



Sparkling innovation in marine seismic sources technology

April 2022



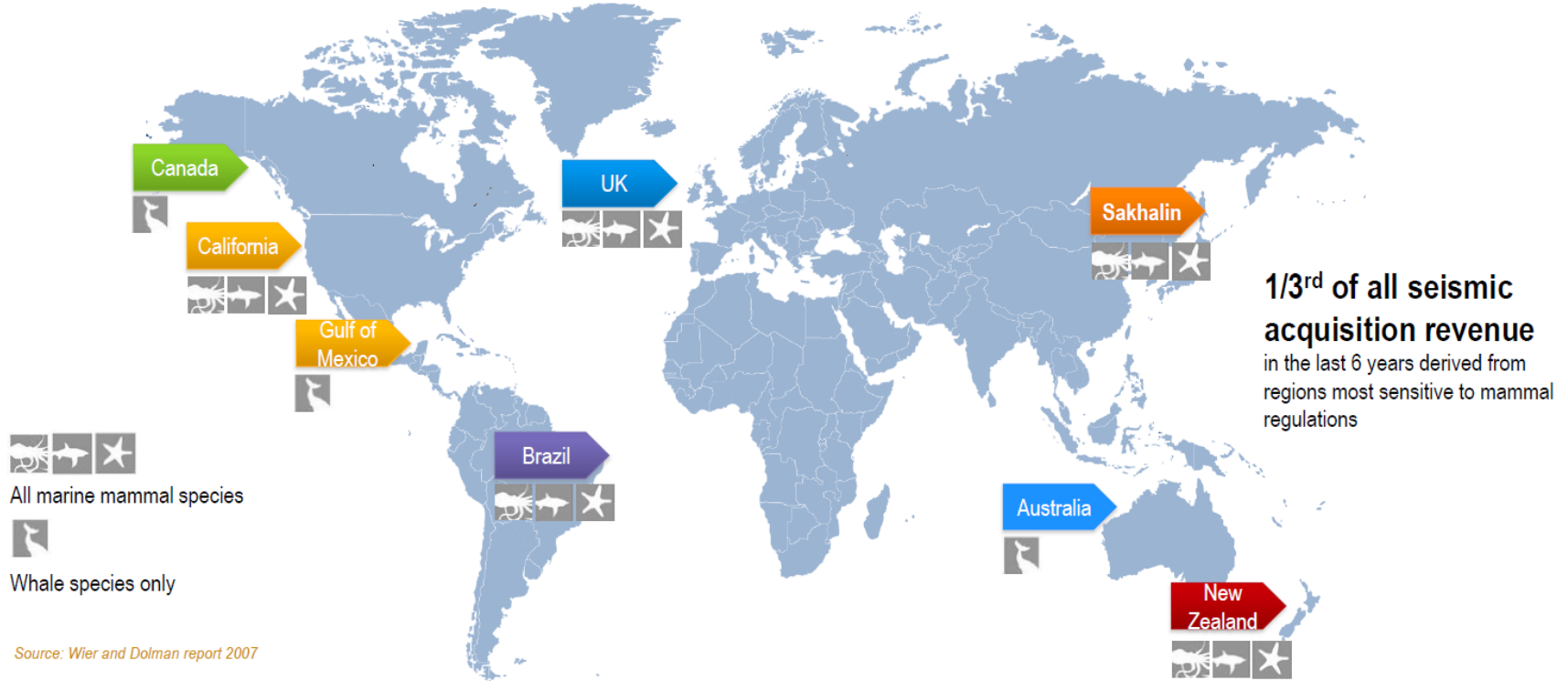
Aberdeen Section

Nicolas Tellier, Chief Geophysicist



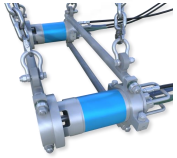
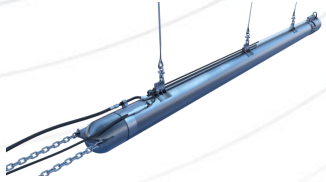
FOREWORD

Expanding marine mammal regulations worldwide



Source: Wier and Dolman report 2007

SUMMARY



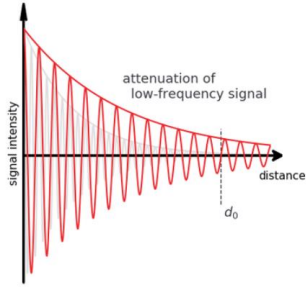
1. The Tuned Pulse Source

2. The BluePulse

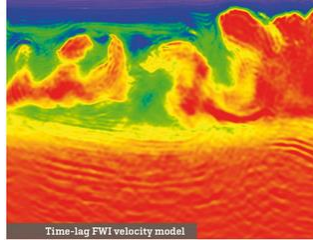
3. Marine Acquisition System update

4. Take away message

Added value of low frequency data



Low frequency waves attenuate and scatter less than high frequency waves...



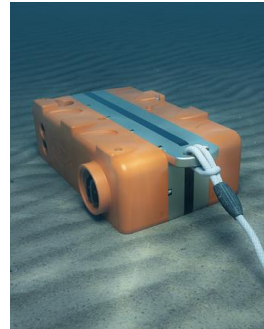
But we need the low frequencies to build velocity models (cycle skips in FWI)



We also need LF data for building blocky earth models...



...and for resolution



Thus, we need low frequency receivers:

- Solid- slanted- and multi-sensor- streamers
- And of course OBN (much better in LF with MEMS)

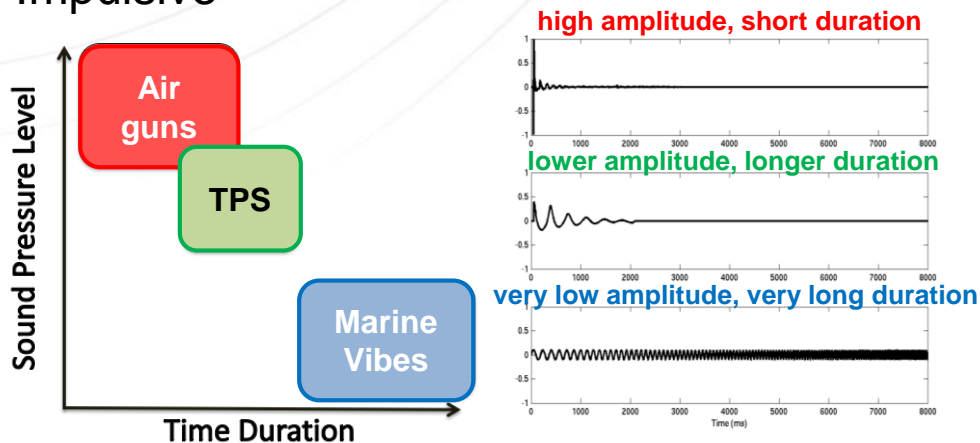


➤ **And also low-frequency sources**

Tuned Pulse Source (TPS) overview

The TPS is a pneumatic source:

- Impulsive



- Low Pressure (1000 psi)
- Large Volume (now 28000 in³)
- New design features



7.5 meter long
2 meters bubble radius



- ✓ More low frequency signal
- ✓ Less High frequency noise

CONFIDENTIAL

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Endurance Test: “Flip-Flop” 50 x 50 meters shot carpet (18 second video)



Sea operational & geophysical validation

Acknowledgment to Shell

Initial project funder
& 1st customer



Plug-and-play on available vessels

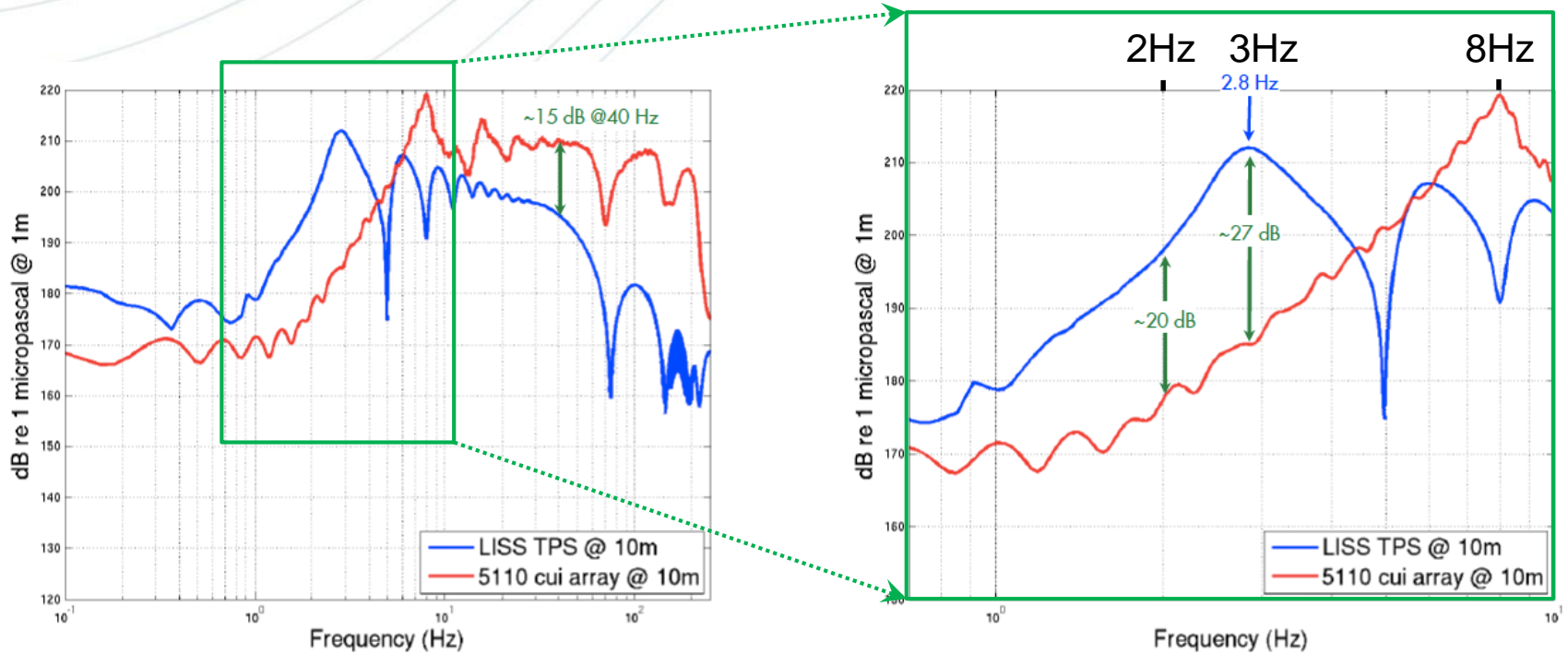
2020 "Sea Trial"
Booms and rigid floats



2021 "Endurance Test"
Slipway with flexible floats

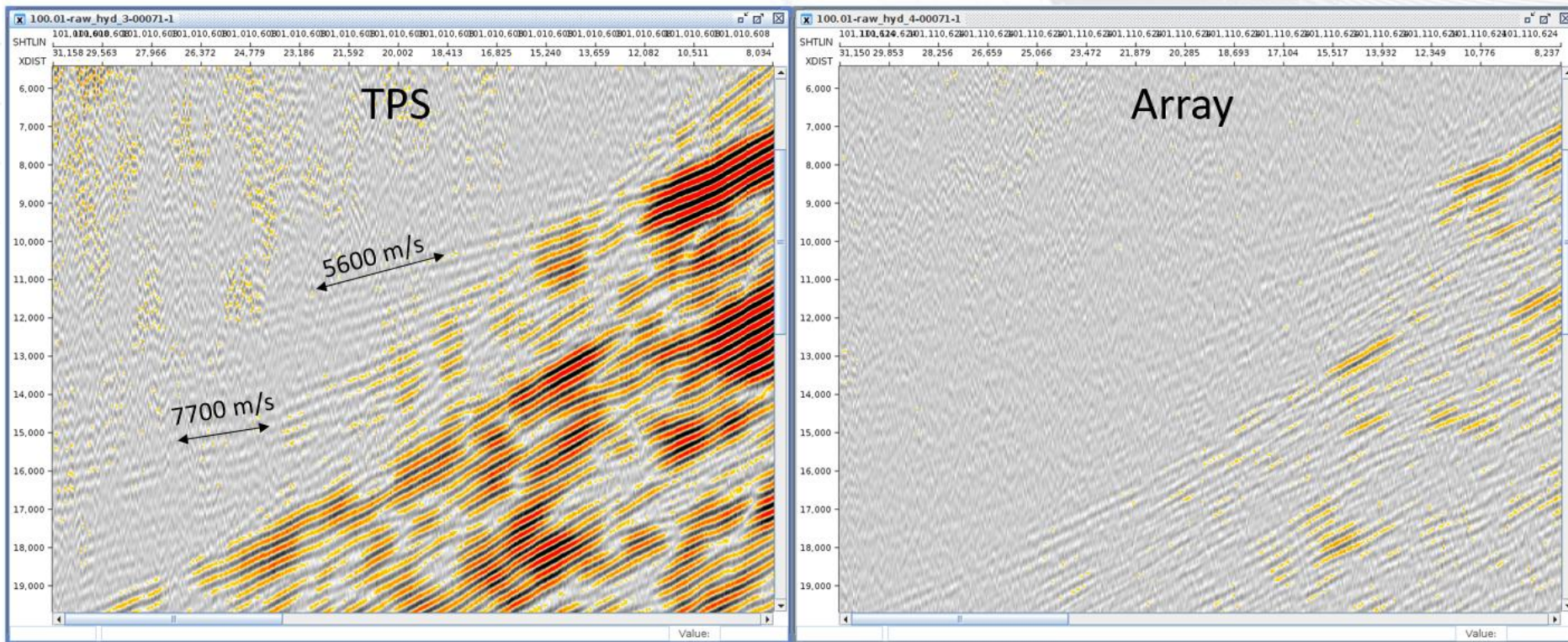


Spectra - TPS vs Conventional Array



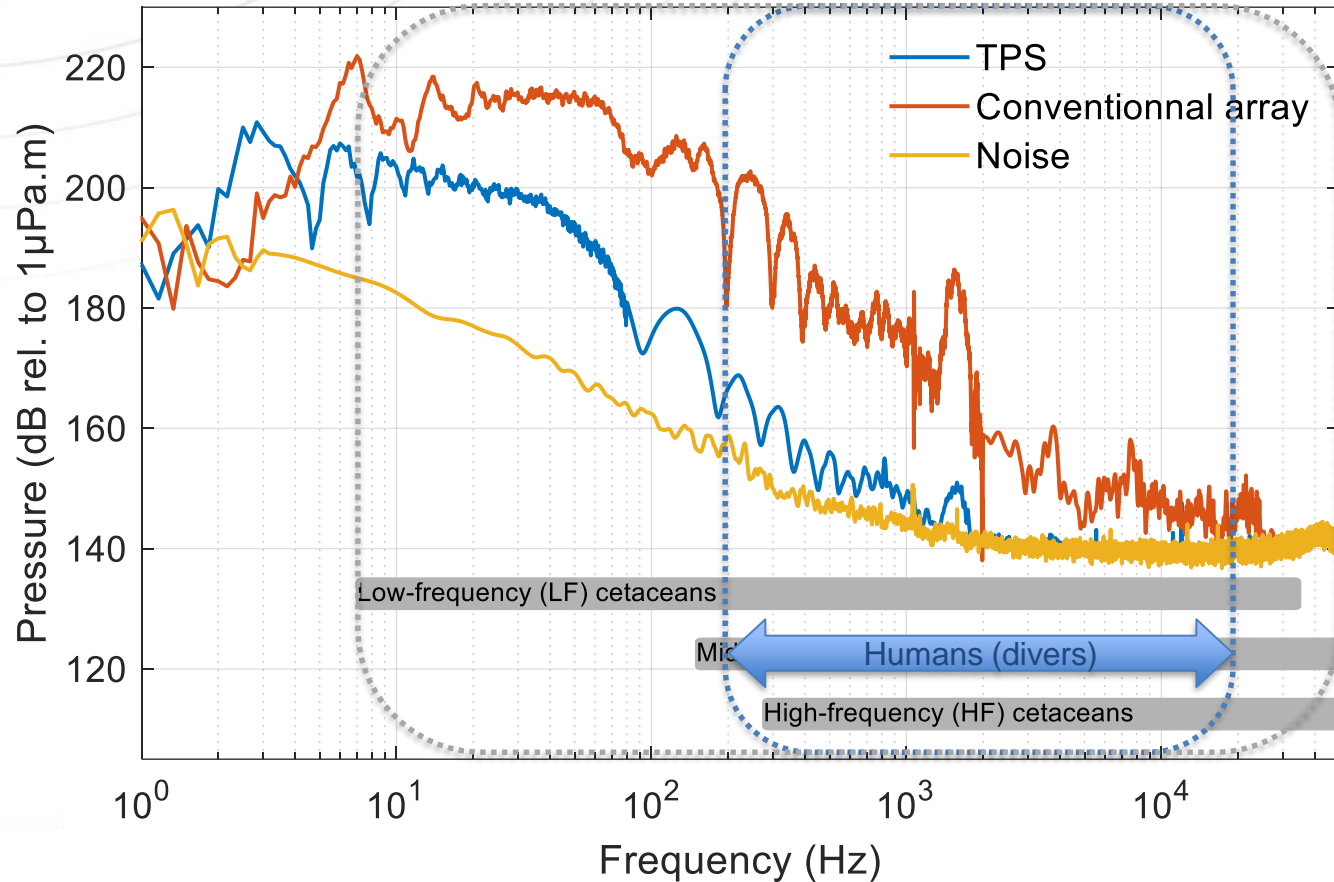
- ✓ Over 20 dB stronger at 1-3 Hz (infra-sound)
- ✓ Over 15 dB weaker above 40 Hz (sound)

Imaging - TPS vs Conventional Array



From “Sea trial of a low frequency enhanced pneumatic source - EAGE 2021 (LISS, SHELL)

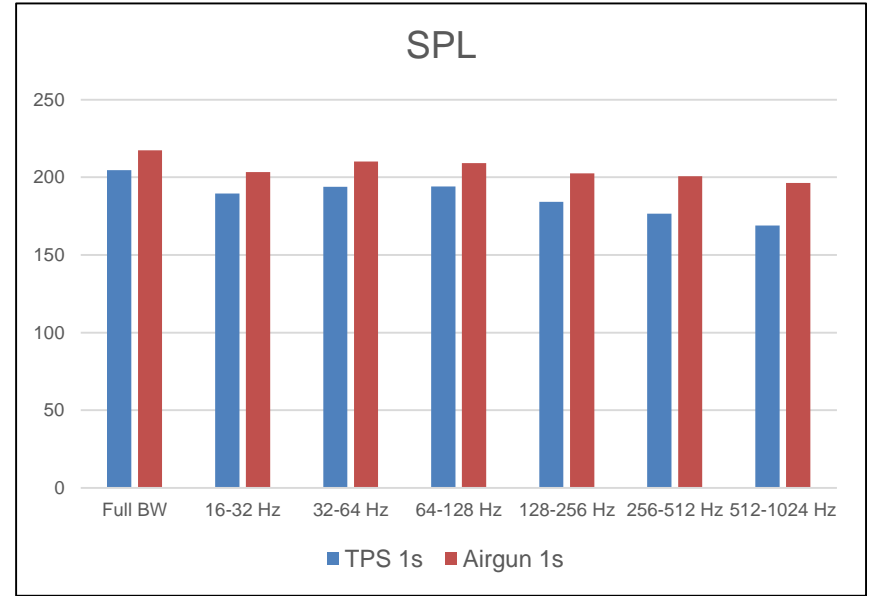
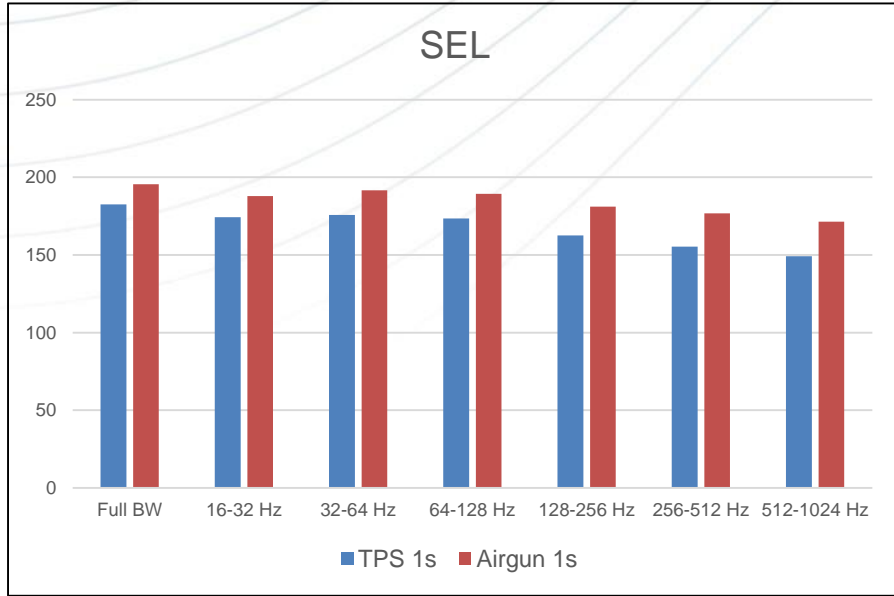
Sea life (and permitting ...for a 28,000 cuin source!)



Ambient noise:
TPS: @ 1.5 kHz
Airguns: @ 30 kHz

TPS' spectrum is 20dB+ lower than Airguns' on most frequencies hazardous for wildlife

Sea life (and permitting ...for a 28,000 cuin source!)



TPS' SEL/SPL are also 20dB+
lower than Airguns' on most
frequencies hazardous for wildlife

What about compressor capacity?

Refilling 28,000 cuin at 1000 psi is more air per shot than 5,000 cuin at 2000 PSI

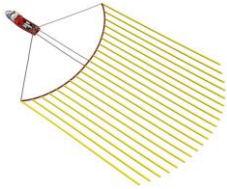
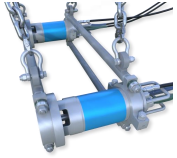
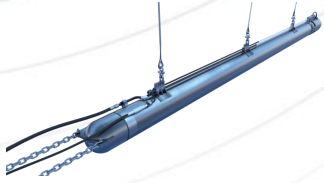


However, recent Shell / Sercel studies demonstrated that:

- The limiting factor is not air compressors, but umbilicals
 - A short (100 m) and thick (1.25 in) hose allows a 26,500 cuin TPS unit to fill to 1000 psi in 25s.
 - TPS is capable to shoot every 25s with almost all types of umbilicals if the accumulator pressure is equal to 1500 psi.
 - Shooting on pressure (i.o. shooting on time or position) possible
- ▶ SEG abstract acceptance pending ⁽¹⁾

(1) SEG 2022 – Shell / Sercel - Low frequency source refilling, umbilical capacity and shooting on pressure

SUMMARY



1. The Tuned Pulse Source

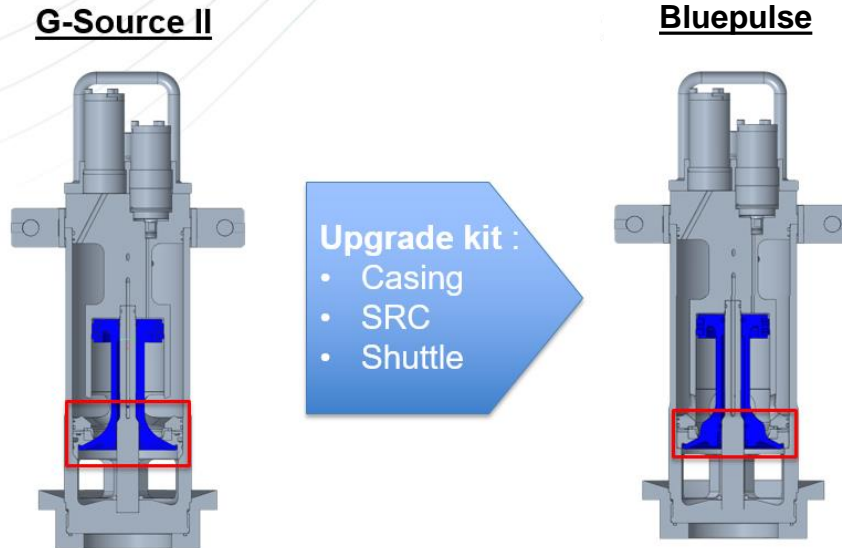
2. The BluePulse

3. Marine Acquisition System update

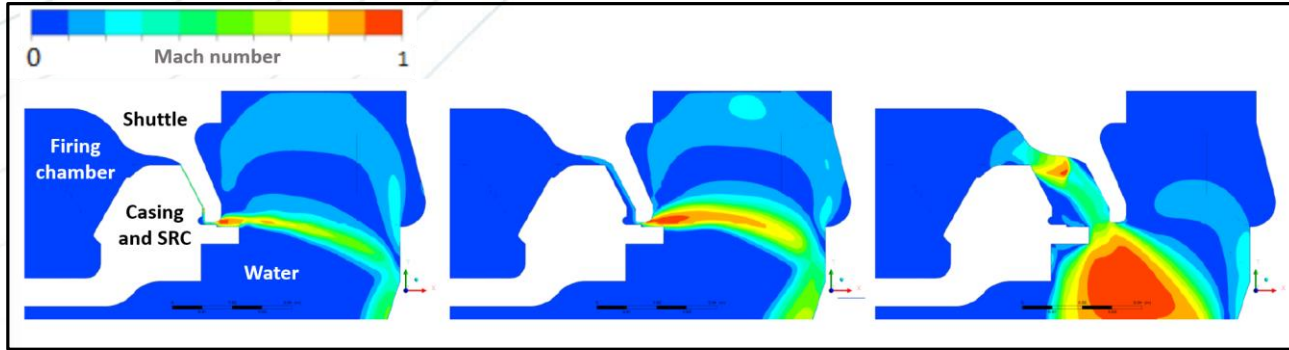
4. Take away message

Overview

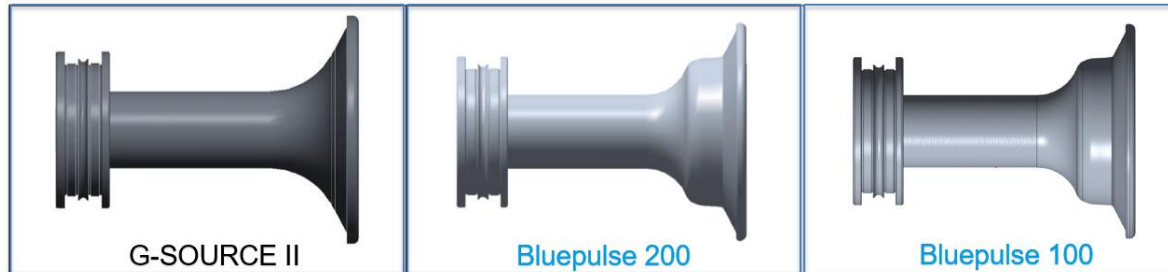
- › An innovative evolution of G-Source II marine source, designed to mitigate environmental footprint of marine acquisitions
- › Available as a dedicated source, or as low cost, straightforward upgrade of G-Source II
- › Same enhanced operation performances as G-Source II



Modelling & Design

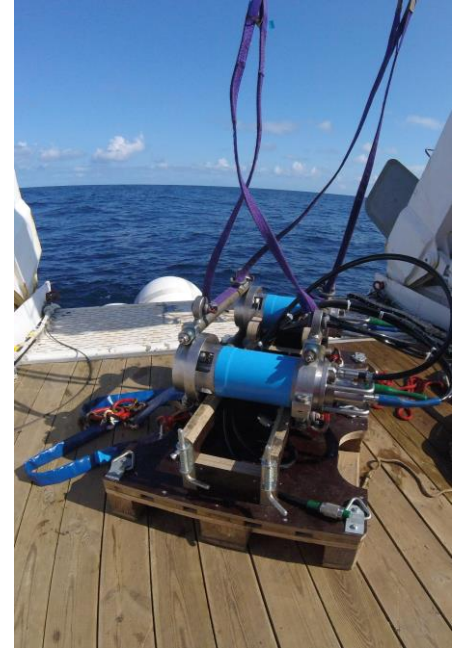
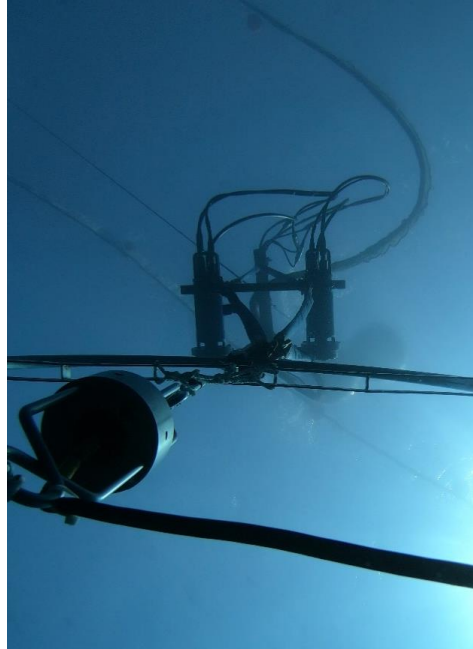
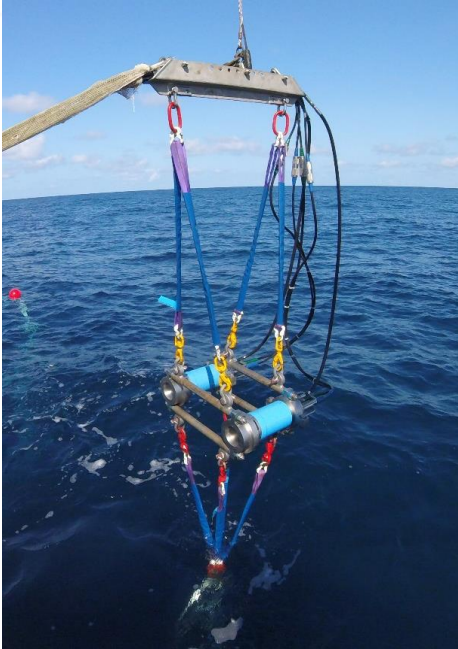


- › Two “S” profiles selected:
 - › Maximization of the pressure of the acoustic peak
 - › Downscaling of the cut-off frequency (down to ~ 200 Hz and ~ 100 Hz).
- › The accurate choice of these two cut-off frequencies was done to suit industry expectancies in terms of signal high-frequency content.



Sea trials and calibration

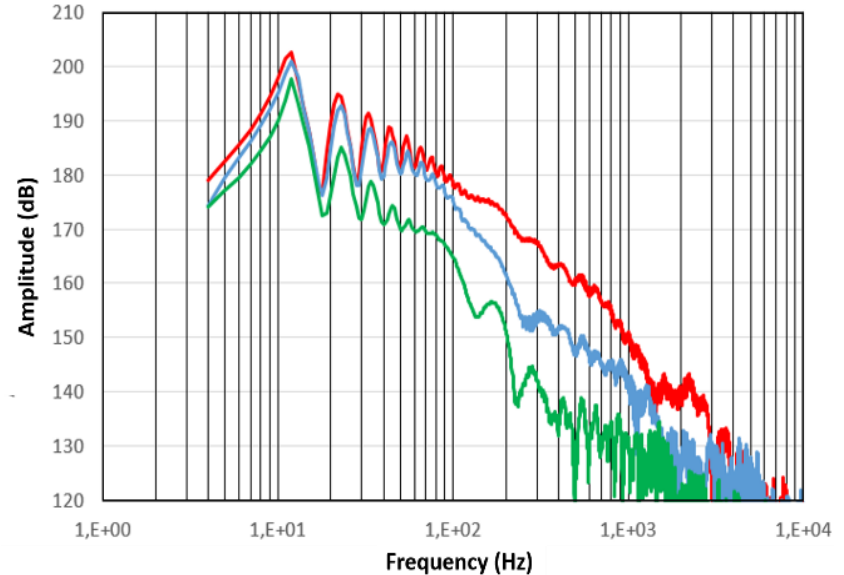
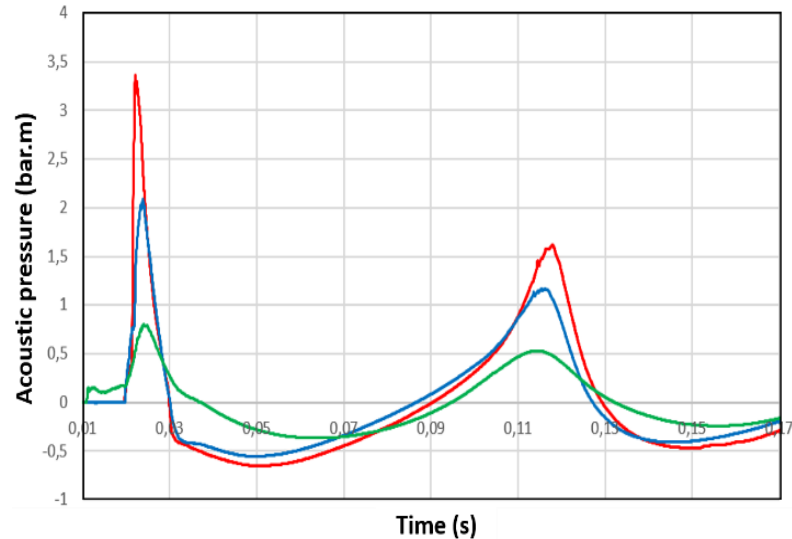
- › Acoustic performances qualified + Full range calibration completed at sea from 2019 to 2021
- › Single/array signature simulation available on request, implementation on Nucleus / GunDalf upcoming



Single source: Near-Field Signature

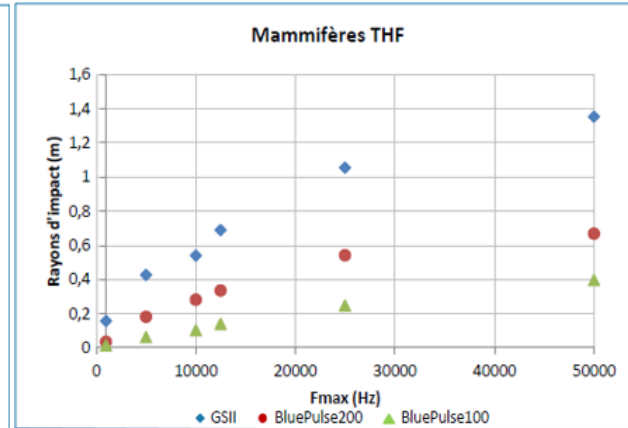
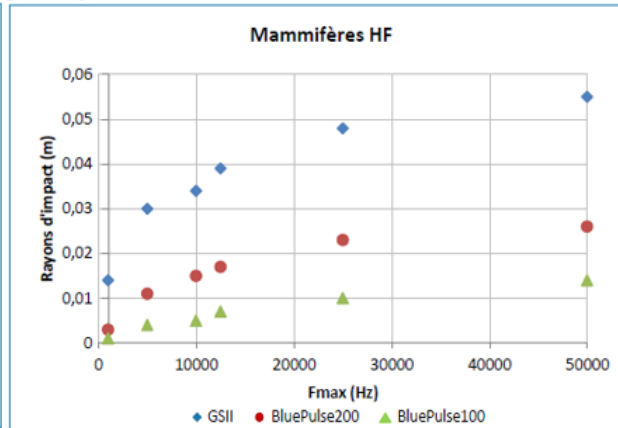
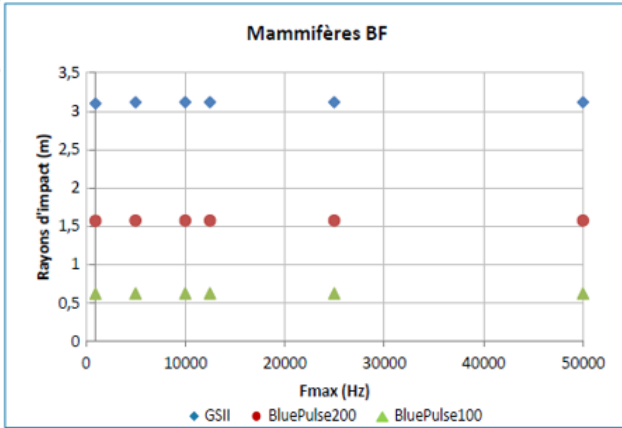
Near-field performances for three 150 cuin. pneumatic sources:

- Standard G-Source II (red),
 - Bluepulse 200 Hz (blue)
 - Bluepulse 100 Hz (green).
- Note the significant difference in slopes at high frequencies, that is directly related to marine life potential disturbance.



SEL / SPL & Exclusion Zone

Impact Radius SELcum: **GSII**, **BP200** and **BP100**, $V=150 \text{ in3}$



Radii for SEL:

$$R_{BP200} \approx \frac{R_{GSII}}{2}$$

$$R_{BP100} \approx \frac{R_{GSII}}{5}$$

Seuils PTS	BF	HF	THF
SPLpk	219	230	202
SELcum	185	183	155

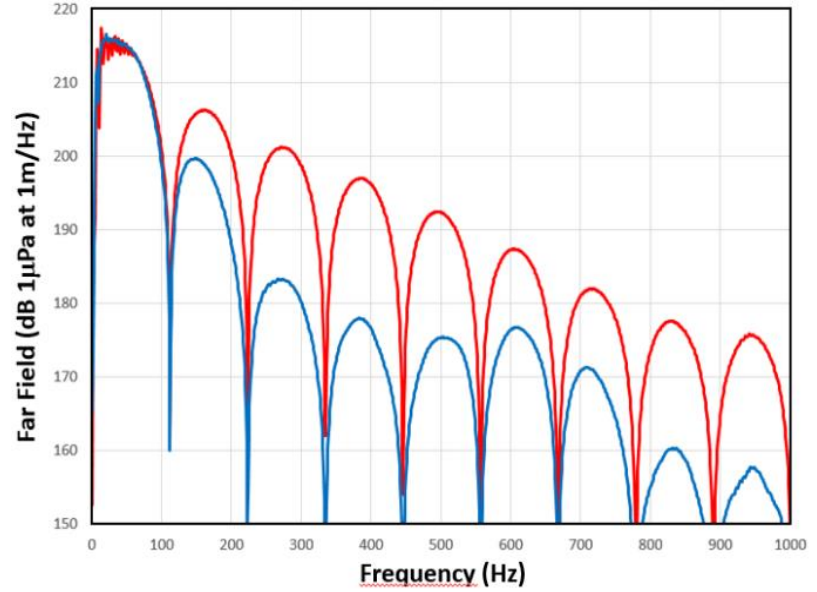
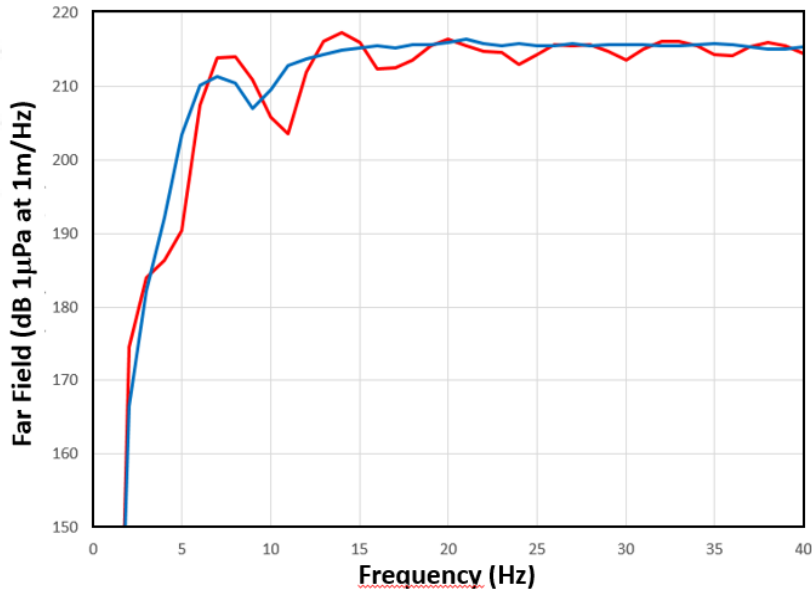
Radii for SPL:

$$R_{BP200} \approx \frac{R_{GSII}}{1,6}$$

$$R_{BP100} \approx \frac{R_{GSII}}{4}$$

Full Array comparison

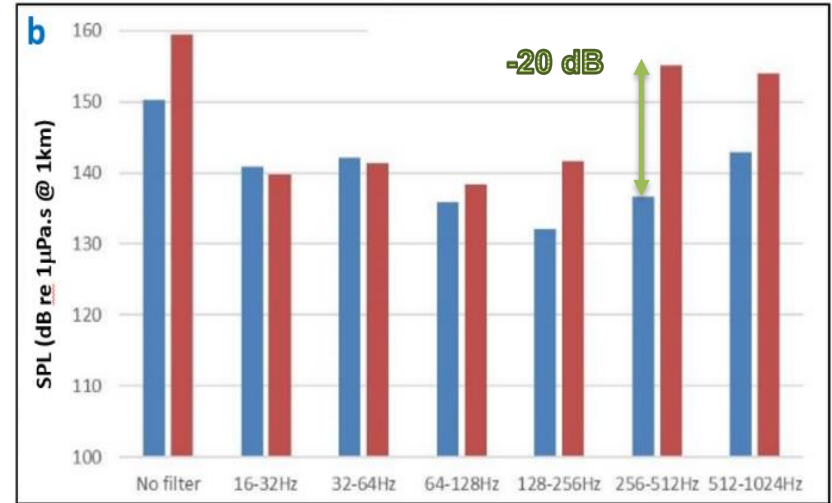
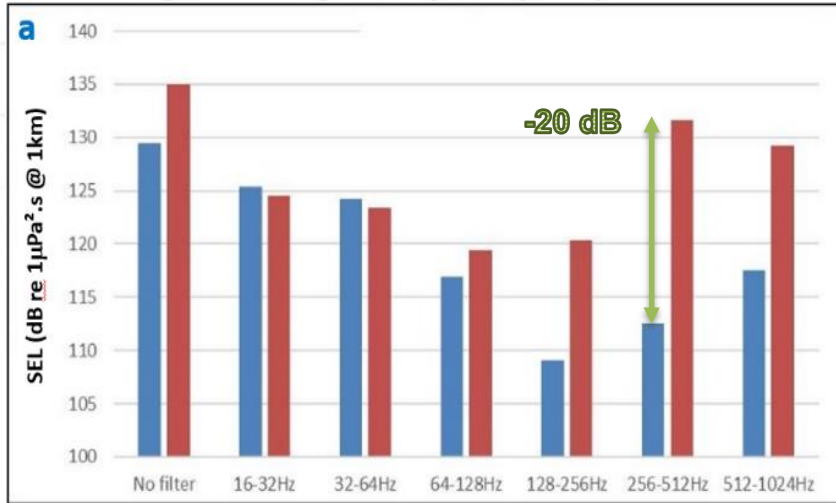
Far-Field Signature



Far Field reconstruction of **Bluepulse 200 Hz (blue)** and conventional **G-Source II (red)** for an array of 4180 cu in at 2000 psi.

Full Array comparison

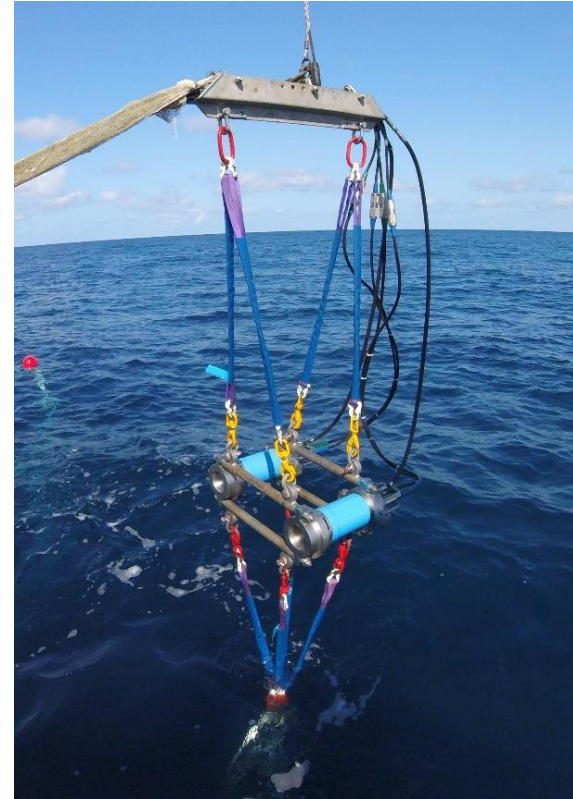
SEL / SPL



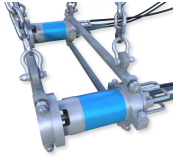
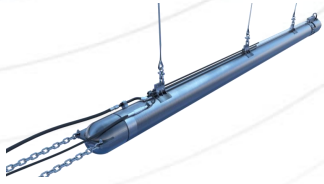
Comparison of SEL (a) and SPL (b) between the conventional **source array (red)** and the **Bluepulse (200 Hz) array (4,180 cu in at 2,000 psi for both arrays)**.

The operational perspective

- ✓ 30% lighter and smaller than current best-in-class industry solutions.
- ✓ Available:
 - As a new source
 - Or as a straightforward upgrade to the existing large installed base of G-Source II (three parts to swap in about 30 minutes)
- ✓ Fully compatible with the most common array sub-harnesses, and with existing equipment inventories (e.g., Mechanical/Electronic Time Break, or Solenoid Valves used to trigger the source).



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HR/UHR 3D: towards sub-meter resolution



Applications



High Resolution (HR)

(to ~1000m):

- ✓ Reservoirs,
- ✓ CCUS,
- ✓ 4D seismic



Ultra-High Resolution (UHR)

(to ~100m):

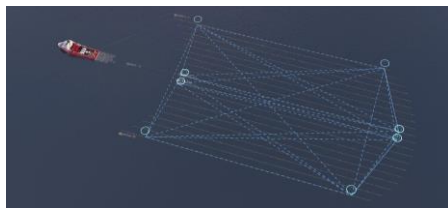
- ✓ Geotechnical site surveys,
- ✓ offshore construction,
- ✓ UXO, geohazards assessment

An industry collaboration



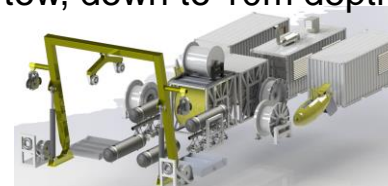
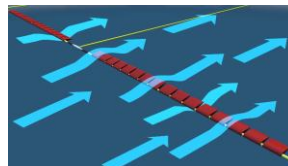
Widespread & proven seismic technologies

- Seal428 Recording system
- SeaPro Navigation system
- QuietSea PAM system compatible
- Any Sentinel streamer



Offshore seismic experts

- Containerized and modular solution, for vessels of opportunity
- Dedicated rigging system (5 knots tow, side deployment)
- Hydrodynamic tow, down to 10m depth



DROP & POP OBN

MicrObsNT

An evolution of the MicrObs node, developed in partnership with Ifremer since 2004.

- A free-fall, self pop-up node rated to 6000 m water depth
- Recovery rate: 99.22% (over 1000's of deployment over ~20 years)
- Launch & Recovery system dedicated to « dense » / high-productivity surveys

State-of-the-art seismic sensors:

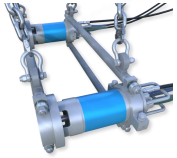
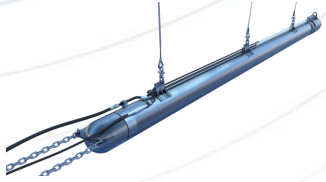
- Sercel hydrophone
- 3C MEMS enabling seismic sensing with:
 - True amplitude ⁽¹⁾
 - True phase ⁽¹⁾
 - True verticality ⁽²⁾
 - True vector fidelity ⁽²⁾



(1) Single-sensor acquisition without data jitter: a comparative sensor study – First Break, Jan. 2021

(2) True vertical and orthogonal OBN sensing with 3C MEMS sensors – 2nd EAGE marine acquisition workshop, Aug. 2020

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TAKE AWAY MESSAGES



Two innovative sources were developed with environmental and geophysical motivations, and are now commercial.

Both were designed as "plug-and-play" solutions, and are compatible with existing equipment inventories.

Their high-frequency output is significantly lesser than conventional air guns:

- ✓ The SEL and SPL associated with shooting operations is 20 dB+ lower
- ✓ Environmental exposure / Exclusion zones can be reduced

The TPS yields unrivalled performances in low-frequency signal generation:

- ✓ Significant added value for Sub-salt, sub-basalt, Full Waveform Inversion (FWI), blocky model building, and improved resolution