS-NG general specifications

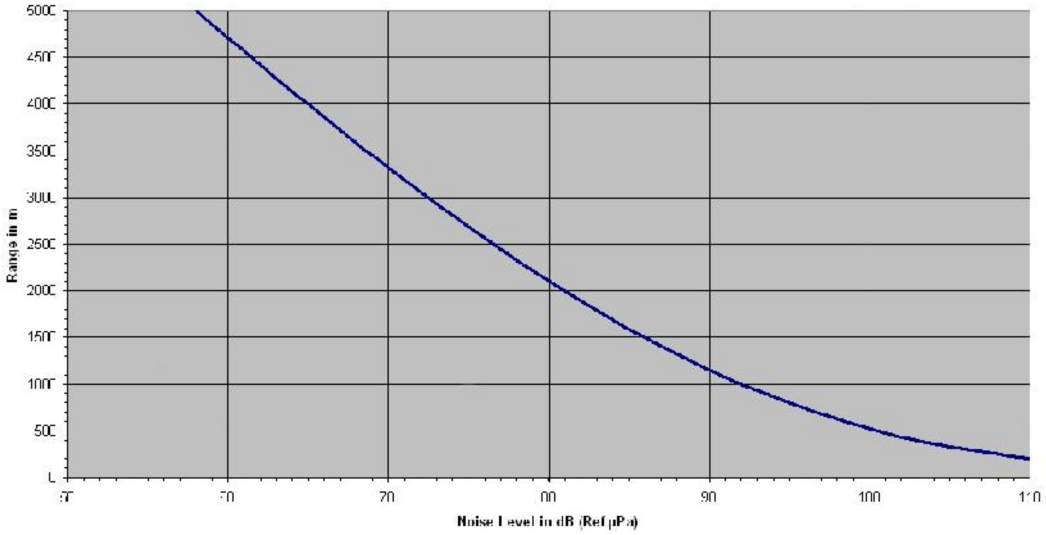
a/ Positioning

Positioning accuracy (1)(2)	0.2% x slant range
Operating range (1)(2)	4,000m
Coverage	200 deg below acoustic array
Operating frequency	22 to 30 kHz MFSK (chirp)
Position refresh rate	1 second min (acoustic, depends on range) 10 Hz with predictive filter
Communication protocol	Ethernet (4 ports) and Serial communication link (4 ports) NMEA proprietary GAPS protocol Multiple other NMEA or binary data telegrams Native compatibility with IXBLUE products

(2) *GAPS is a Global positioning system which provides absolute geo-referenced positioning of the tracked vehicles/object.. Unlike other conventional USBL system the performance (0.2% x range) is inclusive of all sources of error such as GPS (DGPS mode), motion and heading internal sensors*

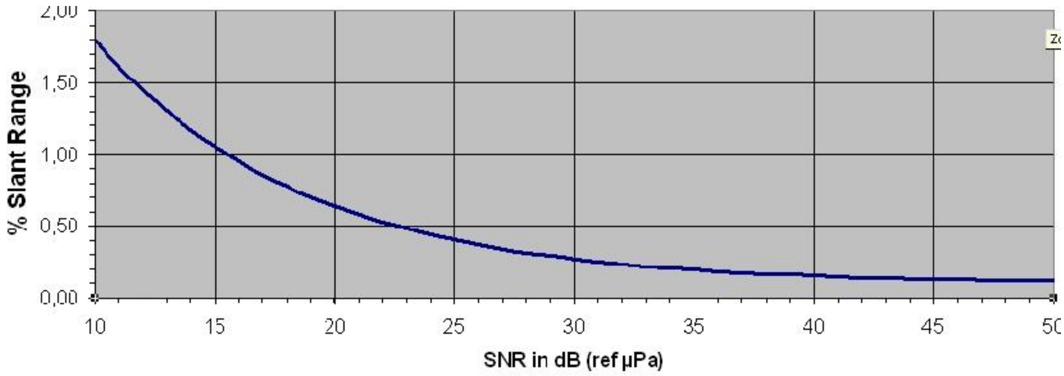
(3) *Range and accuracy of the system depend on ambient acoustic propagation conditions, water depth and signal to noise ratio (SNR) and GPS grade.*
The accuracy and range are nominal in vertical mode of operation and deep water (target below the acoustic array), and decrease in horizontal mode of operation due to multipath effect, Sound Velocity profile.
Nominal 0.2% accuracy is specified for a NIS=70dB (SNR=34dB), 1000m water depth, target below the acoustic array +/-30deg, sea state 6, Sound Velocity ideally compensated:

GAPS maximum range prediction vs. noise level (transponder signal level 188dB ref 1µPa @1m)



GAPS Accuracy versus SNR

- Slant Distance ≥ 1,000 m
- Vertical Angle < 30 deg
- GPS error ≤ 1.5 m



b/ Operating / Environment / Mechanical

Power Supply range	100 to 240 VAC / 50~60Hz ECB Power supply 28 /36VDC on external power supply
Operating temperature	-5 / +35 deg. Celsius
Storage temperature	-20 / +70 deg. Celsius
Housing	Carbon fibre housing + epoxy paint
Weight in air / water	16kg; -7kg in water (positive buoyant)
Overall dimension	638mm x 296mm OD
Depth rate	25m standard

4.5. OCEANO Transponders

Transponders (also named “beacons”) are installed on the tracked vehicle(s) or deployed on sea bed and replies to each surface acoustic array interrogation (GAPS, POSIDONIA, RAMSES) by sending a coded wideband signal subsequently used to calculate the position.
Similarly to USBL and RAMSES systems, iXBlue OCEANO transponder range is coming in …

- low frequency band usable with POSIDONA (all versions), RAMSES 6000, and surface telecommand units TT801
- Medium frequency band usable with GAPS, RAMSES.

Several versions are available from iXBlue range:

- Self contained expandable transponders with internal battery for long term deployment
- Recoverable transponders fitted with release mechanism
- Miniature transponders for installation of small vehicles
- Options for internal pressure sensor, remote or integral transducer head, external plug for responder mode and/or external power supply,
- Shallow water or full ocean water depth,
- 500kg to 300tons SWL (Safe Working Load)
- Etc

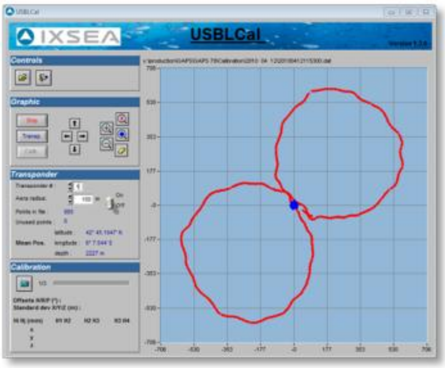
4.5.1. Recommended LF transponder for POSIDONIA II and RAMSES 6000

a/ POSIDONIA system initial calibration

USBL principle requires a perfect knowledge of the attitude of the acoustic array (both in heading and P/R) to measure angles to the tracked targets and calculate position.
The calibration procedure is used to measure and compensate the mechanical misalignments between the acoustic array, the Heading/motion sensor and the horizontal plan after initial installation. This procedure will have to be repeated every time the antenna is removed, or during regular inspections. (typ once every year)

Calibration mainly consists in the following steps:

- Deploy a recoverable transponder on the sea bed with sufficient water depth
- Collect sufficient readings (positions) of this fixed transponder while navigating above it. (Ideally figure of eight)
- Run the calibration algorithm which will ultimately produce a set of calibration coefficients that will be used as long as the alignment between the acoustic array and the motion sensor has not been modified
- Check calibration; recover the mooring line and transponder.



Any releasable transponder in the OCEANO can be used for system calibration.
In order to reduce the number of transponders required for a system we recommend the use of OCEANO RTA61 Universal , which can be operated with both RAMSES and POSIDONIA II during positioning operations later on.

b/ Recommended seabed transponder for RAMSES and POSIDONIA II

Although both RAMSES and POSIDONIA II are able to operate with former OCEANO RT861 series, the best results will be obtained with full wideband transponders (interrogation and reply in wideband modulation).
Sparse array navigation mode can be operated from one transponder deployed on sea bed only, it is recommended to have 3 transponders for better robustness to acoustic propagation hazards, and to allow full LBL capability as required.

OCEANO RTA61 Universal transponder is recommended in this case.

c/ Recommended transponders for vehicle tracking

Many different transponders can be used depending on the deployment scenario: small or large vehicle, self powered or external power supply, omnidirectional transducer or remote transducer heads, transponder or responder mode, etc…
RAMSES itself can be used as a transponder for POSIDONIA II while using its own seabed transponders.
Specifications are provided for a selection of them in next sections, to be chosen depending on the tasks to be carried out.

d/ transponder vs. application table

APPLICATION \ TRANSPONDER (*)	OCEANO **RT861** series	OCEANO **ET861** series	OCEANO **RTA61** series	OCEANO **ETA61** series	OCEANO **MT861** series	HD option (split hydrophone)	HDIR option (dir. hydrophone)	Pressure sensor option	OEM transponder	Cable cutter option	External power supply	Responder mode
Tow fish tracking		●		●	●	●	●	●		●	●	●
ROV tracking		●		●	●	●		●			●	●
AUV tracking		●		●	●			●	●		●	
DP positioning	●		●									
Manned submersible		●		●		●			●		●	
Subsea instrumentation	●	●	●	●	●			●				
Shallow water tracking					●							
Deep tow tracking		●		●		●	●	●		●	●	●
Sparse array navigation	●		●					●				

(*) Transponder designation:

2 letters (RT / ET / MT)	*Recoverable (RT's), Expandable (ET's) or Miniature Transponders (MT's)*
Digit 1 (8, 9, A)	*defines the product generation*
Digit 2 (0, 1, 3, 6)	*defines the maximum water depth (eg 3 for 3000m, 6 for 6000m, 0 for surface only)*
Digit 3 (1, 2)	*defines the frequency band (1 for LF Low Frequency, 2 for MF Medium Frequency)*

4.5.2. Recommended transponder for GAPS-NG and RAMSES

Similarly to LF (Low Frequency) transponders a range of products is available to be used with GAPS and RAMSES which are operating in the MF (Medium Frequency) band.
In addition to proprietary iXBlue transponders and to offer the possibility to operate GAPS-NG and RAMSES with some of the existing third party transponders/responders (mostly operated in the offshore Oil & Gas industry) a mode of compatibility is progressively developed and optionally implemented in these two products.
Please contact the factory for updated list of compatible third party transponders, features and limitations and iXBlue GAPS-NG and RAMSES upgrade policy.

a/ Miniature transponders MT9 series

The OCEANO MT9xx transponder series has been primarily developed for installation on small vehicles such as ROV's, AUV's, or towed bodies. The same basic features are provided in terms of functionalities (transponder, responder, internal or external power supply) and optional configuration (integral or split transducer head, various depth rating).

Note 1 MT912S (1000m depth rating) is free to export due to its limited operating water depth

Note 2 MT9's series is fitted with a rechargeable internal battery and is fully programmable through its serial communication link, which make it usable without having to open it throughout its life time

Note 3 previous generation MT8 series is still available and supported however we do recommend the use of MT9 series for new projects

OCEANO MT912S miniature transponder (integral transducer head shown on picture).

b/ full size Medium Frequency transponders for GAPS-NG / RAMSES

RTA / ETA's transponders have been developed originally to be used with RAMSES. They can be used with GAPS-NG (latest generation) which is sharing the same frequency band and modulation.
Thanks to their additional functionalities (releasable version RTA, larger battery autonomy) ETA / RTA's will be appropriate whenever long life transponders are required, of in case of DP or sparse array navigation applications.

c/ transponder vs. application table

APPLICATION / **TRANSPONDER (*)**	OCEANO **RTA62**series	OCEANO **ETA62** series	OCEANO **MT9x2** series	OCEANO **MT8x2** series	HD option (split hydrophone)	HDIR option (dir. hydrophone)	Pressure sensor option	OEM transponder	External power supply	Responder mode
Tow fish tracking			●	●	●	●	●		●	●
ROV tracking		●	●		●		●		●	●
AUV tracking		●	●	●	●		●	●	●	
DP positioning	●									
Manned submersible		●	●		●			●	●	
Subsea instrumentation	●	●	●	●			●			
Shallow water tracking			●	●						
Sparse array navigation	●						●			

(*) Transponder designation:

2 letters (RT / ET / MT)	*Recoverable (RT's), Expandable (ET's) or Miniature Transponders (MT's)*
Digit 1 (8, 9, A)	*defines the product generation*
Digit 2 (0, 1, 3, 6)	*defines the maximum water depth (eg 3 for 3000m, 6 for 6000m, 0 for surface only)*
Digit 3 (1, 2)	*defines the frequency band (1 for LF Low Frequency, 2 for MF Medium Frequency)*

4.6. Software and firmware

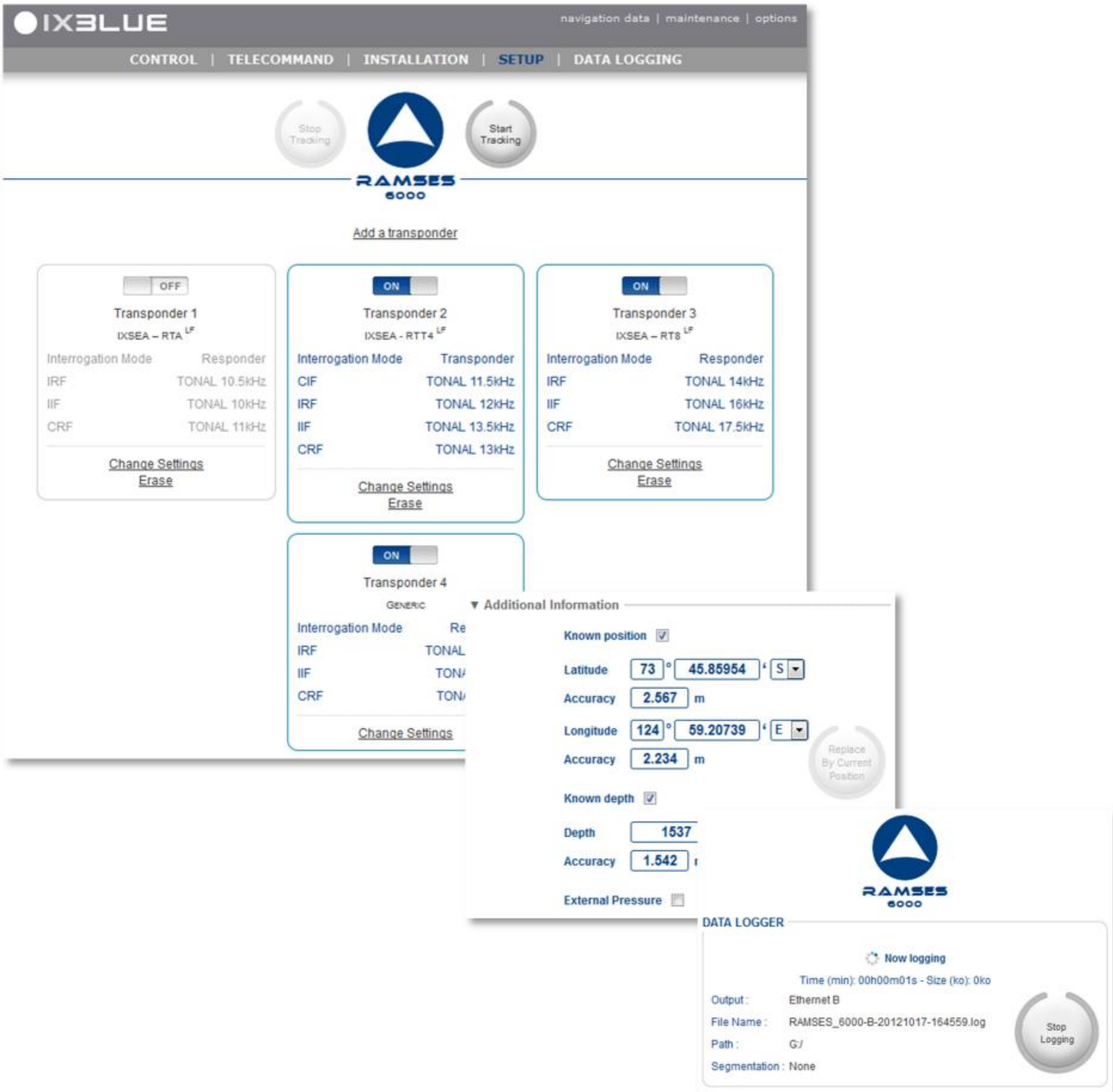
4.6.1. iXBlue unified WEB-based MMI (Man Machine Interface)

Every single positioning building block in the subsea positioning solution (PHINS/ROVINS, POSIDONIA, RAMSES, GAPS) is delivered with iXBlue new WEB-based graphic user interface which is progressively installed to the full range of products, providing a common look-and-feel with all systems.
Directly Ethernet compatible, this new feature greatly improves the ease of installation and operation of the equipment thanks to its interactive menu screens and network characteristics. The products are easily interfaced to any TCP/IP network, and running the WEB-based GUI is achieved with any terminal with WEB browser installed (PC computer, MAC, pocket PC's, remote or wireless devices, etc): dedicated PC and software is no longer required.

Using graphic and conversational menu screens the ROVINS WEB-based GUI allows:

- Definition of the installation parameters i.e., the parameters that do not change from one mission to another, for instance orientation and misalignment of PHINS with respect to the vehicle (MECHANICAL PARAMETERS option), lever arms for external monitoring points, the INPUTS (external sensors, UTC), the OUTPUTS and the IP address, DHCP and PPP modes, network mask (NETWORK option)
- Defining the set-up parameters i.e., the parameters that may vary from one mission to another or even during the same mission: activation of the sensors used by the Kalman filter, ZUPT mode (INIT &UPDATE); the WARNING CONFIGURATION, the DVL CALIBRATION, transponders interrogation and reply frequencies, etc…
- Monitoring each subsystem operations such as
    - Follow the navigation sequence
    - Display in real time data delivered or used
    - Be informed of the Status
    - Record data
- Performing maintenance tasks including:
    - System restart
    - Firmware updates
    - Parameters reset
    - Support contact

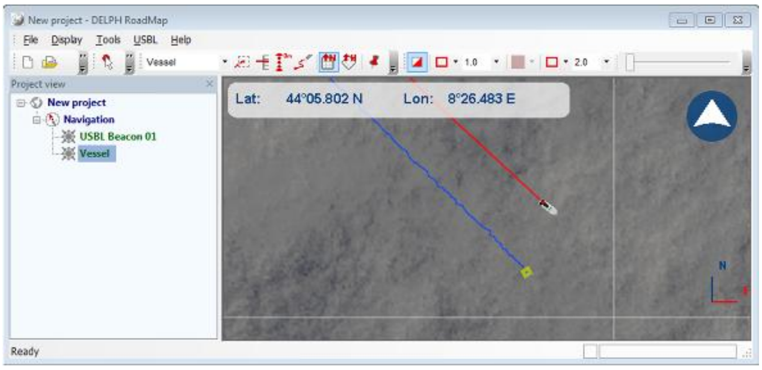
Note: the use of the WEB-based User Interface is not necessary to operate equipment. It is a tool for configuring the positioning building blocks. (POSIDONIA, RAMSES etc), modifying configuration during operation, and displaying or recording data output.



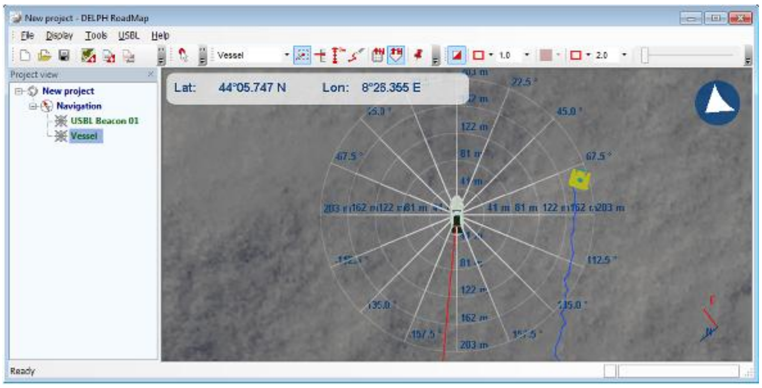
4.6.2. DELPH RoadMap display software

Most iXBlue positiong building blocks provide data telegrams with each measured position for use with any third party navigation package, with various communication protocols.
Several outputs are available (Ethernet and RS232 format) which allow data distribution to different peripherals.
Industry standard data telegrams are provided to easily interface each sensor to standard navigation packages from the market place such as Winfrog, Quinsy, etc.
Additionally iXBlue offers DELPH – RoadMap, a display package for visualisation of the tracked vehicles in several modes (2D, 3D) with basic tools to interact of the screen plots.
Although not a navigation package as such DELPH RoadMap provides nice functionalities to display all of your data on screen, from any iXBlue positioning building block.
The following screenshots are typical examples.

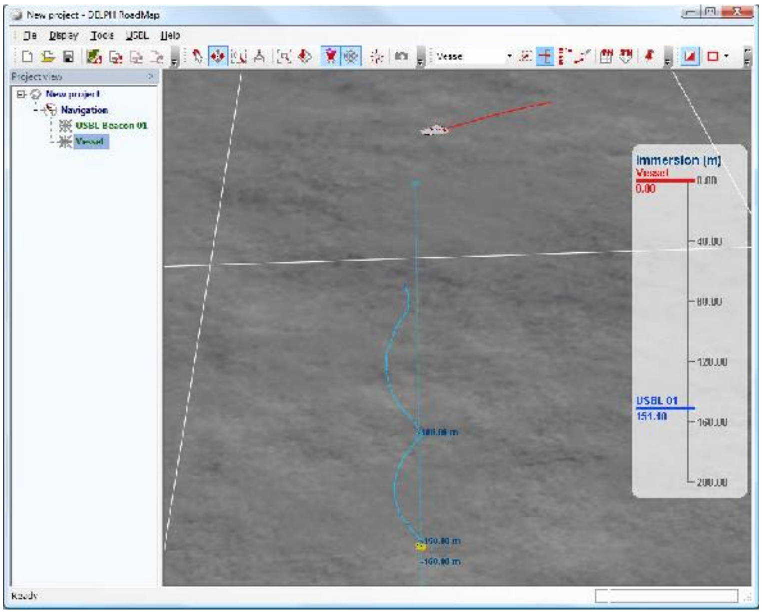
2D Long/Lat coordinates…



2D Polar representation



3D mobile view



4.6.3. Data post-processing tool: DELPH INS, DELPH RAMSES, USBL Replay

The DELPH software package is a post-processing and batch productivity tool for the iXBlue INS (PHINS, ROVINS), USBL (POSIDONIA, GAPS) and RAMSES positioning systems.
Powerful data editing and processing functions together with data export capability make this tool ideal for quick and easy navigation enhancement.
This software is the processing data solution helping you to get the best from your iXBlue products.

a/ DELPH INS main features and benefits:

- Sensors management
  Using the processing panel you can include or remove aiding sensors from the calculation.
  For each sensor in the calculation you can choose to use data acquired by the INS during the survey or to use data stored in an external file.
- Allow you to post-process your data with custom INS settings
  The heart of the DELPH INS software is based on the Extended Kalman Filter algorithm existing in the INS itself. This filter provides an optimal integration of inertial and external data. The computation process is based on models of external and inertial sensors errors. The error models of external sensors are specific for each type of sensor.
- Enhance the quality of the data using dedicated algorithms

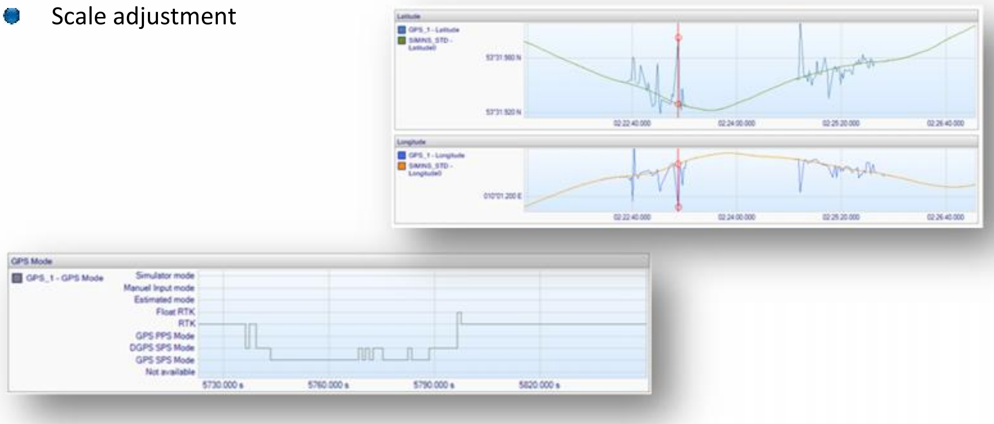
b/ DELPH RAMSES and USBL replay main features and benefits:

- Beacon management
  The user can review and change the settings of the beacons interrogated by RAMSES during the survey
- Edit or use a different sound velocity profile
- Using the processing panel you can include or remove aiding sensors from the calculation.
  For each sensor in the calculation you can choose to use data acquired by the INS during the survey or to use data stored in an external file.
- For USBL Review and/or change antenna lever arms, attitude / heading sensor misalignment
- Data export tools

b/ Data display

The main part of the software is dedicated to data display.
To display a data in a graph you just have to drag and drop the desired variable from the Variables panel to the center of the window. Multiple data sharing the same units may be displayed in the same graph or split into several graphs. To browse the data several tools are available using the mouse or the keyboard:

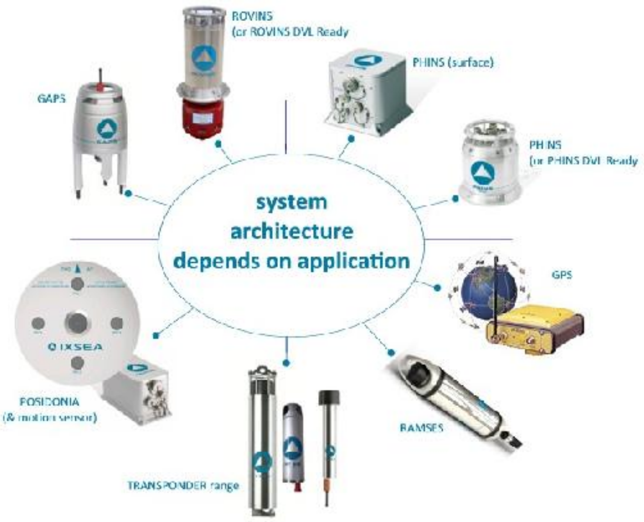
- Panning
- Zooming
- Scale adjustment



5. A scalable configuration for all kind of positioning requirements

All iXBlue positioning building blocks are positioning sensors or sub-systems that can be used as such.
This approach is the key for up-to-date subsea positioning systems. The advantages of such an approach are of 3 types:

- Only the advantages of each individual technologies is kept,
- It does provide redundancy, thus robustness
- It enables a modular approach, where the system architecture can be set to meet the specific needs of one given application



For most of the time every single project is having specific requirements which will lead to a different list of equipment to be installed and used. Thanks to the "building block" concept it is possible and simple to add, remove or change the configuration. There are however some limitations that must be remembered during the system architecture design:

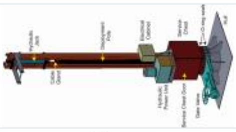
- **Low Frequency or Medium Frequency?**
  The iXBlue acoustic systems are operating in two distinct frequency bands. LF (Low Frequency) with POSIDONIA and RAMSES, MF (Medium Frequency) with GAPS and RAMSES.
  Although the features are comparable there is no cross-compatibility for evident physical reasons, although both systems are able to operate simultaneously. As a consequence, POSIDONIA cannot use pre-deployed GAPS (MF) beacons, and the other way around.
- **LF (Low Frequency) typical application**
  LF based systems using POSIDONIA II / RAMSES 6000 / INS will better serve applications such as deep tow vehicle tracking, full ocean depth application, and/or all projects requiring long range tracking or significant SNR (Signal to Noise Ratio) in case of noisy or difficult environment
- **MF (Medium Frequency) typical application**
  MF based systems using GAPS-NG / RAMSES / INS will be a preferred solution for extreme shallow water to ranges in excess of 4,000m. The benefit of GAPS-NG will be fully used in that case, with ease of deployment and use provided by GAPS, and ability to operate in shallow or extreme shallow waters.
- Some iXBlue customers are using both LF and MF systems however whenever all features are required. (ex: tracking AUV during its descent, or in extreme shallow water conditions)

5.1. Recommended configuration for a full solution

Three scenarios are examined below, with POSIDONIA II using deployable acoustic array, POSIDONIA II using Flush mount acoustic array, and GAPS.
The list of products includes main components that are required for a full INS/Acoustic combined solution, and

excludes all non standard cables, installation, wiring, setting to work, hull work for USBL installation etc.
It is strongly recommended to enter a discussion with iXBlue at time of positioning solution design for a customised and final best solution.
POSIDONIA II based solution will be discussed more into details.

a/ POSIDONIA II and deployable acoustic array based configuration

			required	Nice to have	optional	Other sensors
Surface ship						
POSIDONIA II	Deployable antenna		1			
	USBL-Box (top side electronics)		1			
	PHINS surface			1		
	Deployment machine		1			
	Acoustic telecommand unit TT801-15			1		
	DELPH software				1	
Subsea vehicle						
	PHINS 6000		1			
	DVL (PHINS / DVL ready optional)				1	
	RAMSES 6000		1			
	OCEANO MT861S miniature transponder			1		
	Pressure sensor					1
To be deployed on sea bed (DP, sparse array navigation)						
	OCEANO RTA61 Universal		4			

b/ POSIDONIA II and flush mount acoustic array based configuration

			required	Nice to have	optional	Other sensors
Surface ship						
POSIDONIA II	FLUSH antenna		**1**			
	USBL-Box (top side electronics)		**1**			
	PHINS surface			**1**		
	DELPH software				**1**	
Subsea vehicle						
	PHINS 6000		**1**			
	DVL (PHINS / DVL ready optional)				**1**	
	RAMSES 6000		**1**			
	OCEANO MT861S miniature transponder			**1**		
	Pressure sensor					**1**
To be deployed on sea bed (DP, sparse array navigation)						
	OCEANO RTA61 Universal		**4**			

b/ GAPS-NG based configuration

			required	Nice to have	optional	Other sensors
Surface ship						
GAPS-NG	GAPS-NG		**1**			
	DELPH software				**1**	
Subsea vehicle						
	PHINS 6000		**1**			
	DVL (PHINS / DVL ready optional)				**1**	
	RAMSES		**1**			
	OCEANO MT912S miniature transponder			**1**		
	Pressure sensor					**1**
To be deployed on sea bed (DP, sparse array navigation)						
	OCEANO RTA62 Universal		**4**			

5.2. Example of a complete POSIDONIA II USBL based solution

The purpose of this chapter is to provide a detailed explanation of a typical positioning solution, progressively enhanced by adding other iXBlue building blocks (INS, RAMSES, etc). The effect on performance and features is analysed at each significant step.
For this example a POSIDONIA II based system with deployable acoustic array is used.

5.2.1. POSIDONIA II alone features and benefits

Most acoustic positioning systems are operating in the medium frequency range, (approx. 20~30kHz) which enables sufficient slant range for most operations. In deeper seas environment, or when noise level is significant those systems reach their limit unless boosting acoustic transmitted power and adding more transponders for redundancy and measurement consistency.
POSIDONIA II is operating in lower frequency band (12~18kHz) which naturally provides longer ranges and superior ability to work in difficult conditions.

Using standard iXBlue beacons (Wideband, 192dB radiated power) POSIDONIA II offers up to 10,000m slant tracking distance with 0.2% x range accuracy.

- Long range and/or high noise level environment capability
- Interfaces to existing DP desk (DP1 to DP3)
- Standard output power iXBlue beacons with option for high power / directional transducer
- Extreme long range track records
- Wide range of iXBlue beacons (LF frequency range)

With this simple configuration positioning can be achieved up to 10,000m (depending on acoustic & propagation conditions), with a simple transponder installed on the tracked vehicle and without having to deploy anything on sea bed.

a/ improve or maintain the range with directional transducer

In case the system is operated with higher noise level (ship's noise, ambient noise), the maximum range can be significantly reduced.
Rather than having higher radiated power at the subsea transponder level, which leads to additional although different problems (energy consumption, size of electronics), the use of a directional transducer with a reduced beam pattern (+/- 30deg) allows focusing the energy toward the surface receiver.
iXBlue transducer PET861-DIR60 is using a Tonpiltz technology and high efficiency transducer assembly which provides an additional 6dB minimum compared to a standard hemispherical standard transducer.
This simple and easy solution allows 2,000 to 3,000m additional range.
Note:
Electronic impedance matching for directional transponder requires special setting of the electronic board in the transponder itself.

b/ Use high accuracy heading and motion sensor

The position to the target is calculated using slant distance and bearing angles (X & Y).
Since the acoustic array is installed on a moving platform (surface ship) its absolute position must be known with sufficient accuracy (calibration procedure) and its motion carefully monitored and compensated (AHRS sensor) in order to get the best performances out of the POSIDONIA II system.

Depending on the version (Flush mount or deployable array) and mode of operation (permanent installation or vessel of opportunity) a mechanical structure must be prepared such as …

- side pole with portable acoustic array at the end
- flush acoustic array permanently installed under the vessel (must be dry-docked)
- electromechanical hoisting system for deployment of the acoustic array when required
- etc

Whatever the installation method is the relative positions of the acoustic array and heading/motion sensor must be rigid, repeatable and stable over the system operation time.

An accuracy of 0,15deg or better for heading and 0.05deg for Pitch & Roll is recommended in order to reach nominal performances of the POSIDONIA II USBL system.
iXBlue manufactures high grade Fiberoptic Gyroscope and Motion sensors, OCTANS, which is a perfect match with POSIDONIA II requirements:

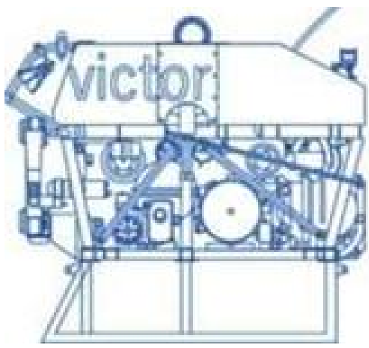
- heading accuracy : 0.1deg (x secant latitude)
- pitch and roll accuracy : 0.01 deg
- refresh rate : up to 100Hz

c/ Use PRESSURE Sensor

In case of high elevation of the target the angle measurement accuracy decreases. (Woodward law, physics characteristics)
If a pressure information is available POSIDONIA II automatically integrate this additional information into the algorithm to improve the depth information, which in turns allow the system to better estimate bias in X/Y data and correct it.
POSIDONIA II can use either optional pressure sensor installed in the iXBlue transponder (optional, data retrieved through umbilical or through the acoustic channel) or third party pressure sensor if available on the tracked vehicle.

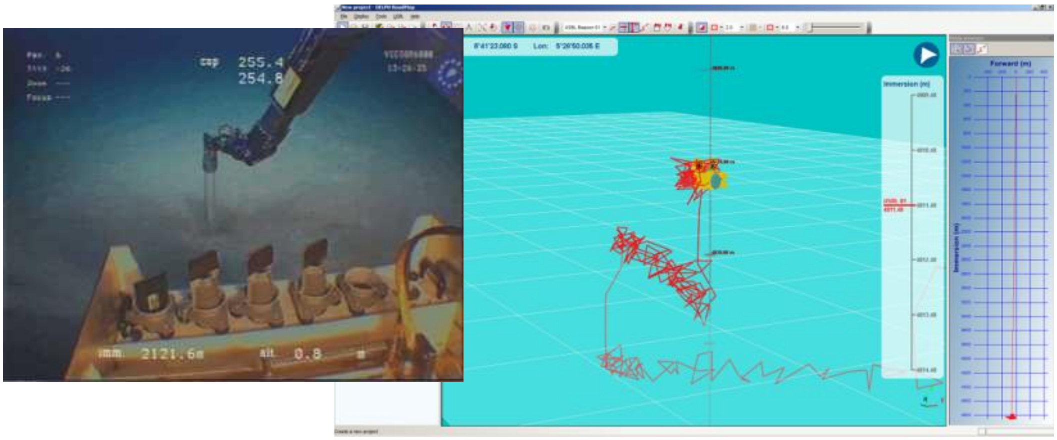
d/ ConGlobe, a real life example

The example below is reported by IFREMER during a recent scientific experiment off coast Gabon / West Africa:
POSIDONIA II is the main USBL positioning system installed on the whole IFREMER scientific fleet. The recent scientific experiment CONGOLOBE was carried out from onboard the R/V “Pourquoi Pas?” offshore Gabon on the sites of terminal lobes of the submarine canyon of the Congo river, operating the deep sea “VICTOR” ROV at depths of 5,000m.
CONGOLOBE took place from December 2011 to January 2012 and aimed at studying the local biodiversity with the contribution of the fresh terrestrial phytodetritus brought in by the river.



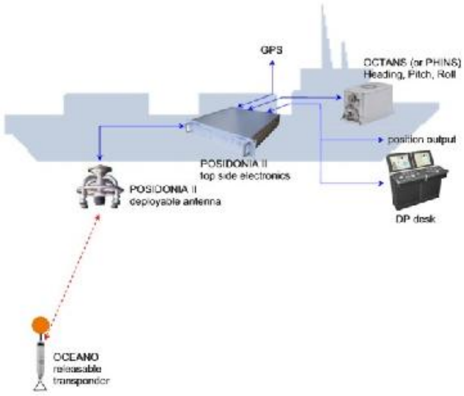
The IFREMER VICTOR 6000 is a deepwater remote-controlled system dedicated to scientific ocean research. It is instrumented and modular and can perform high quality optical imaging and can carry and operate various equipment and scientific tools.
The lower part of the vehicle is composed of an instrumented scientific module which can be changed according to the type of assignment. It contains most of the instrumentation as well as the sampling basket. Positioning of the system is achieved with one POSIDONIA II transponder together with iXBlue PHINS INS.

During CONGOLOBE experiment and using standard omnidirectional iXBlue transponder installed onboard VICTOR 6000 up to 5 different subsea locations have been surveyed from 4,700 to 5,000 m with imaging and sampling subsea materials of interest.
With 0.12% x range (@ 1σ and 5,000m WD) pure acoustic accuracy POSIDONIA II proved to be the perfect tool for accurate and convenient subsea vehicle tracking.

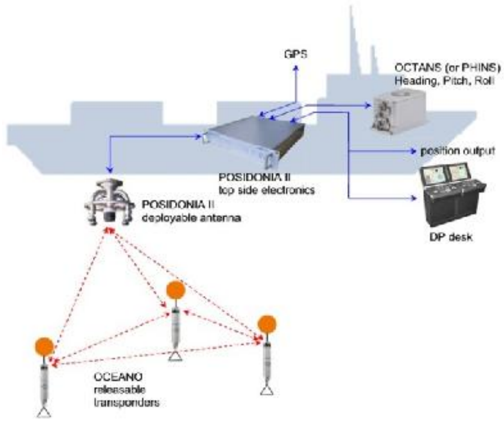


5.2.2. POSIDONIA II used for Dynamic Positioning

iXBlue USBL acoustic positioning systems (GAPS, POSIDONIA II) already provide the DP capability and can interface to DP desk using standard industry leaders communication protocols.
With one or several transponders previously deployed and calibrated on sea bed, USBL or L/USBL modes are available for surface vessels (DP) or subsea vehicle (follow-DP) modes.
The massive range capability offered by POSIDONIA II provides consistent position refresh in most severe conditions in all modes (USBL, L/USBL), the flexibility of the top side unit allows DP2 / DP3 modes with all arbitration / priority between the systems operated.
Although DP function is provided the mode of operation is nothing but conventional, and if accuracy is required several beacons must be deployed on sea bed which is expensive and time consuming. Moreover in case of GPS outages the absolute reference is lost as well as absolute positioning.



DP aiding with USBL only typical configuration
USBL POSIDONIA II is using the position to the sea bed transponder to feed the DP desk with a standard USBL telegram.

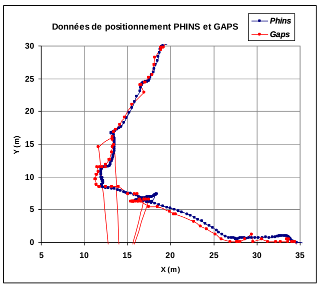


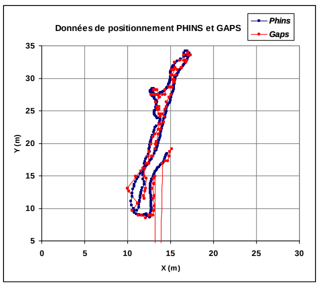
DP aiding with L/USBL mode
With L/USBL mode an array of transponders is deployed on sea bed which forms a Long Baseline positioning system and provide superior position reference to the DP-Desk.

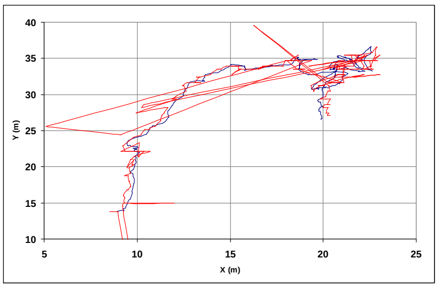
5.2.3. POSIDONIA II (USBL) and PHINS/DVL

Utilising a subsea PHINS on the subsea vehicle will produce some significant performance improvements.
In that case PHINS is the core of the positioning solution and is coupled to external aiding sensors such as DVL, pressure sensor and USBL positioning system.
The natural drift of the INS is then fully contained, the update rate up to 100Hz + full vehicle attitude provides a smooth and high quality positioning, with extremely robust positioning thanks to redundant configuration:
Typical performance in that case is :

- Absolute positioning = USBL improved by a factor of 3 typical
- Drift without USBL (PHINS / DVL) : 3m/s at 3 knots
- Positioning Update rate: 100Hz
- Full attitude monitoring: Heading, Pitch, Roll, Position, Depth







5.2.4. Sparse Array navigation: PHINS, USBL, RAMSES

a/ Auto-calibration (RAMSES, PHINS, 1 subsea beacon with unknown initial position)

As previously explained, RAMSES is capable of using a beacon whose position is unknown to start with. This beacon will be used to prevent the INS from drifting during the mission, as long as it is in range of RAMSES.
In terms of final precision, auto-calibration abilities are mainly dependent on the quality of the positioning source during the initial part of the survey, very good accuracy throughout the time of operation being sustainable in case of a quick calibration after INS alignment procedure, or surface calibration using a GPS.

This example demonstrates how the asserted beacon position (orange trajectory) converges during the first minutes of operation to the real position, which will serve as a reference for the following job (blue trajectory). Initial position of the beacon is absolutely unkown. The process is automatic, and no difference between the two "operating modes" (calibration & navigation) is made in real for the operator

b/ Maximum accuracy with PHINS, DVL, RAMSES and 2 beacons

The best performance will be achieved with a configuration where PHINS INS can be aided by RAMSES and 2 beacons on the sea bed, deployed in such a way that a 2 axis observability can be obtained for INS drift compensation.
This is sparse array navigation, with LBL-like level of performance without the hassle of LBL large array of transponders deployment and initial calibration.

With SLAM being capable of positioning with comparable accuracy both the mobile system and its environment, RAMSES repositioning abilities will greatly improve Phins/DVL performance over time, with minimal operational costs and constraints. The final accuracy is dependent on various parameters, from lever-arm knowledge to the beacon calibration precision, but sub-metric live absolute accuracy can be easily obtained using pre-positioned beacons. Accuracy is slightly degraded using only one beacon, especially at long ranges, but optimal accuracy is obtained starting from two beacons only.

Sparse Array sea trial results

A recent sea trial (March 2014) was conducted in Mediterranean sea in order to illustrate the potential and benefits of iXBlue Sparse Array navigation solution using INS and RAMSES.

The equipment used:

- PHINS / DVL installed on a pole so that absolute reference can be made available with GPS
- RAMSES (Medium frequency version installed on the same pole
- Up to 3 transponders deployed on sea bed (iXBlue releasable transponder model OCEANO RTA2500S Light)
- GPS-RTK absolute reference

The test plan
The transponders are deployed on sea bed and carefully calibrated. Water depth is 30m approximately. PHINS/DVL/RAMSES are installed on a side pole and connected to GPS-RTK.

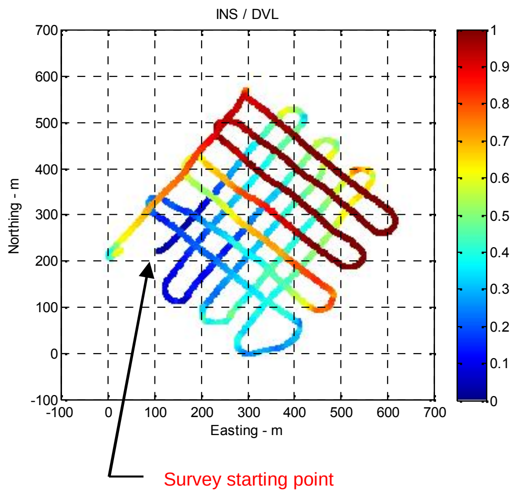
A grid survey is carried out with all data logged for later post-processing, baseline 500x500m
Using iXBlue DELPH-INS post-processing tool the data is post-processed and position accuracy compared with absolute GPS reference, using…

- PHINS/DVL only with GPS disconnected after initial alignment
- PHINS/DVL and RAMSES with one only transponder aiding
- PHINS/DVL and RAMSES with two transponders aiding

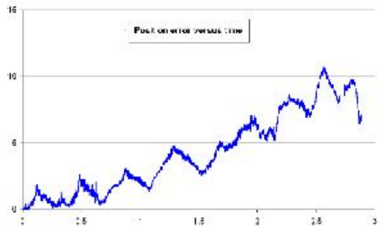
Test results

The graphics below show the grid survey with the position accuracy compared to absolute GPS-RTK. The colour bar graph on right indicates the error, with dark blue showing no error compared to GPS and dark red error >1m.

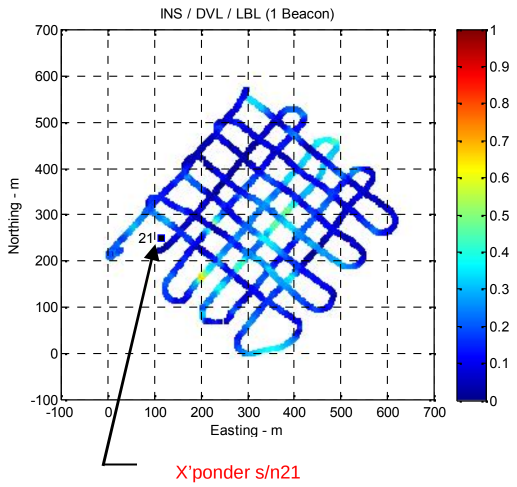
1/ PHINS/DVL only after initial alignment



Comment:
We have here a typical PHINS/DVL result. Despite the high grade characteristics of PHINS coupled to DVL a residual drift is progressively accumulating (0.1% x travelled distance typical) which causes the error to grow and pass the 1m limit (dark red on left)
Below is drift vs. time typical PHINS/DVL drift for such trajectory pattern:

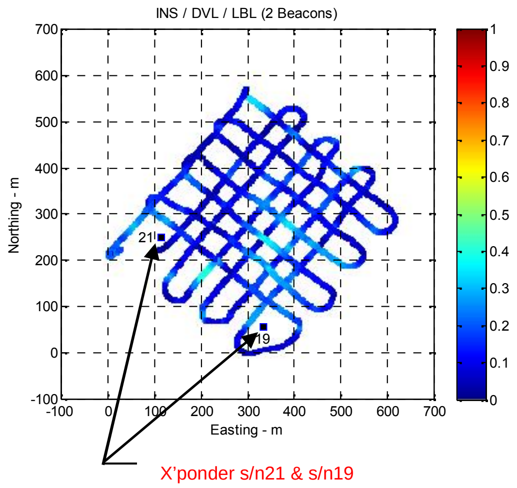


2/ PHINS/DVL and RAMSES aided with one transponder only



Comment:
The same data set is processed with the contribution of RAMSES interrogating transponder s/n21 deployed near survey starting point.
One can see the dramatic reduction of error in position compared to GPS. The drift is almost fully contained below 0.5m during the whole survey, with one transponder only.

3/ PHINS/DVL and RAMSES aided with two transponders



Comment:
In order to "kill" the small residual area with error still ≥0.5m a second transponder (s/n19) is introduced in the post-processing.
We have then a full survey with position accuracy compared to GPS RTK contained below <0.5m at all time, and is the range of 0.2m during most of the survey.

Test results
The above real life data display demonstrates the performance of iXBlue Sparse Array navigation using iXBlue RAMSES and INS. Starting from one beacon only the position drift can be fully contained below half meter as long as the vehicle remains within acoustic range to the transponder(s).
Both systems (INS, RAMSES) are self-contained, integrate all interfaces to external sensors and produce real time data immediately usable for the navigation.
With no complex integration required (simply plug RAMSES to INS), no umbilical needed, and no mandatory communication to surface, the system is simple to use even on remotely operated vehicle like AUV's.

6. Specification and performance

6.1. Relative vs. absolute positioning

Thanks to "SLAM" algorithm RAMSES/PHINS are able to automatically localise transponders deployed on sea bed without having to calibrate them first, then use them to contain the drift of the INS position. As long as relative positioning is good enough for the specific task being carried out this mode of operation is providing simple and quick to deploy navigation relative reference frame, with sub-metric accuracy in real time.

In case absolute (long/lat) positioning is needed the transponders (2 of them) must be either calibrated, or installed on known positions.
Calibration can be achieved using different methods:

- Prior to full dive and before the INS drifts the beacons are interrogated by RAMSES and "SLAMED" so that their position is known in absolute coordinates. A specific trajectory is required for the SLAM to be efficient
- Using the surface ship available USBL beacons are interrogated repeatedly so that a statistical error reduction can be obtained. Typically one hundred successive interrogation will reduce the USBL inherent error by SQR(100), i.e. factor of 10, which can lead to an accuracy of 20cm @1,000m range with an average 0.2%xrange USBL characteristic.
  The beacons positions are then initialized in PHINS/RAMSES for subsequent reference and drift reduction.
- Classical box-in techniques may be used as well, with USBL interrogation of each individual beacon.

6.2. Performance estimate (simulation)

The performance estimate hereafter has been established for another project in order to demonstrate the progressive improvement on the navigation with positioning building blocks (such as POSIDONIA, RAMSES, DVL and pressure sensor) progressively added to the configuration.

6.2.1. Initial conditions

RAMSES range to beacons	500m slant distance
Noise level (used for perf. Estimate)	100dB µPa @1m /sqrt(Hz)
Acoustic transmit level	191 DB (OCEANO iXBlue beacons)
Pulse duration	10ms
Bandwidth	5,500Hz
Directivity	omni directional beam pattern
Expected SNR with above parameters	30dB min, comfortable conditions

To evaluate positioning performance, a simulated trajectory is created and data simulated for the external sensors (USBL,DVL, LBL, depth sensors) and the internal accelerometers created from empirical data. The data sets is created to be similar to the those expected within operating environment. The processing software inside ROVINS is then used to synthesise the expected output

6.2.2. Simulated trajectory and sensors available

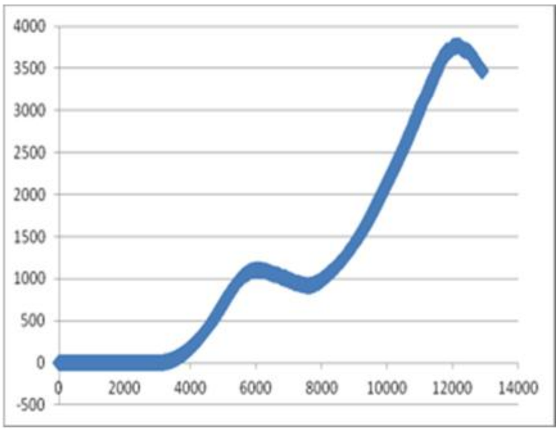
Trajectory:
The longitude is always 150° during the motion. The latitude changes from -4° to -4.00195°.

Vibrations are added to this motion in translation, along the 3 axis. The average of acceleration is 0 and the acceleration spectrum is flat between 5 and 60 Hz, for a standard deviation of 1 g rms

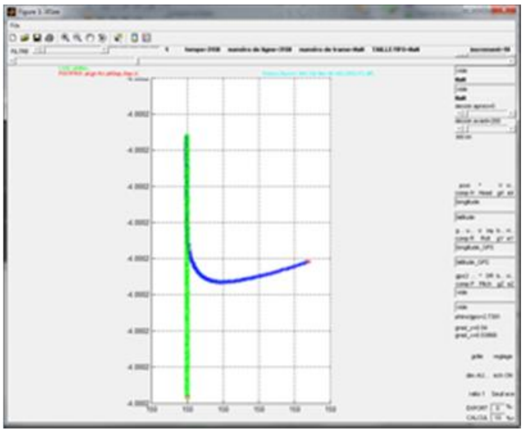
- Starting point: heading 180°, latitude -4°, longitude 150°, depth 1,600m.
- During 2,000 s, the position is static.
- During 10,800 s there is acceleration to the South up to 0.02 m/s and we keep this speed. The depth is stable.

GPS:
GPS is perfect and corresponds to the true motion, including vibrations, @ 1 Hz. This will be used as a reference.
DVL:
Standard Workhorse Teledyne DVL in bottom tracking mode.
Data output is [0,0,0] during the 2,000 s and [0.02,0,0] during the rest of the simulation. Rate is 1 Hz.
DEPTH:
Pressure sensor with an accuracy of 0.01% F.S., at 1 Hz.
USBL:
the rate is 0.33 Hz. The noise level is pessimistic and corresponds to a standard deviation of 6 m (error peak to peak 30 m):
Transponders:
Four (4) transponders are used during the simulation. They are placed at the following locations:
Transponder #1: latitude -4° , longitude 150.001°, altitude -1600m
Transponder #2 : latitude -4° , longitude 149.999°, altitude -1600m
Transponder #3: latitude -4.002° , longitude 150.001°, altitude -1600m
Transponder #4: latitude -4.002° , longitude 149.999°, altitude -1600m
which corresponds to a square of 222 m side. The rate is 0.33 Hz.
Added a white noise with 0.05 m standard deviation and a systematic error due to speed of sound variations depending on the latitude (+/-0.5m/sec)

6.2.3. ROVINS + pressure sensor simulation results



Pure inertial performances



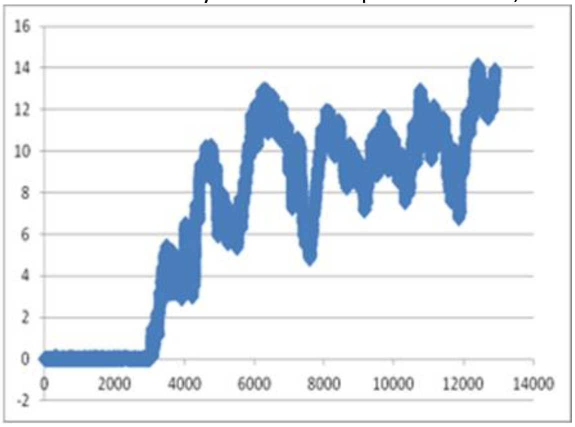
Trajectories (green is the reference, blue is [ROVINS+DEPTH])

The drift is significant as it could have been expected:
1 m after 1 mn,
10 m after 5 mn,
600 m after 30 mn and
1000 m after 1 h

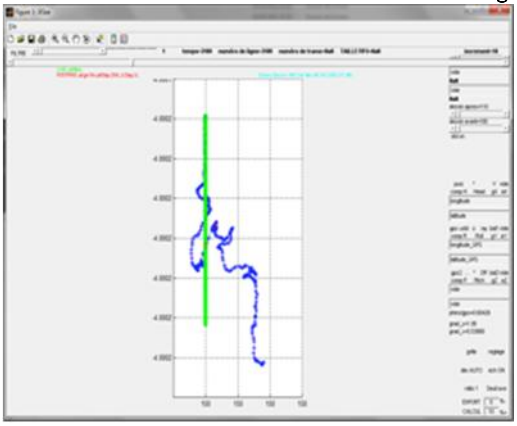
6.2.4. ROVINS + pressure sensor + DVL simulation results

The DVL is added into the simulation to estimate its contribution

The drift is massively reduced compared to 6.2.3, with a maximum deviation of 14m after 3 hours navigation



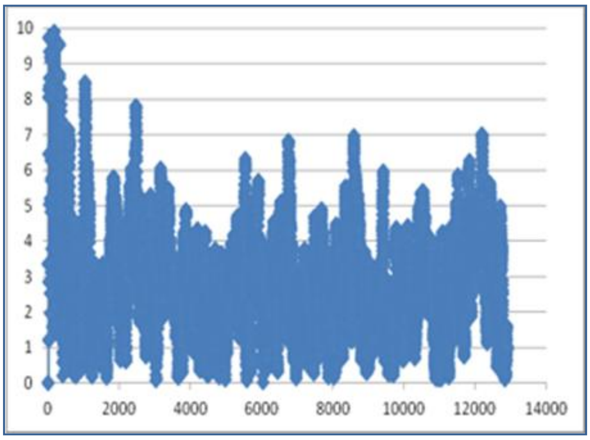
ROVINS + DVL + Pressure



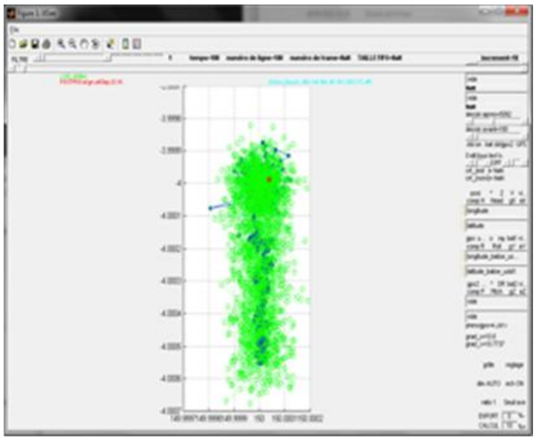
Trajectories (green is the reference, blue is [ROVINS+DEPTH+ DVL])

6.2.5. ROVINS + pressure sensor + DVL + USBL simulation results

ROVINS is improving the USBL position by a factor of 5



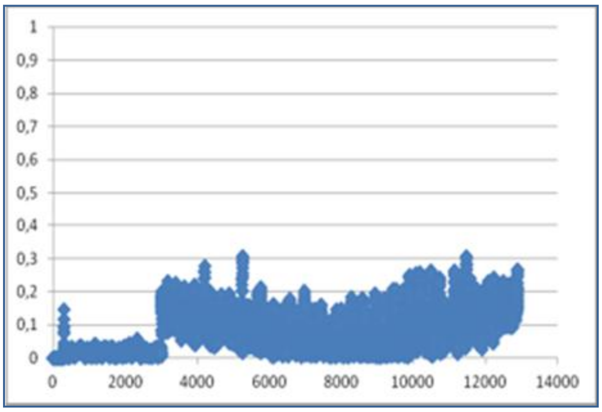
ROVINS + DVL + Pressure + USBL



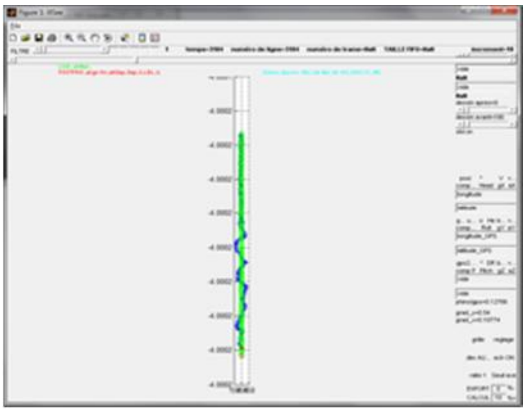
Trajectories (green is the reference, blue is [ROVINS+DEPTH+ DVL+USBL])

6.2.6. ROVINS + pressure sensor + DVL + USBL + ROVINS simulation results

All sensors are integrated into the simulation, including the last positioning block RAMSES and its four reference beacons



ROVINS + DVL + Pressure + USBL + ROVINS



Trajectories (green is the reference, blue is

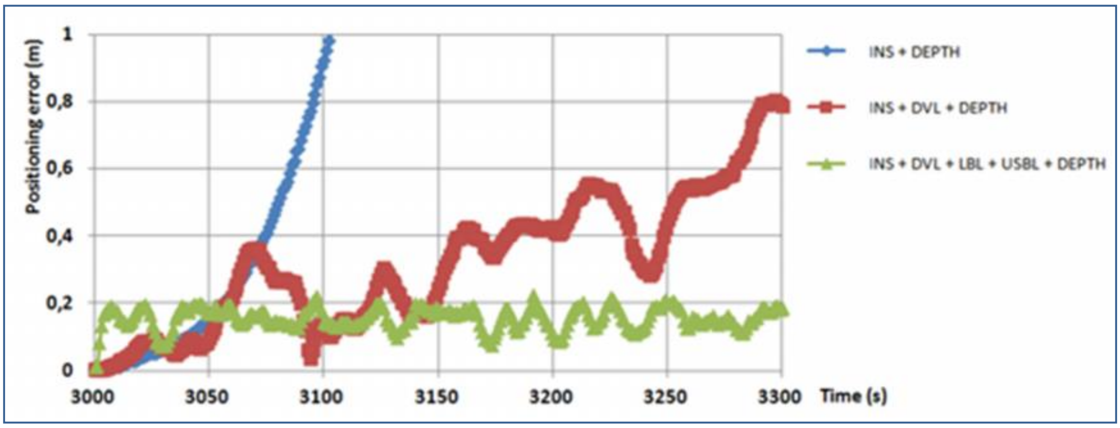
[ROVINS+DEPTH+ DVL+USBL + ROVINS])

When using ROVINS + LBL + DEPTH measurements, the performance is a function of the range accuracy provided by the RAMSES (± 150mm peak to peak) enhanced by the filtering capability of the ROVINS. Finally, the limitation is the uncertainty of the speed of sound. The chosen model for speed of sound uncertainty generates the oscillations to both the left and right of the curve.

For that reason, an obvious QA/QC requirement exists in monitoring the different speed of sound measurements provided by the SVS sensors on the vehicles . For the given ranges (≈ 200 m), the differences between different SVS must be known to < 0.5 m/s to guarantee 100mm relative accuracy in positioning. This is easily achievable by using quality real-time SVS sensors that are regularly calibrated.

It is important to note that the overall system accuracy is not enhanced by the use of all aiding sensors. Maximum accuracy is achieved with the use of ROVINS+LBL+DEPTH sensors only. This confirms that global performance concerning accuracy is mainly provided by the ROVINS and RAMSES. Using other sensors (DVL and USBL) allows for an increase in the period between acoustic updates (which will improve transponder battery life) and provides redundant data to aid the INS when the acoustic environment is excessively noisy

6.2.7. conclusion



These performances are very important to estimate the required acoustic recurrence (or acoustic update rate). Considering speed input will be available at any stage (operator command or DVL during transit):
the 100mm drift is reached after ≈ 1 mn using only ROVINS, DVL and DEPTH. It means the acoustic update rate can be around 30 s to guarantee 100mm positioning accuracy.
the 400mm drift is reached after ≈ 3 mn. It means the acoustic update rate can be around 90 s to guarantee 400mm accuracy on positioning.

7. Benefits, References

7.1. Advantages of the proposed solution

- **A modular approach**
  The iXBlue solution is based on a modular approach. The user can decide which equipment and architecture he wants to use, based on his needs for a dedicated application. It can be USBL only, or INS+USBL, INS+LBL sparse array also.
  Notably a full LBL network is not required, as it is possible to deploy only a LBL spare array, which means an improved productivity and reduced operational costs.

- **A state-of-the-art solution with INS and data fusion**
  The proposed solution is not only the up-to-date approach for subsea positioning, it is also based on state-of-the-art equipment and system architecture allowing all operational functionalities:
  - ✓ Unrivalled position recurrence (100 Hz with INS option)
  - ✓ mobile positioning solution with USBL+INS (saving of time and yet a very good accuracy)
  - ✓ high accuracy positioning with INS + LBL spare array (enhanced accuracy since the INS filters LBL noise)
  - ✓ robustness against GPS dropouts and noise on one hand, plus robustness against acoustic positioning dropouts and noise on the other hand, thanks to INS.
  - ✓ a combination of all those advantages when using altogether the equipment thanks to data fusion.

- **Operational cost savings**
  The integrated underwater positioning system allows significant cost savings due to reduced mobilization time, not only in its USBL+INS configuration, but also when using the LBL Sparse Array feature due to savings in deployment and recovery: the LBL Sparse Array does not require to have the full LBL network deployed to be operational. Already starting from 1 single beacon deployed the accuracy is improved, 3 is the optimum.

- **An upgradeable system**
  State-of-the-art positioning systems are based on acoustic positioning, inertial systems, data fusion... For each of those technologies, iXBlue belongs to the rare companies which are really highly qualified. But more importantly, iXBlue is the only company whose expertise embraces this whole spectrum.

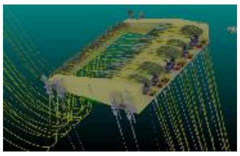
- **An open system**
  Unlike other systems, the solution proposed by iXBlue is open, meaning it can be interfaced with third party equipment..

- **Direction and attitude of the vehicle**
  PHINS provides the full attitude of the subsea vehicle (heading, roll and pitch) with an extreme accuracy.

7.2. User track records

iXBlue is the manufacturer of choice for the world leading ROV and AUV manufacturers. iXBlue supplies INS and FOG IMU gyro-compass systems for Oceaneering International, Acergy, SONSUB, Schilling Robotics, ECA and Deep Ocean to name a few.
More than 200 USBL positioning systems have been supplied to world-class oceanographic institution, O&G companies and defence organisations.

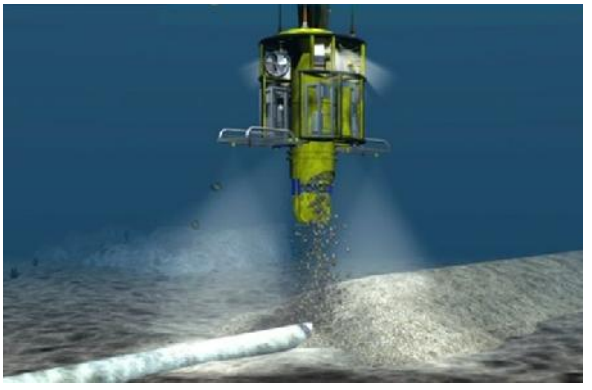
			INS	USBL GAPS	POSIDONIA	RAMSES	DVL
Inertial navigation							
US Navy	AUV positioning for mine counter measures. Vehicle: Reliant (Bluefin)		✓				
Woods Hole	Oceanographic Institute Vehicles: NEREUS (11,000m), SENTRY (6,000m), ABE (4,500m)		✓				
SUBSEA7	Survey Vehicle: Geosub		✓				
Inertial + USBL navigation							
MMTAB	Multibeam survey with tow fish		✓	✓			
FUGRO	Survey. Vehicle: Echo Surveyor II		✓				
C&C Technology	Survey. Vehicle: C-Surveyor I		✓	✓			
Belgian Navy	Mine Counter Measure Vehicle : Double Eagle		✓	✓			
MARUM – University of Bremen	Research Vehicle: B-Seal		✓	✓	✓		

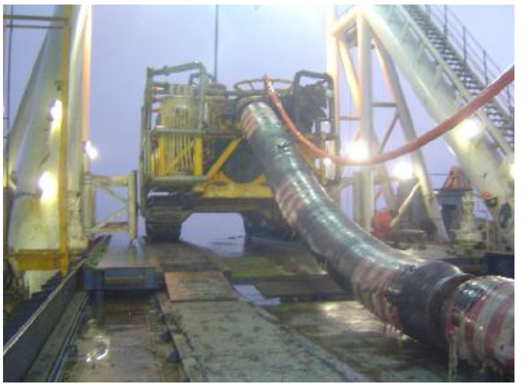
			INS	USBL GAPS	POSIDONIA	RAMSES	DVL
Inertial + USBL navigation, con't							
IHM Spain	Tow fish with synthetic aperture sonar		✓		✓		
Petrobras / Cybernetix	Riser Monitoring System		✓	✓			
SUBSEA Resources	Ship wreck cargo recovery		✓		✓		✓
Inertial + USBL + LBL navigation							
IFREMER	ROV and AUV positioning Vehicles: Aster-X, Idef-X, Victor		✓	✓	✓	✓	✓
NIOT	Oceanographic Institute		✓		✓		✓
SAIPEM	Metrology (spool piece measurement)		✓			✓	✓
Dynamic Positioning							
IFREMER	"Pourquoi Pas?" vessel				✓		
P&O Maritime	GAPS interface to DP Kongsberg, onboard Celtic Explorer			✓			

7.3. Installation Examples of IXBLUE Equipment Applications

7.3.1. Dredging and Fall pipe ROV vessels

iXBlue equipment is installed on multiple Fall pipe ROV vessels (max 2,000m). OCTANS and PHINS performed very well and are particularly designed to handle heavy vibrations when dumping huge stones.





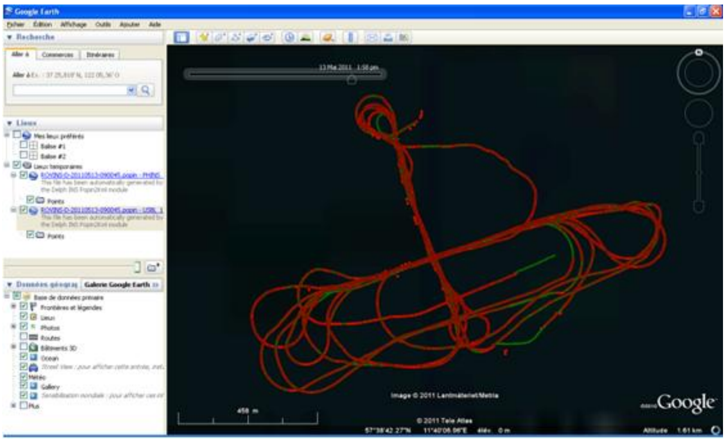
Some references:

- Van Oord Tertnes – 2x OCTANS 1x PHINS
- Van Oord Stornes – 3X ROVINS
- Van Oord NordnES – 3X OCTANS
- Boskalis – Rockpiper – 2x PHINS
- Tideway – Seahorse – 1x PHINS
- Tideway – Flintstone – 2x OCTANS
- Tideway – Rolling stone – 2x imu90
- JDN – Simon Stevin – 3x imu90
- JDN – Willem de Vlamink – 2x imu90

PHINS on the TERTNES vessel (Van Oord

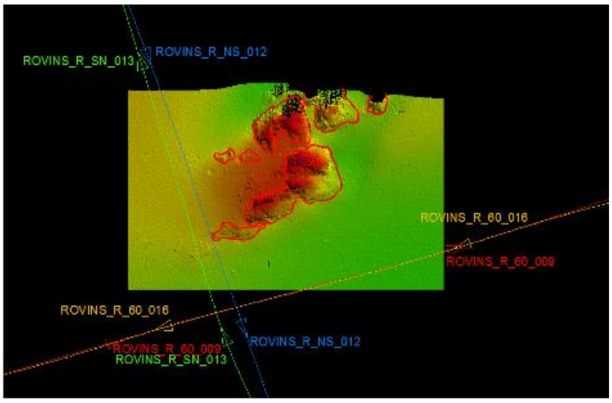
7.3.2. Testimonial 1 - Multibeam survey

A Swedish company performs high resolution marine survey to supply the industry and authorities with detailed information for seafloor constructions, installations and environmental investigations
This company uses ROVINS and GAPS to position the Multibeam (on a tow fish).

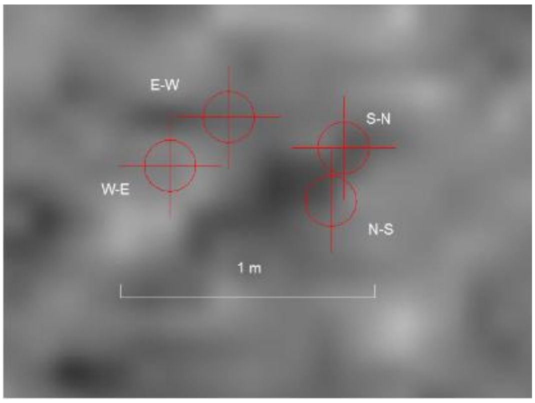


Tow fish trajectory (green: ROVINS + GAPS / red: GAPS)

They performed evaluation trials to show absolute accuracy of ROVINS + GAPS positioning (INS + USBL). The test consisted in making different lines above a visible object on the seabed, detect it with the Multibeam and position the different contacts using ROVINS+GAPS position.
The distance between vessel and tow fish is 200m. The water depth is 50m.



Vessel trajectory and zoom on the object



The grouping of the targets in AutoCAD on mosaic

As can been seen in the above below, the greatest distance between the same target from 4 different files with 4 different directions is 0.68m with tow fish heading.

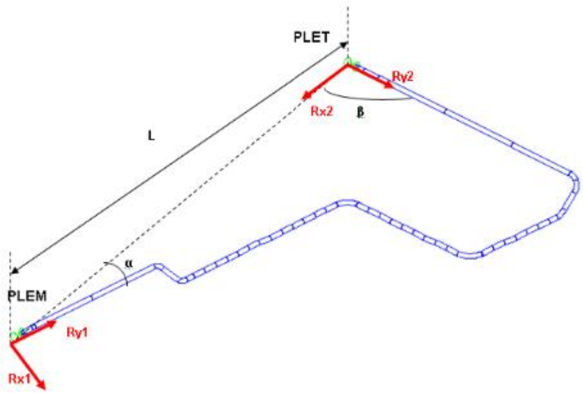
Distance (m)	N-S	S-N	W-E	E-W
N-S	-	0.22	0.65	.052
S-N	0.22	-	0.68	0.47
W-E	0.65	0.68	-	0.30
E-W	0.52	.047	.030	-

"We have used both ROVINS as well as PHINS with both GAPS and HiPAP systems for positioning of ROVs and ROTVs. After the firmware upgrade about a year ago the real time data from the PHINS was improved a lot. The post processed data has always been very good.
The combination of ROVINS and GAPS has been so good that we are planning to have this as a standard setup on all ROV and towed platforms,
At the moment we try to resolve an equally good solution for the depth filtering. We have not yet tried the wave filtering in the ROVINS but hope that this will solve our issues."
Jonas Andersson, June, 08th 2012
MMT,
R&D Manager
Tel: +46 (0)31 762 03 99
Email: jonas.andersson@mmt.se

7.3.3. Testimonial 2 – Metrology SAIPEM

SAIPEM is an international company providing engineering, procurement, project management and construction services to the Oil and Gas industry, with head office located in Italy (ENI group).
SAIPEM trusted iXBlue for providing a subsea metrology tool based on RAMSES, PHINS and DVL.
Merging inertial and acoustic technologies for metrology brings a lot of advantages:

- An inertial + acoustic metrology takes around 4 hours (including ROV dive and recovery) instead of the 24 hours required with classical acoustics metrology
- The solution is accurate and redundant. Multiple indicators provide the user with real time parameters confirming the relevance and quality of the data.



Typical spool piece measurement

Metrology tool used by SAIPEM

"In the aim to optimize subsea metrology operations, SAIPEM chose IXBLUE for its flexibility and its motivation to find the best compromise to reach his customer's purposes.
The chosen solution is the combination of several sensors: an inertial navigation system (PHINS) and a rangemeter (RAMSES).
These equipments are deployed deepwater and are manipulated by ROVs. The robustness and reliability have then been tested during several campaigns.
These sensors were performing considering accuracy and reliability. Manipulated in difficult environments, these equipments were also very robust.
We are very satisfied with it."
Laurent de Kervasdoué , May, 25th 2012
SAIPEM SA,
Surveying & Positioning
Tel: +33 (0)1 61 37 81 85
Email : Laurent.DE-KERVASDOUE@saipem.com

7.3.4. Testimonial 3 – IFREMER Complete positioning system

IFREMER, the French Research Institute for Exploitation of the Sea (Institut français de recherche pour l'exploitation de la mer) is an oceanographic institution in France with worldwide exposure.
IFREMER focuses its research activities in the following areas:

- Monitoring, use and enhancement of coastal seas
- Monitoring and optimization of aquaculture production
- Fishery resources
- Exploration and exploitation of the oceans and their biodiversity
- Circulation and marine ecosystems, mechanisms, trends and forecasting

- Engineering of major facilities in the service of oceanography

IFREMER operates different vessels and subsea vehicles (ROV and AUV). They recently decided to upgrade all their subsea positioning systems with latest iXBlue products including GAPS, POSIDONIA, RAMSES and PHINS.

Some pictures of IFREMER assets:

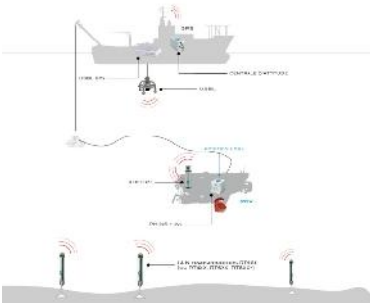
IFREMER's vessel "Pourquoi Pas?"

IFREMER's vessel "Europe"

IFREMER's NAUTILE

IFREMER's ROV (VICTOR)

The same Inertial & Acoustic positioning system described throughout this document is now installed on several vessels and vehicle and successfully operated, with a global project to implement a common hardware and software navigation solution on the whole fleet.



"IFREMER, for scientific applications, operates acoustic positioning systems (USBL and LBL). To solve obsolescence issues, IFREMER chose IXBLUE products (PHINS + POSIDONIA + RT900 + RAMSES) that meet the requirements for scientific applications.
This new system is installed on 2 vessels and have performed scientific campaigns since March 2011.
Systems are simple to use and easy to deploy. Web-based MMI are intuitive.
The positioning accuracy of subsea vehicles is in the specification that IXBLUE announced.
The feedback from surveyors is positive both in the simplicity to use it as the quality of the positioning."

Toussaint EDMOND, May, 28th 2012
IFREMER
Manager of the modernization project of subsea positioning systems
Tel: +33 (0)4 94 30 48 00
Email: Toussaint.Edmond@ifremer.fr