Marine Seismic Technology – Greener Methods?

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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.

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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
Human Ambient sea noise (sea state 4) 100 dB (1 μPa)
Whale breaching 200 dB (1 μPa)
Calving iceberg 220 dB (1 μPa)
Seismic Array (actual) at 1 m 235 dB (1 μPa)
Sperm whale click 236 dB (1 μPa)
Lightning strike 260 dB (1 μPa)
Undersea earthquakes 272 dB (1 μPa)
Hearing loss
Displacement
Curiosity
Nothing
Fear
Surprise
Fright
Annoyance
Stress
Hearing loss

Amplitude spectra of farfield signatures at 100 m

September 2012

September 2012
Increased Efficiency $\rightarrow$ Reduced Exposure

fewer days on each survey results in a smaller environmental footprint
Larger Spreads And Faster Turnaround

Sail Line Separation
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)

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)
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

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Configuration</td>
<td>6 streamers with 100m separation</td>
<td>16 streamer with 75m separation</td>
</tr>
<tr>
<td>Sail Line Separation</td>
<td>300m</td>
<td>600m</td>
</tr>
<tr>
<td>Number of Source Points</td>
<td>N</td>
<td>N/2</td>
</tr>
<tr>
<td>Survey Duration</td>
<td>M days</td>
<td>M/2 days</td>
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</table>
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
Environmental Impact Assessment

Project Risk Assessment

Environmental Permit

Planning, planning, planning….
Marine Mammal Observers

Passive Acoustic Monitoring

Soft-start

Fisheries Liaison Officer

Sound Propagation Modelling

Exclusion Zone

Community Liaison Officer

Sound Monitoring

Thermal Imaging

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Sound Propagation Modelling/Environmental Modelling
Sound Propagation Modelling

→ Estimation of sound level at distance

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

Array 3090T: un-weighted SEL curves versus distance (semi-cylindrical propagation model)
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:
SEG 2013: Ray Abma and Allan Ross (BP), Popcorn shooting: Sparse inversion and the distribution of airgun array energy over time

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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


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Alternative Sources: The Marine Vibrator 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 (…)

Sponsors: ExxonMobil, Shell, and Total


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.

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(...)