Marine Seismic Technology – Greener Methods?

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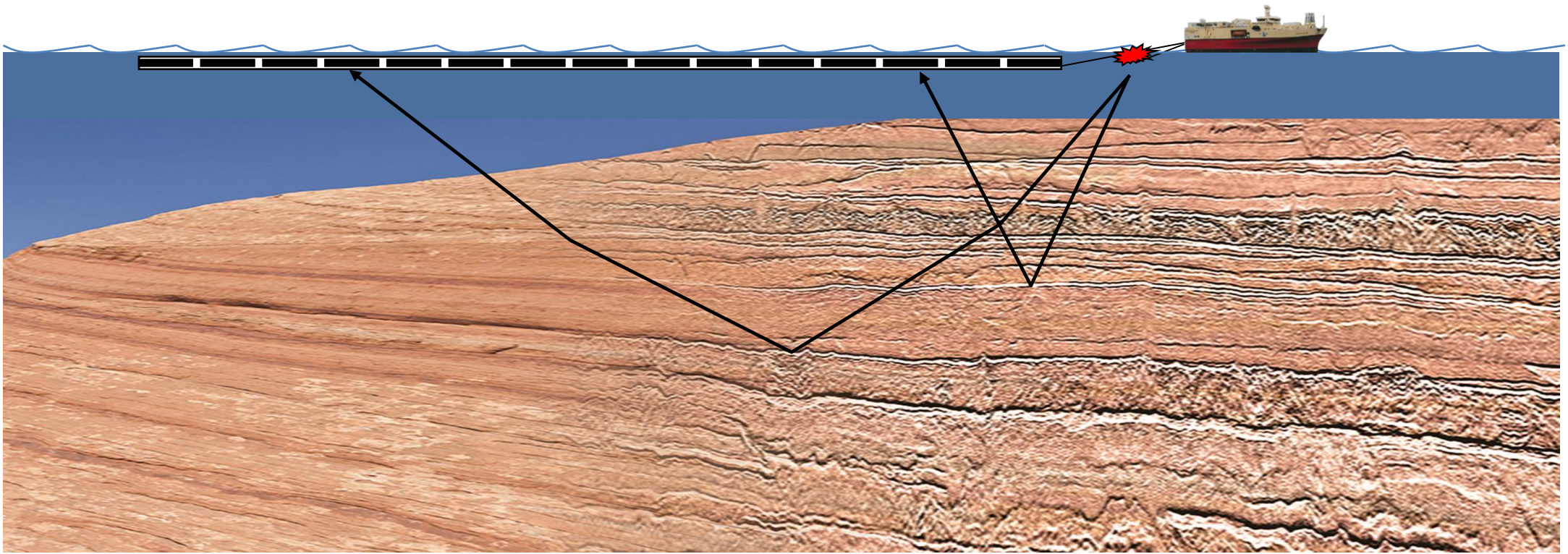
Fisk og Seismikk 2016, 6.-7. April 2016

Outline

- What is Seismic?
- Sound
- Increased Efficiency – Reduced Exposure
- Planning and Mitigation
- Alternative Marine Seismic Sources
- Summary

What is Seismic?



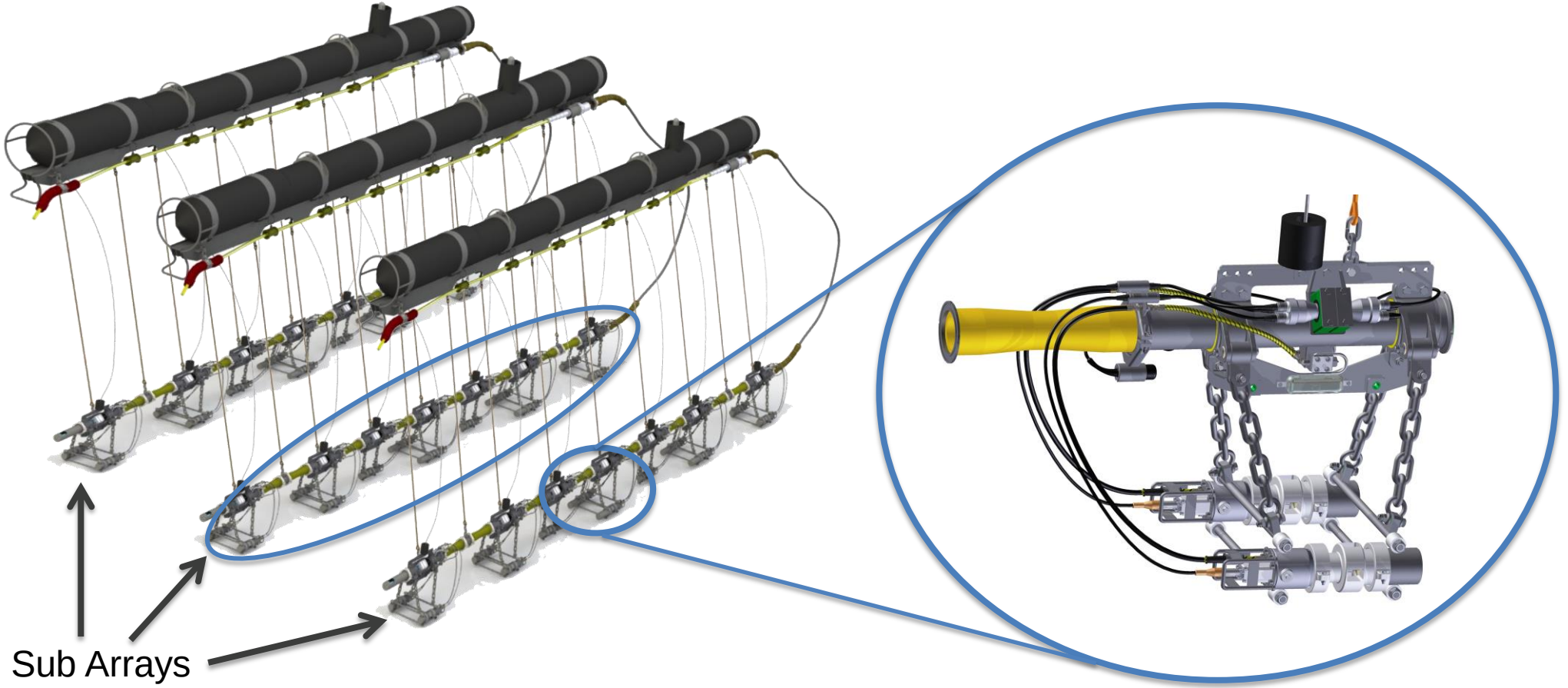
Soundwaves, created by high-pressure air, propagate into subsurface.
Reflected soundwaves from geological interfaces are recorded by sensors mounted in long cables behind the seismic vessel.

Main Elements of an Marine Seismic Acquisition System

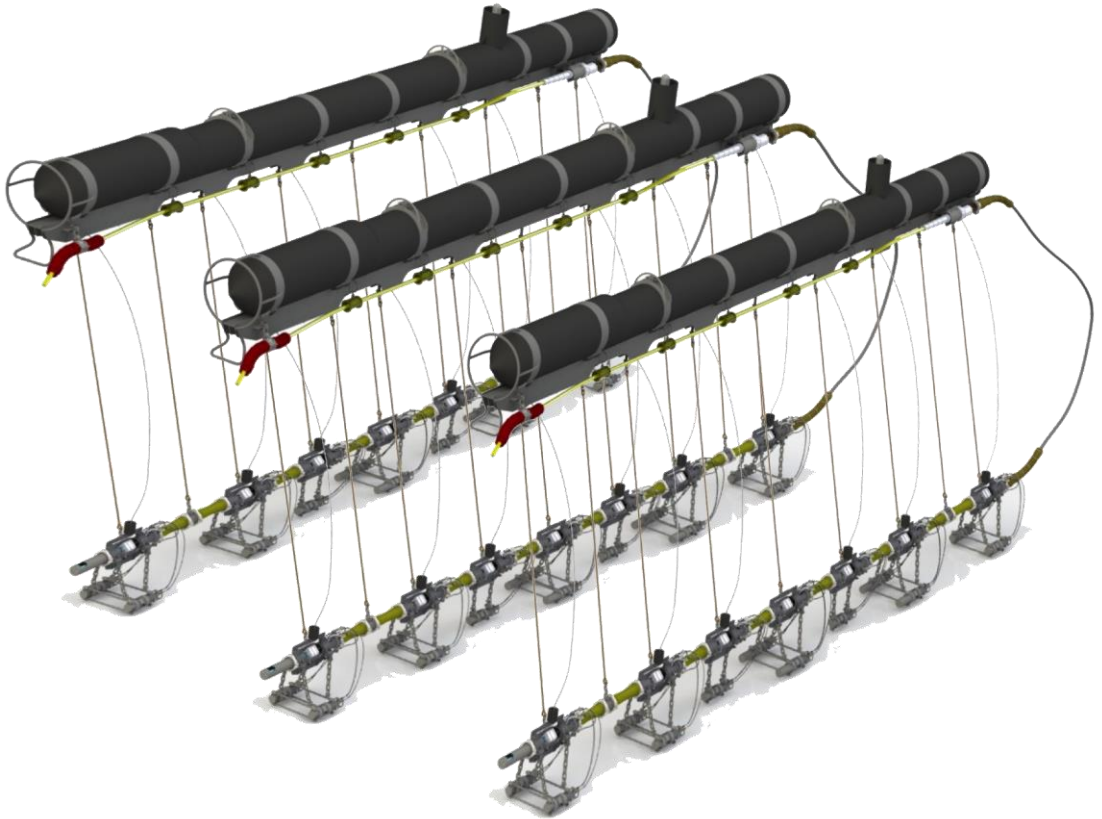
- Marine Seismic Sources:
  - generate sound waves
- Receivers:
  - listening devices (sensors)
- Recording System:
  - store the recorded data

How We Produce Sound: Marine Seismic Source Arrays

Marine Seismic Source Array

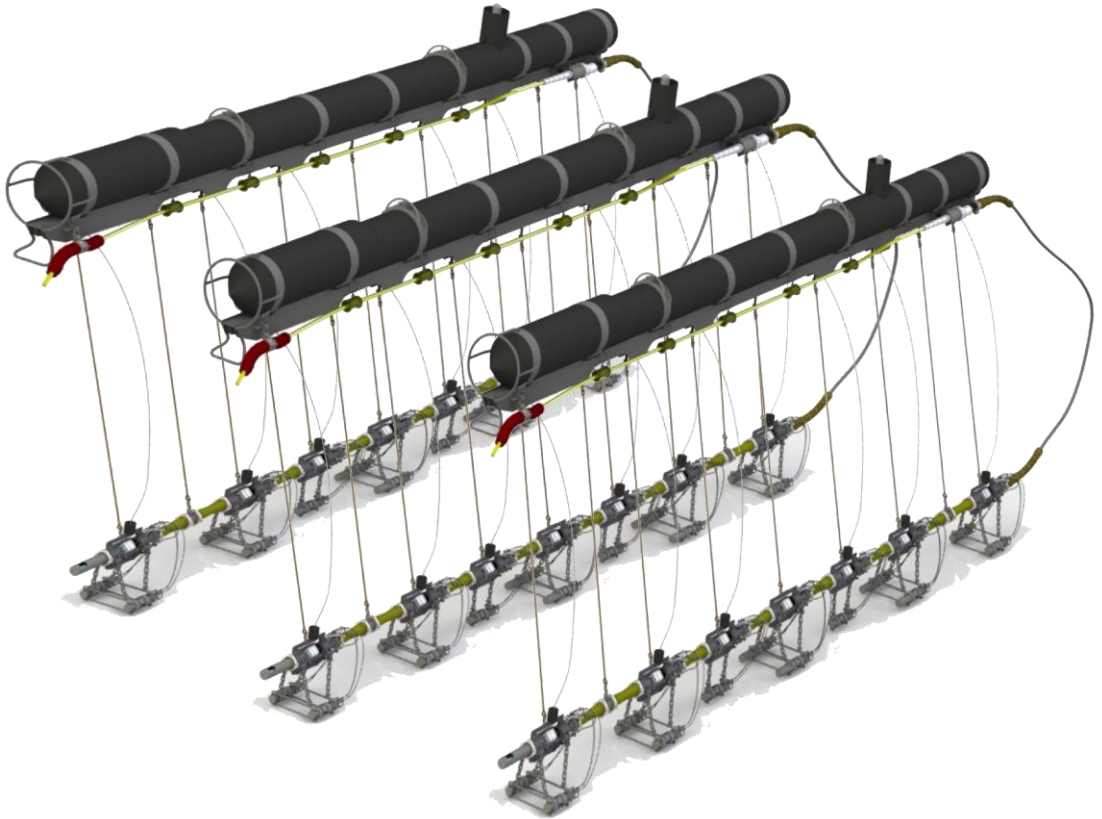


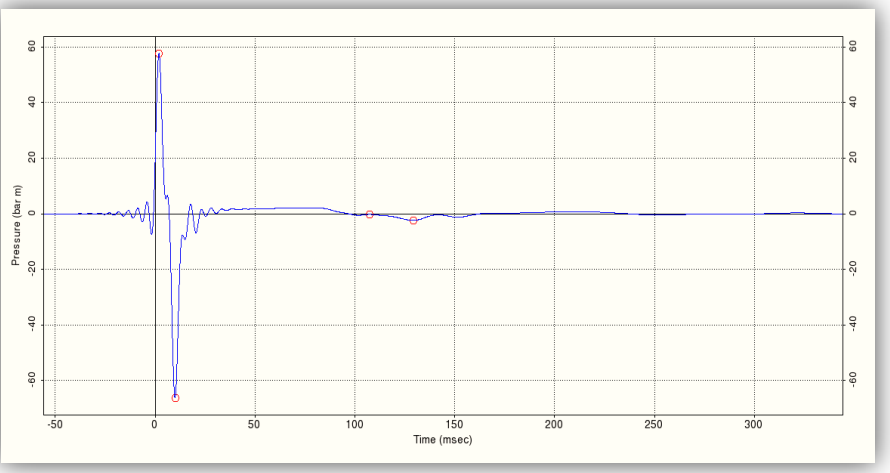
Marine Seismic Source Array: Principles



- High pressure air is released from the seismic source into the surrounding water.
- The air bubble expands and the pressure in the bubble drops below the hydrostatic pressure
- Contracts and the pressure increases
- Oscillates while rising towards the sea surface

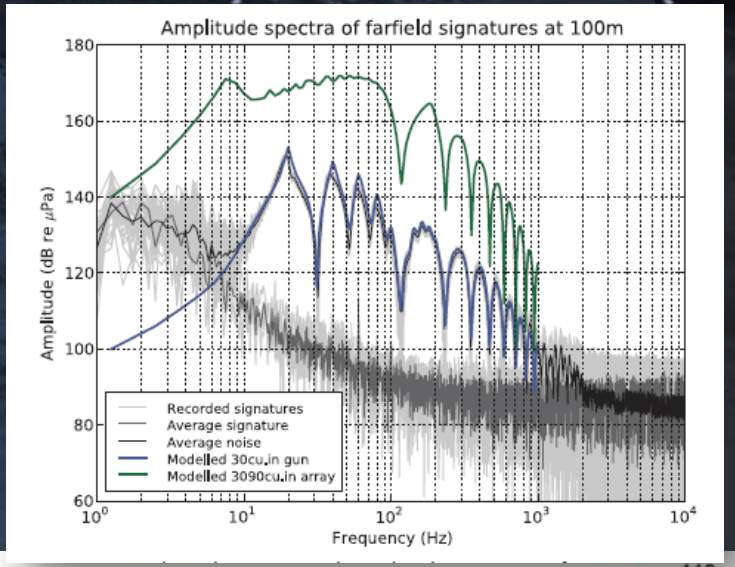
Sound Generated by a Marine Seismic Source

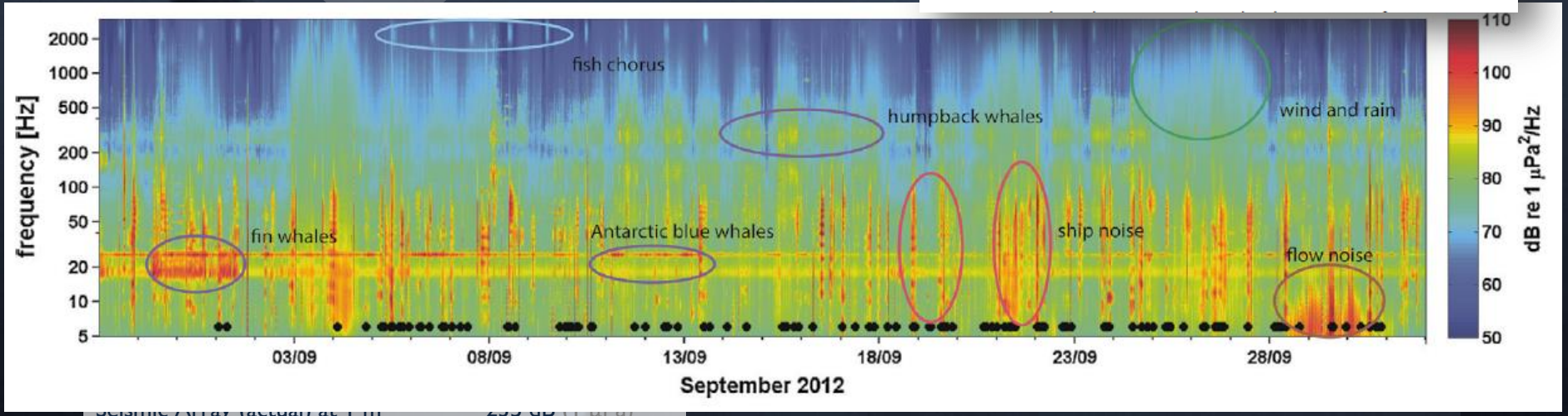




Typical output (sound) from a marine seismic source array.

Impacts of Sound



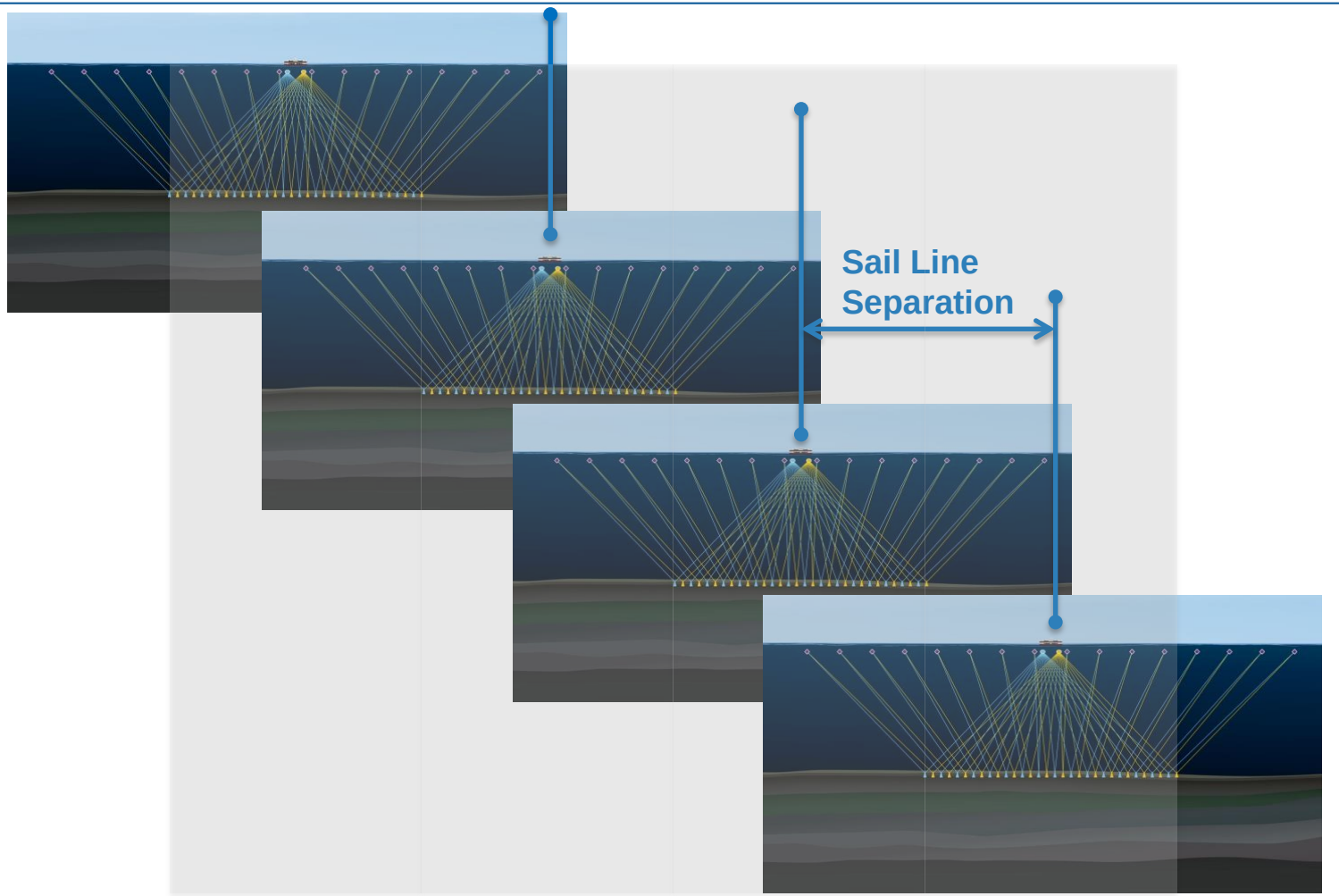


Seismic Array (actual) at 1 m	255 dB (1 µPa)
Sperm whale click	236 dB (1 µPa)
Lightning strike	260 dB (1 µPa)
Undersea earthquakes	272 dB (1 µPa)

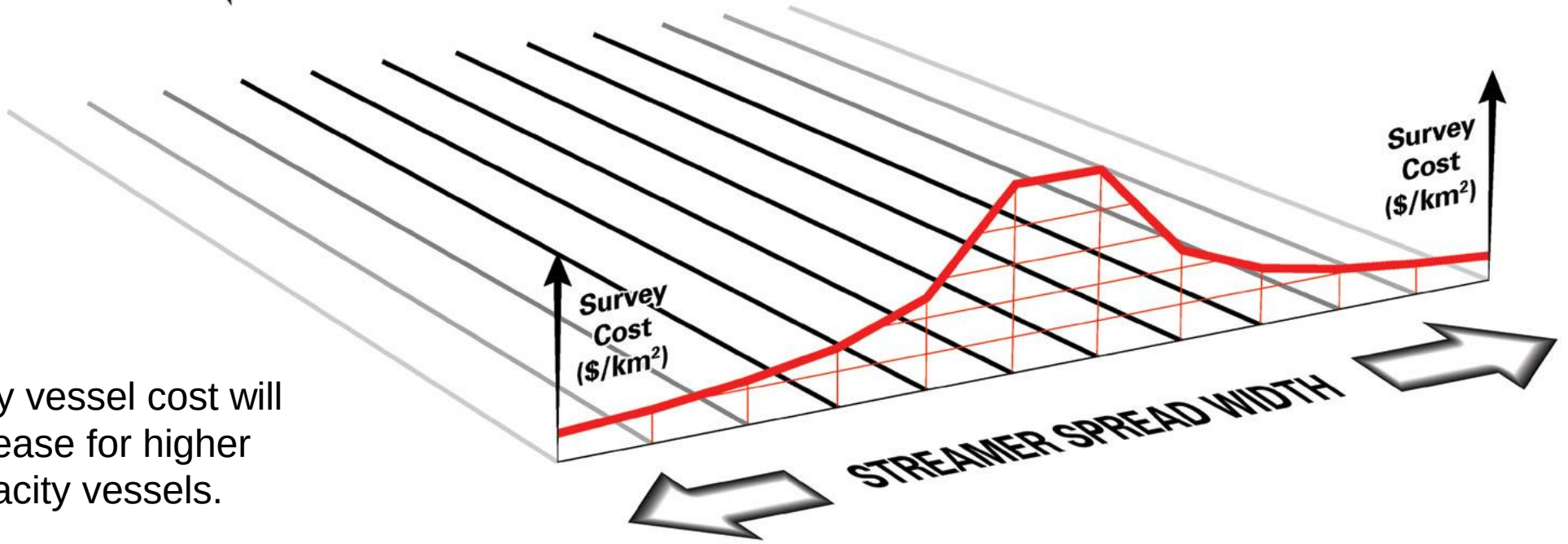
Increased Efficiency → Reduced Exposure

fewer days on each survey results in a smaller environmental footprint

Larger Spreads And Faster Turnaround



Wider tow generally means higher efficiency (and lower cost per km2)



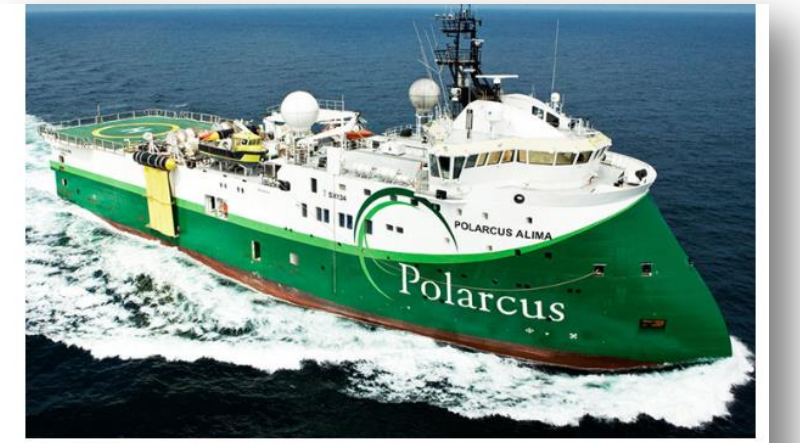
Daily vessel cost will increase for higher capacity vessels.

Ultra-wide Tow 3D Marine Seismic

“Dolphin has just mobilized the 'world's largest floating object' …”

- 12 x 150m
- Spread width of 1850m

source: Dolphin Geophysical (March 2015)



Polarcus Alima

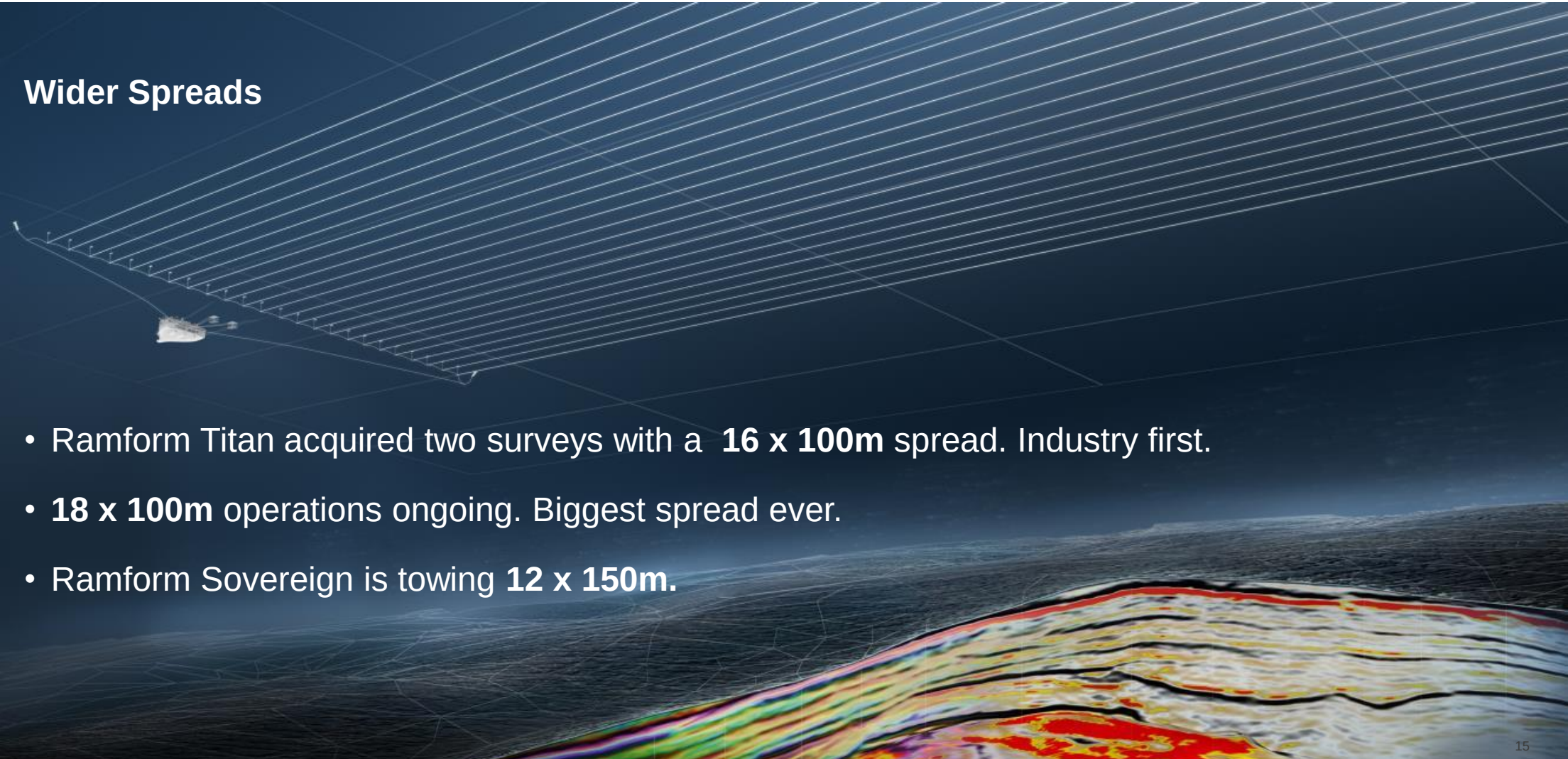
Largest man-made moving object

Polarcus breaks records with its current ultra-wide 3D marine seismic project offshore Myanmar.

- 10 x 200m
- Spread width of 1800m

source: www.geo365.no (January 2016)

PGS Fleet Capability Highlights 2015/2016



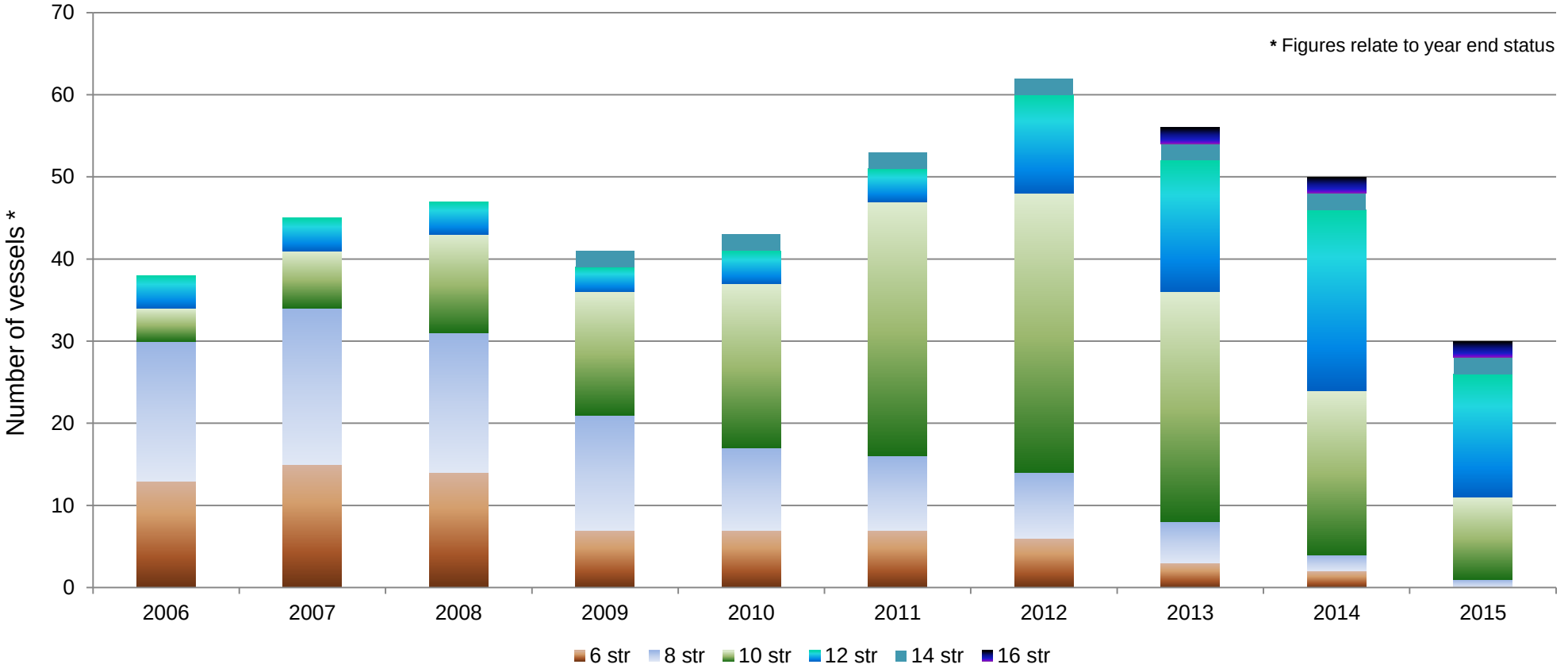
Wider Spreads

- Ramform Titan acquired two surveys with a **16 x 100m** spread. Industry first.
- **18 x 100m** operations ongoing. Biggest spread ever.
- Ramform Sovereign is towing **12 x 150m.**

Larger Spreads And Faster Turnaround

	6 Streamer Vessel (2006)	16 Streamer Vessel (2016)
Configuration	6 streamers with 100m separation	16 streamer with 75m separation
Sail Line Separation	300m	600m
Number of Source Points	N	N/2
Survey Duration	M days	M/2 days

Seismic Vessel Count and Renewal

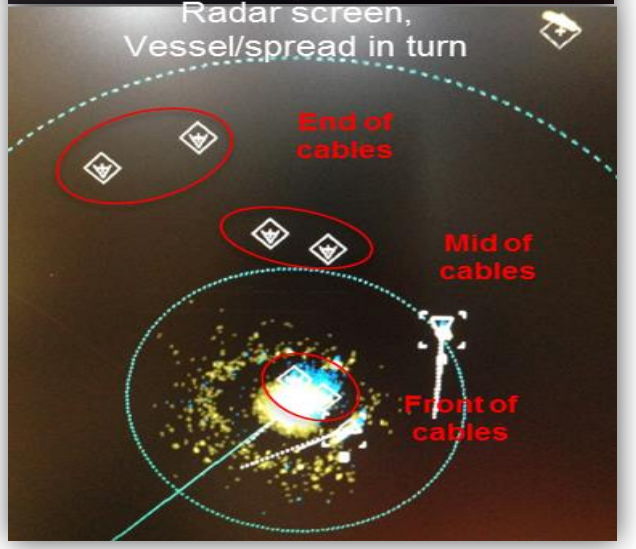


The total number of 3D seismic streamer vessels has been reduced significantly.

Collision Avoidance: AIS and Virtual AIS

- **What is AIS?**
  - In accordance with IMO requirements all SOLAS ships in international traffic above 300 gross tons must have an **Automatic Identification Systems (AIS)** installed onboard.
  - Its purpose is to help ship crews to avoid collision with other vessels as well as to allow maritime authorities to track and monitor ship movements. Today's AIS allows ships to communicate with other ships and land based base stations through VHF signals.

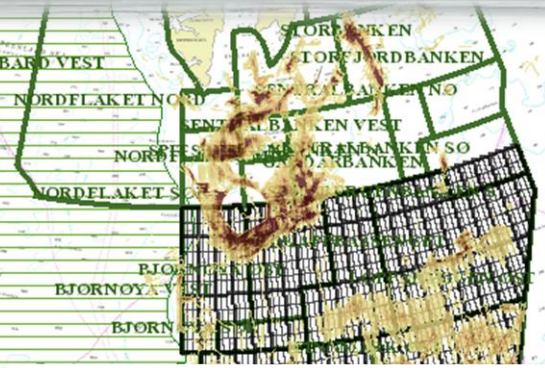
- **Virtual AIS**
  - Virtual AIS transmits positions that are **not physical** AIS transponders
  - In PGS case, Integrated Navigation System (INS) provides input positions from the deployed streamer spread.
  - Six coordinates are marking the **outer edges** of the deployed streamer spread, at front, mid and tail.
  - These coordinates are transmitted as AIS message code #21, used for Aids to Navigation (AtoN).

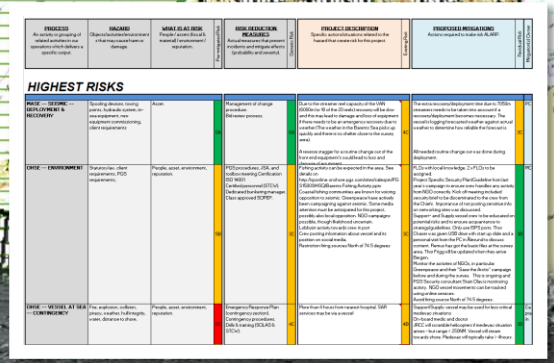


Planning and Mitigation

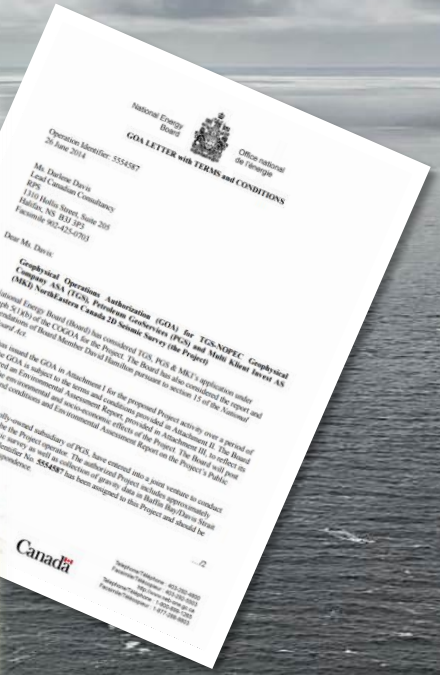
Planning, planning, planning….

Environmental Impact Assessment





Project Risk Assessment



Environmental Permit

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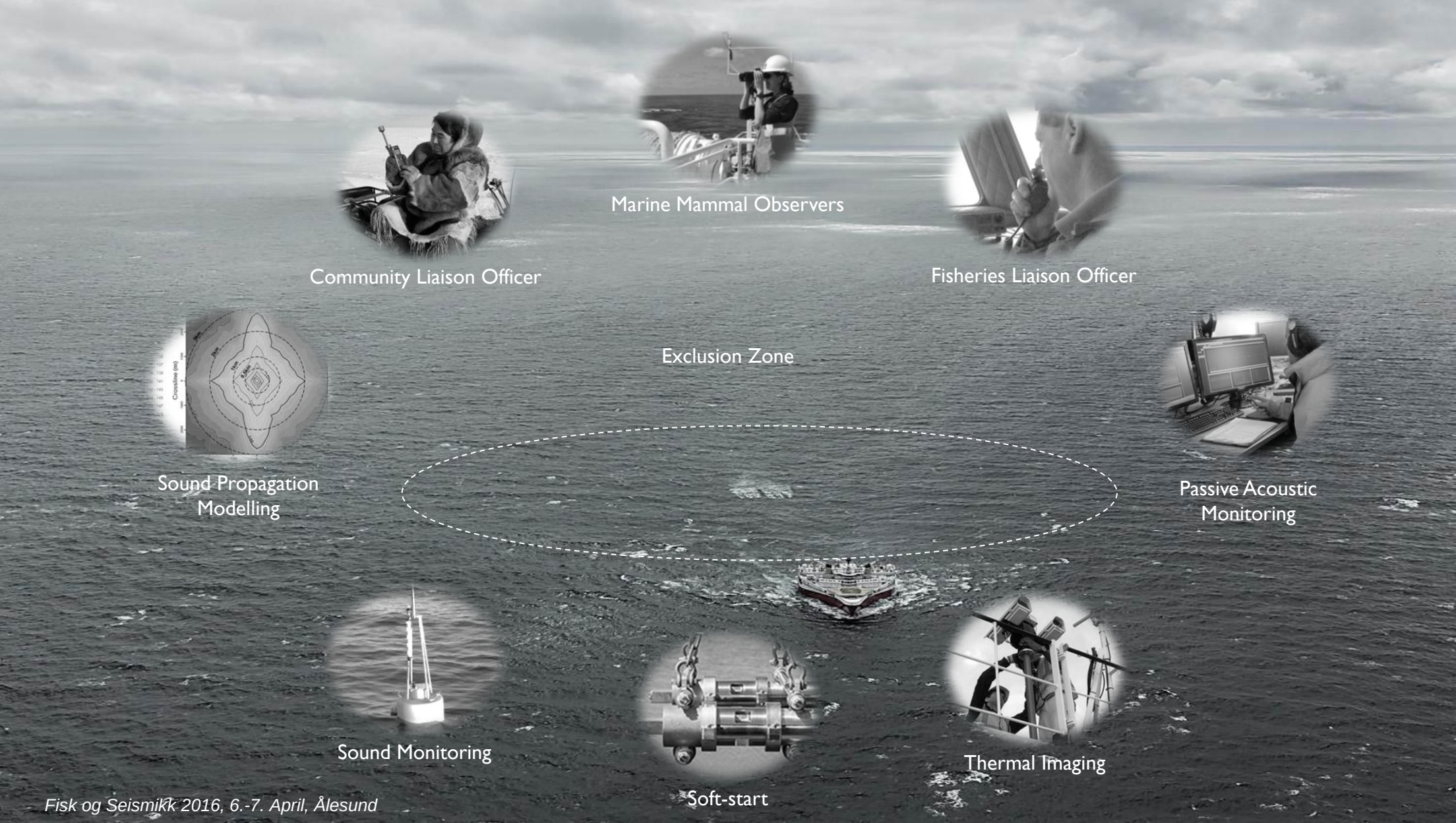
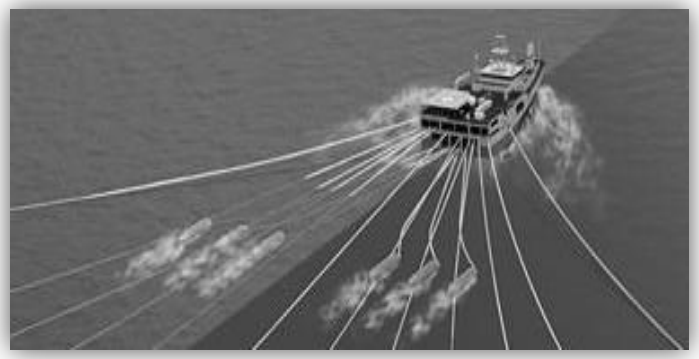

Marine Mammal Observers
Community Liaison Officer
Fisheries Liaison Officer
Exclusion Zone
Sound Propagation Modelling
Passive Acoustic Monitoring
Sound Monitoring
Soft-start
Thermal Imaging

Sound Propagation Modelling/Environmental Modelling

Sound Propagation Modelling

→ Estimation of sound level at distance



Marine Seismic Source Output

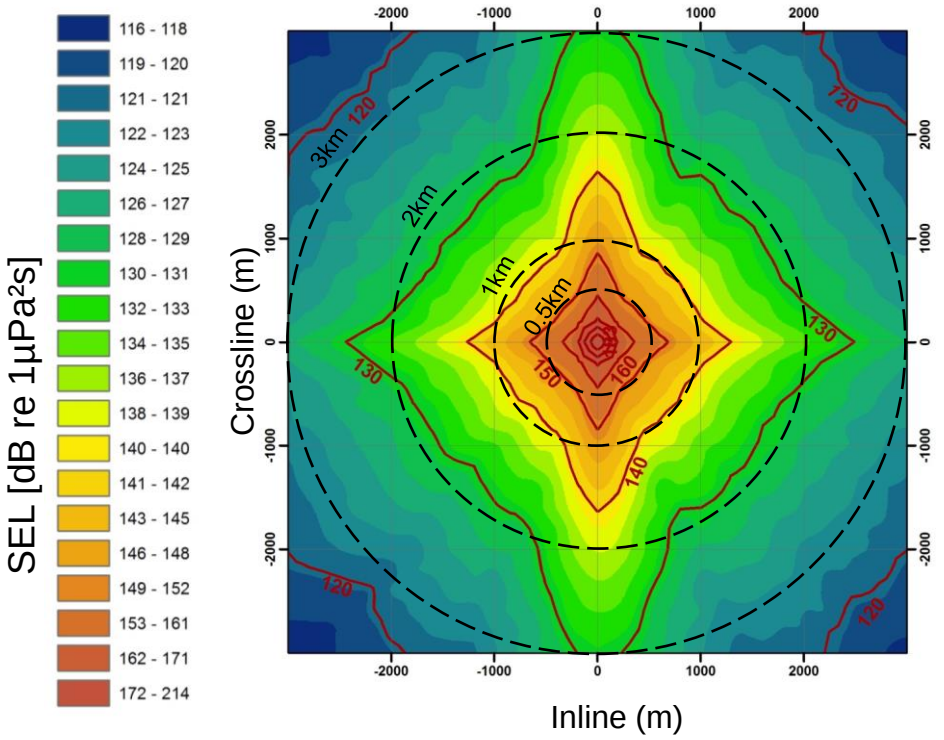
Sound Propagation

Hearing Bandwidth

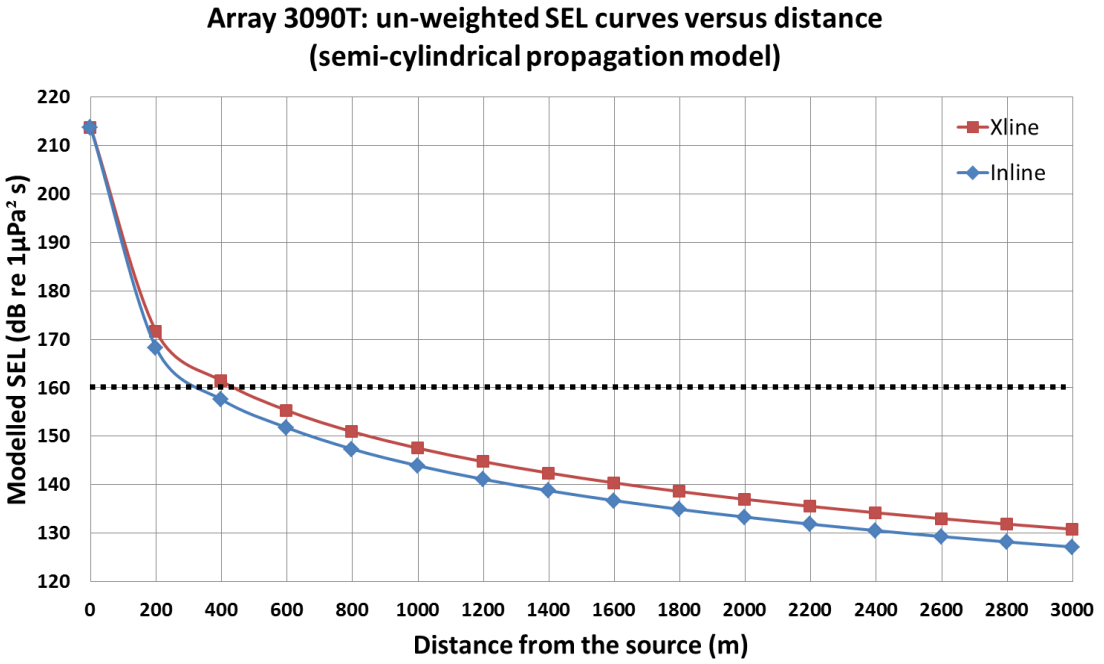
Purpose:

- Risk assessment
- Planning of mitigation measures

Sound Propagation Modelling: Planning of Exclusion Zones

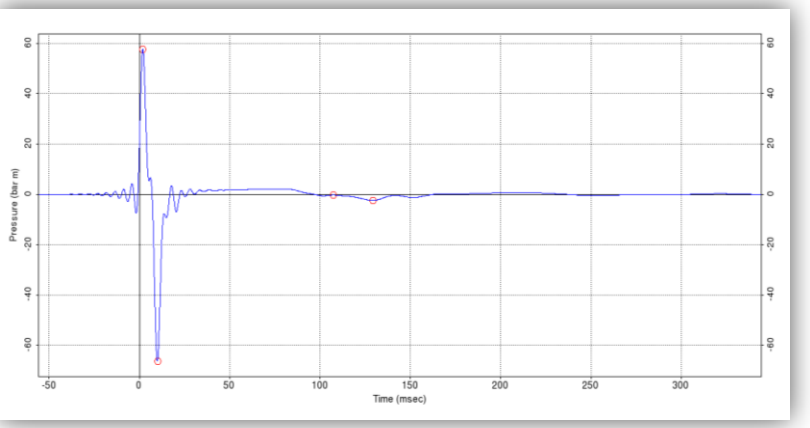


- Compute decay of Sound Exposure Level (SEL) with distance
- Define circumference in which threshold SEL value will likely not be exceeded



Research & Development:

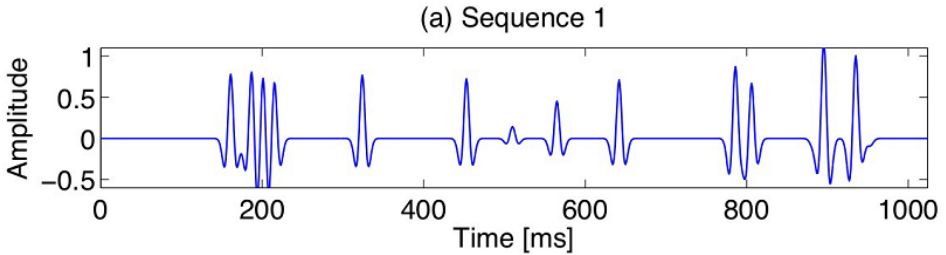
Alternative Marine Seismic Sources

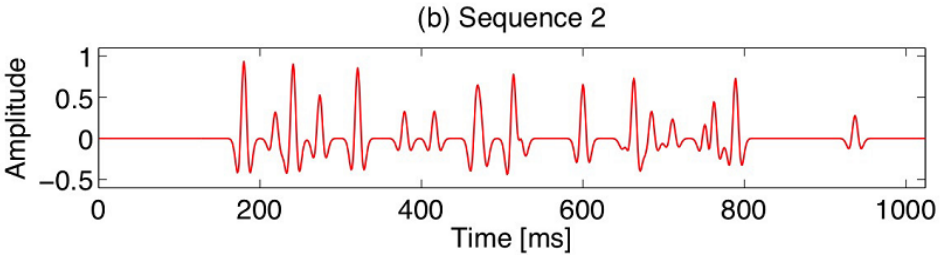


Typical output (sound) from a marine seismic source array.

Encoded Source Sequences ("Popcorn Shooting")

- Robertsson et al. (2008) discussed the idea of firing a marine source array sequentially (rather than activating all sub sources at the same time).
- Sub-elements are fired individually over a range of time, yielding a sequence of smaller impulses.
- "Popcorn Shooting" can reduce peak sound level output.



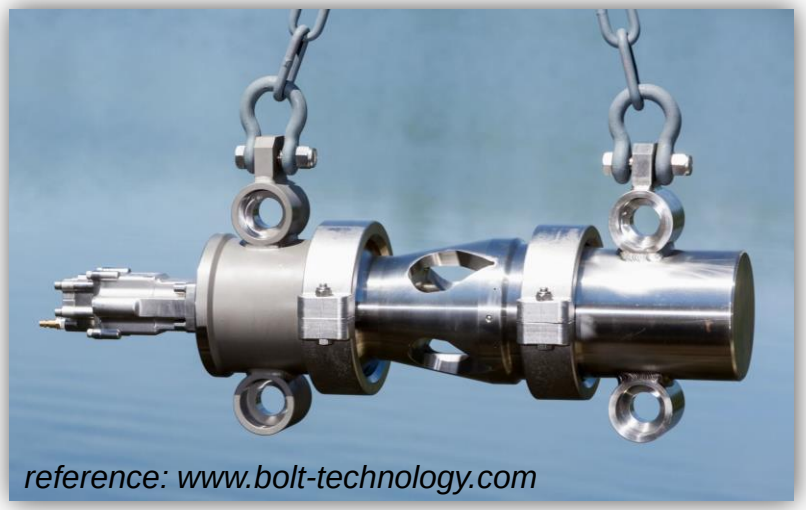


References:
EAGE 2014: M.B. Mueller (ETH Zurich), J.O.A. Robertsson (ETH Zurich) & D.F. Halliday (Schlumberger Gould Research): Simultaneous Source Separation Using Encoded Source Sequences*
SEG 2013: Ray Abma and Allan Ross (BP), Popcorn shooting: Sparse inversion and the distribution of airgun array energy over time

Marine Source with Flexible Bandwidth Control

"eSource"

- designed to reduce the impact of seismic on marine life
- key principle is the gradual release of air
- by controlling the air released the spectral content of the pressure signal can be tuned



reference: www.bolt-technology.com

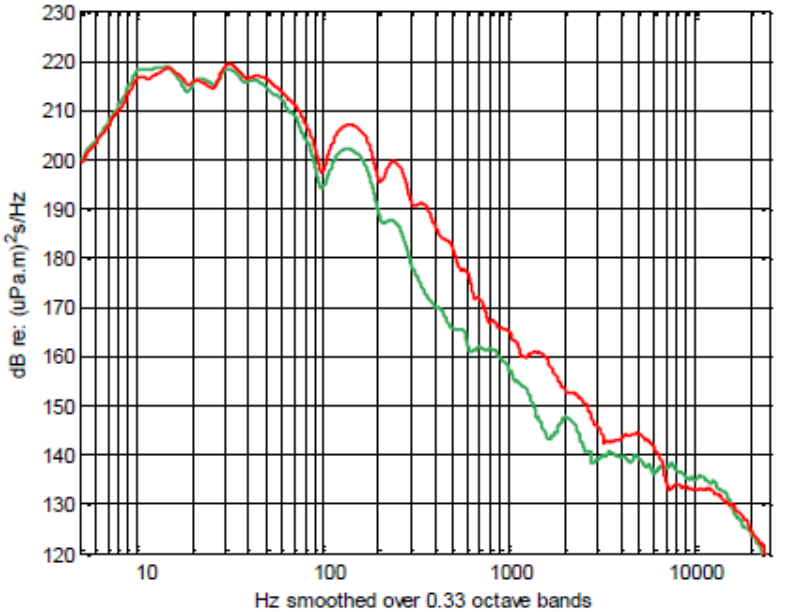


Figure 5: Example vertical far-field energy spectra of a 3,300 in^3 array (simulated from near-field measurements) of: air-guns with the new design (green) and standard air-guns (red) with the same mix of volumes and the same firing pressure. The source arrays are at a depth of 7.5 m. Note that the spectra differ significantly only above the ghost notch (100 Hz).

Reference (SEG 2014): **Attenuated high-frequency emission from a new design of air-gun,** Emmanuel Coste, Schlumberger, David Gerez and Halvor Groenaas, WesternGeco, Jon-Fredrik Hopperstad, Schlumberger Gould Research, Ola Pramm Larsen, WesternGeco, Robert Laws*, Schlumberger Gould Research, Jack Norton and Matthew Padula, Bolt Technology Corporation, and Michel Wolfstirn, WesternGeco.

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Alternative Sources: The Marine Vibrator Joint Industry Project

MV JOINT INDUSTRY PROJECT

- *"The motivation for the project is to mitigate some of the environmental objections to seismic surveying in certain parts of the world (…)"*

Photo provided by PGS

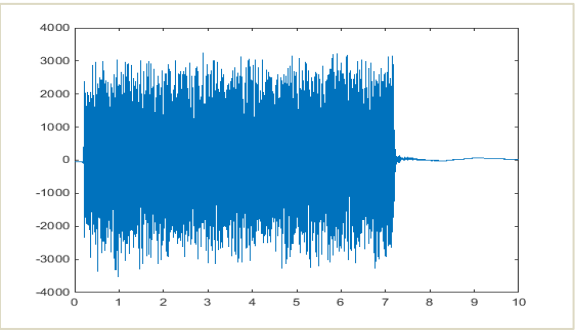
Sponsors: ExxonMobil, Shell, and Total

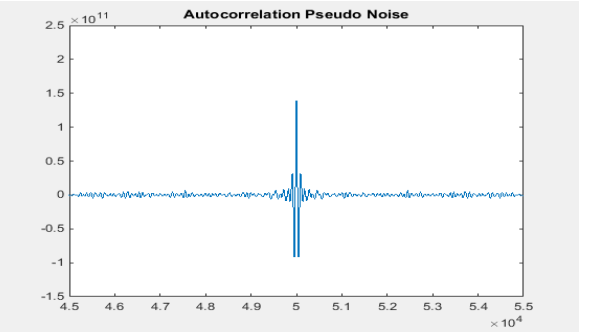
Vendors: PGS, Applied Physical Services, and Teledyne Webb Research.

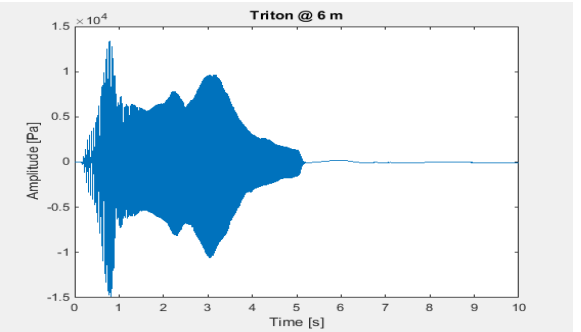
Reference: SEG Workshop 2015 "Next Generation Marine Sources"

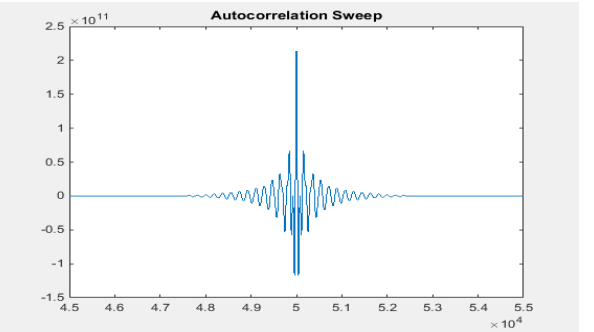
Arbitrary Signal Generation

- Use of pseudo noise (PN) sequences reduces the amplitude/Hz with an additional 20 dB
- The sound will be similar to natural background noise
- Many sources can be operated simultaneous









Final Remarks & Acknowledgements

- ***We want to conduct our business responsibly with regards to impacts on the ecosystem and with respect to other users of the ocean (e.g., fishermen).***
- ***Planning is critical. We aim for effective and efficient risk management.***
- ***Responsible also means supporting advancements in seismic technology and in our common knowledge of the oceans.***

Special thanks to

- *Magnus Christiansen, Jens Fredrik Wisløff, Alexander Goertz, Rune Tenghamn (PGS)*

(…)