iXblue Corporate presentation
Independent, High-Technology, Industrial Company

600+ employees

120M€+ turnover

80% export

Founded in 2000
Global Footprint

12 offices worldwide
Products & Services

- Specialty fibers and components
- Underwater acoustic communication and positioning
- Sonars
- Modulation solutions
- Motion simulators and Pan & Tilt
- Ships and drones
- Inertial sensors
- Navigation systems
- Sea operations
- Artificial intelligence
ixblue in France

- Lannion:
  - Specialty Fibers
  - Accelerometers
  - Navigation

- Brest:
  - Underwater Acoustic Positioning
  - Acoustic Labcom

- Bonneuil-sur-Marne:
  - Motion Simulators & Stabilized platforms

- Saint-Germain-en-Laye:
  - Navigation Headquarters

- Besançon:
  - Integrated Optics

- St-Etienne:
  - Hardened optical fibers Labcom

- Six-Fours-les-Plages:
  - Artificial Intelligence Robotics

- La-Ciotat:
  - Sonars
  - Sea Operations Shipyard

- Bordeaux:
  - Cold Atoms Labcom

- 9 industrial sites

- R&D and Production

- 3 Joint Research Laboratories

- Several EEC R&D programs
Our products are used from the depths of the oceans to outer space in very diverse applications. We encourage strong cross-fertilization, technical and methodological synergies between those applications.
Our vision

We master the key technologies for the development of autonomous vehicles, marine exploration and photonics. In these fields, we contribute to the mutations of the world and we open up new horizons. On and under the sea, underground, on land, in the air and in space.
Subsea Positioning and Communication
CANOPUS system
Principles of subsea positioning

- INS, Inertial Navigation Systems
- LBL, Long BaseLine acoustic positioning systems
- USBL, Ultra Short BaseLine positioning systems
CANOPUS system
Principles of subsea positioning

- In LBL mode...
  - Range measurement to fixed transponders
  - Algorithm calculates the resulting position
  - Possible combination with inertial navigation system:
    - Robustness
    - Sparse array navigation
    - Increase positioning accuracy

- Require to deploy fixed transponders on the seabed
- Require to box-in the fixed transponders
- Decimetric positioning accuracy whatever the water depth
- Autonomous positioning method
CANOPUS system
Principles of subsea positioning

- In **USBL** mode ...
  - ✔ Slant range + bearing estimation
  - ✔ Estimation of the position of the transponder
  - ✔ Possible combination with inertial navigation system:
    - • Robustness
    - • Increase positioning accuracy

- Does not require to deploy fixed transponders on the seabed
- Does not require to box-in the fixed transponders
- Positioning accuracy is a % of slant range
- Position of the transponder is known remotely
CANOPUS system
Principles of subsea positioning with an INS
CANOPUS system

iXblue offer

- Master each technology individually
- Combine them and provide a robust system
- Reach simplicity and performance
# CANOPUS system

A range of sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAPS</td>
<td>The fully integrated, portable and pre-calibrated USBL for universal applications</td>
</tr>
<tr>
<td>POSIDONIA</td>
<td>Long range USBL positioning system</td>
</tr>
<tr>
<td>INS</td>
<td>A range of FOG based INS for all applications</td>
</tr>
<tr>
<td>RAMSES</td>
<td>An Acoustic Synthetic BaseLine positioning system, a complementary approach to LBL</td>
</tr>
<tr>
<td>Transponders</td>
<td>Low or medium frequency transponders to operate with iXblue acoustic systems</td>
</tr>
</tbody>
</table>
Introduction to Sparse-LBL

USBL
- Ultra-Short BaseLine
- Range and bearing measured.
- Combined with Position attitude and heading.
  ➔ USBL with integrated INS give best performances

WEAKNESS:
- Range dependent accuracy
- Surface based system ➔ Vessel required
Introduction to Sparse-LBL

LBL
- Long BaseLine
- Position computed from ranges to known seabed transponders

WEAKNESS:
- More than 3 Transponders required to produce a single position
- Time consuming calibration
- Low time-stamping precision
- Slow update rate (<1Hz)
Introduction to Sparse-LBL

Sparse-LBL concept
- Acoustics-Inertial coupling to overcome LBL limitations
- Each and single range is used by an INS to help navigation

⇒ Accurate positioning ultimately achieved with a single transponder
System Architecture

Connection diagram

1. Seamless integration with IXBlue range of INS
2. Minimum connection: 12-36VDC power
   Ethernet link
3. RAMSES module available in OEM version
4. One single module for USBL, LBL & sparse positioning
   + SLAM Calibration
Both C-PHINS and RAMSES algorithms are based on Kalman filtering techniques.

- INS Kalman filter is dedicated to navigation
- RAMSES Kalman filter can
  - Compute its own position
  - Calibrate a set of transponders (SLAM)

When coupled to C-PHINS INS:
- **INS navigates** using RAMSES ranges
- **RAMSES calibrates** using INS positions
- **RAMSES QC INS position**, to fix it if required

Dual Kalman architecture offers an optimum flexibility to upgrade a standard navigation system with Sparse-LBL capability.
CANOPUS Software

Plan
Prepare the job (how many TP’s, where, expected performance, etc).

Deploy and calibrate
Configure and calibrate.

Operate and monitor
Produce QA/QC, reach expected performance, Raise alarms.

Post-process
Improve performance and additional QC.
CANOPUS Software

**Plan**
Prepare the job (how many TP’s, where, expected performance, etc).

**Deploy and calibrate**
Configure and calibrate.

**Operate and monitor**
Produce QA/QC, reach expected performance, raise alarms.

**Post-process**
Improve performance and additional QC.
CANOPUS Software

Plan
Prepare the job (how many TP's: where, expected performance, etc.).

Deploy and calibrate
Configure and calibrate.

Operate and monitor
Produce QA/QC, reach expected performance. Raise alarms.

Post-process
Improve performance and additional QC.
CANOPUS Software

**Plan**
Prepare the job (how many TP’s, where, expected performance, etc).

**Deploy and calibrate**
Configure and calibrate.

**Operate and monitor**
Produce QA/QC, reach expected performance. Raise alarms.

**Post-process**
Improve performance and additional QC.

iXblue
CANOPUS Software

Plan
Prepare the job (how many TP’s, where, expected performance, etc).

Deploy and calibrate
Configure and calibrate.

Operate and monitor
Produce QA/QC, reach expected performance. Raise alarms.

Post-process
Improve performance and additional QC.
Tests at sea
Sparse navigation
Shallow water
**IXBLUE CANOPUS**

Typical Navigation Performance

**INS / DVL-BT**
- Travelled distance: 6 000 m
- Speed: 2,5 knots

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS $1\sigma$</td>
<td>0.29m</td>
<td>0.25m</td>
<td>0.39m</td>
</tr>
<tr>
<td>Mean (bias)</td>
<td>0.49m</td>
<td>0.21m</td>
<td>0.53m</td>
</tr>
</tbody>
</table>

Metric precision, function of the travelled distance and of the considered trajectory

$Max \ error \sim 1,2 \ m \ with \ 6000 \ m \ max \ horizontal \ distance \ (\Leftrightarrow 0.02\% \ T.D)$
IXBLUE CANOPUS
Typical Navigation Performance

INS / DVL-BT / Sparse LBL (1 x TP)
+ forward/backward Post Processing
  - One single TP used

INS / DVL / LBL (1xTP)
≡ Smooth error
   No drift

≡ Live non drifting navigation
Precision almost equivalent to the one achievable with a full LBL array

Post-processing brings back full accuracy: smooth navigation, with rare error pikes

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS 1σ</td>
<td>0.10m</td>
<td>0.12m</td>
<td>0.15m</td>
</tr>
<tr>
<td>Mean (bias)</td>
<td>0.05m</td>
<td>-0.05m</td>
<td>0.07m</td>
</tr>
</tbody>
</table>
Tests at sea
Sparse navigation
Deep water
Results at sea

Integration on Ifremer EUROPE vessel
GAPS mounted on a pole, coupled to DGPS

IdefX AUV equipped in standard with
- C-PHINS in AUV dry compartment
- RDI DVL, CTD in wet section
- KM EM2040 multibeam echo sounder

Ramses temporarily integrated in wet section for test duration
Results at sea

Dive, with only 1x aiding transponder

✓ Real time observation:
  ✓ Small drift in water column, w. AUV on top of the transponder...
  ✓ ... which is then perfectly compensated when reaching seabed
✓ No USBL fix required as well with one single TP
Results at sea

Real Time navigation performances over the dive:

- Reference = RAW USBL data
- <5m match “only” to USBL reference is achieved...
- With part of error coming from the USBL itself!
Results at sea

Isobath continuity between lines and surveys illustrate geo-referencing quality
Results at sea

- Experience full scalability of the system to define advanced work procedures
  - Mission planning (required amount of TP, required mooring length to cover all survey area)
  - Transponder deployment + fast calibration
  - USBL aiding during AUV launch (helps nav in area corner)
  - During AUV navigation vessel is free to deploy other vehicles
  - USBL aiding during AUV recovery
  - Immediate availability of survey results to plan next dives...
  - ... while data can be post-processed to further enhance navigation to full merge of USBL points

Real time sparse-LBL over tens of km², using 2 TP only
A case study
Deep sea mining
A case study: Deep sea mining

Positioning of various AUV and ROV ... in a very complex environment
A case study: Deep sea mining

Required equipment
A case study: Deep Sea Mining

Transponder placement and visibility map
A case study: Deep Sea Mining

From the visibility map to positioning accuracy estimation
iXblue subsea positioning

- Reduction of the number of transponders on the seabed
- Robust and efficient acoustic data link between subsea devices and from subsea to surface
- Intuitive and up to date tools
- Performant and field proven hardware
Thank you!