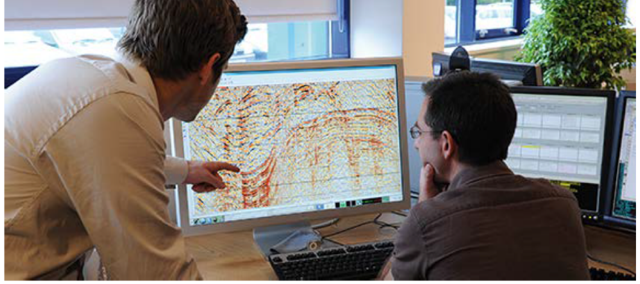


Marine Seismic Surveys: What are they, and how are they done?

A Brief Introduction to Seismic Surveying

Dr. Bob Gisiner, IAGC

www.iagc.org

International Association of Geophysical Contractors

IAGC

ENERGY STARTS HERE™

1 May 2019

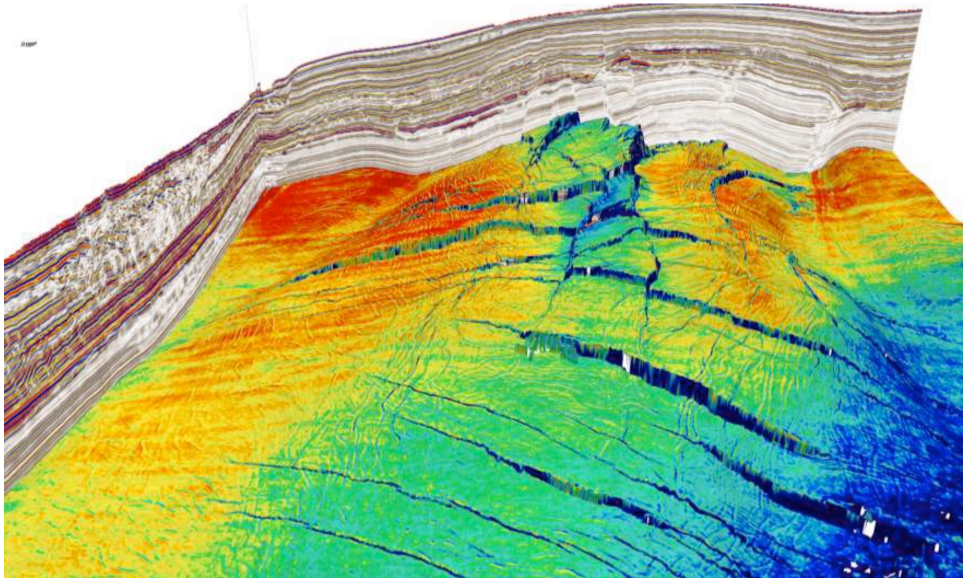
Today's Agenda

I. The Sound Source
   - *I. Single Source*
   - *II. Seismic Array*
   - *III. Other Sources*

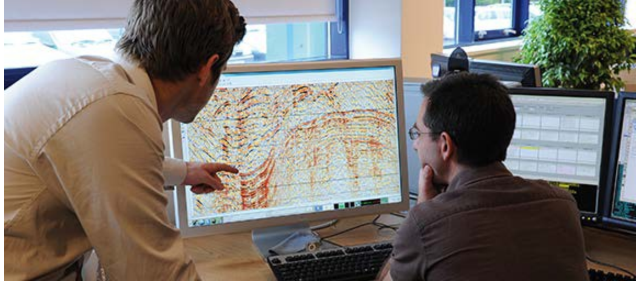
II. Performing a Survey
   - *I. Equipment*
   - *II. Vessel Operations*

III. Types of Surveys
   - *I. 2D, 3D, and 4D*
   - *II. Multi-vessel Surveys*
   - *III. Life-of-Field Surveys*

IV. Uses of Seismic Surveys
   - *I. Oil & gas exploration*
   - *II. Site selection for cables, pipelines and offshore wind*
   - *III. Earthquake and tsunami forecasting/preparedness*
   - *IV. Global geophysics/plate tectonics*
   - *V. Support of expanded EEZ claims*



Andrew Long PGS

Single Source

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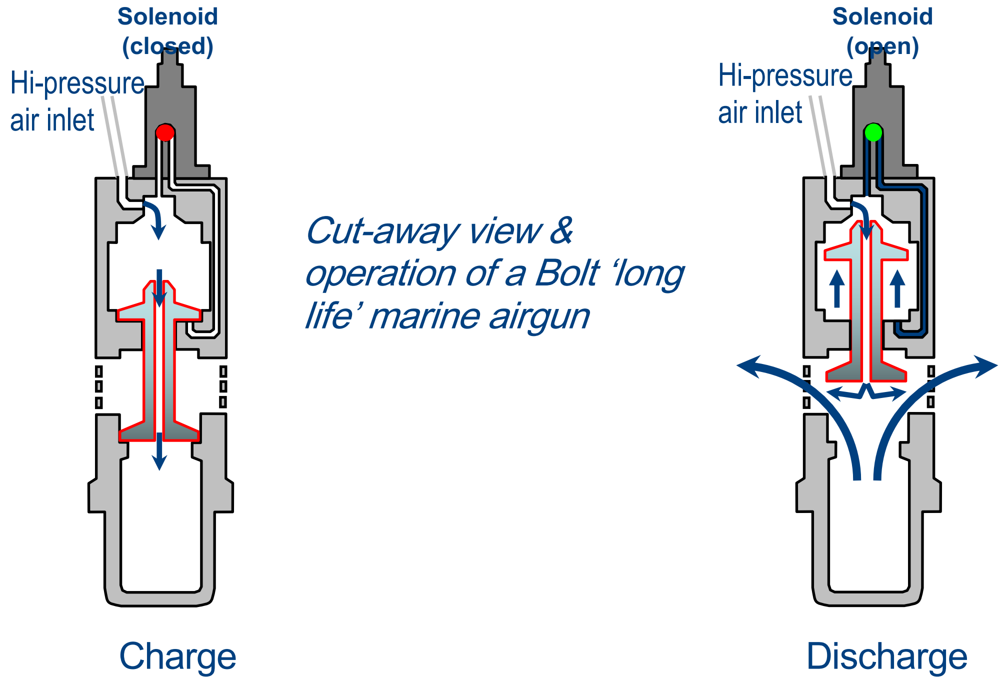
Basics Of A Compressed Air Seismic Source



Cut-away view & operation of a Bolt 'long life' marine airgun

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A Seismic Source Array in Action

International Association of Geophysical Contractors

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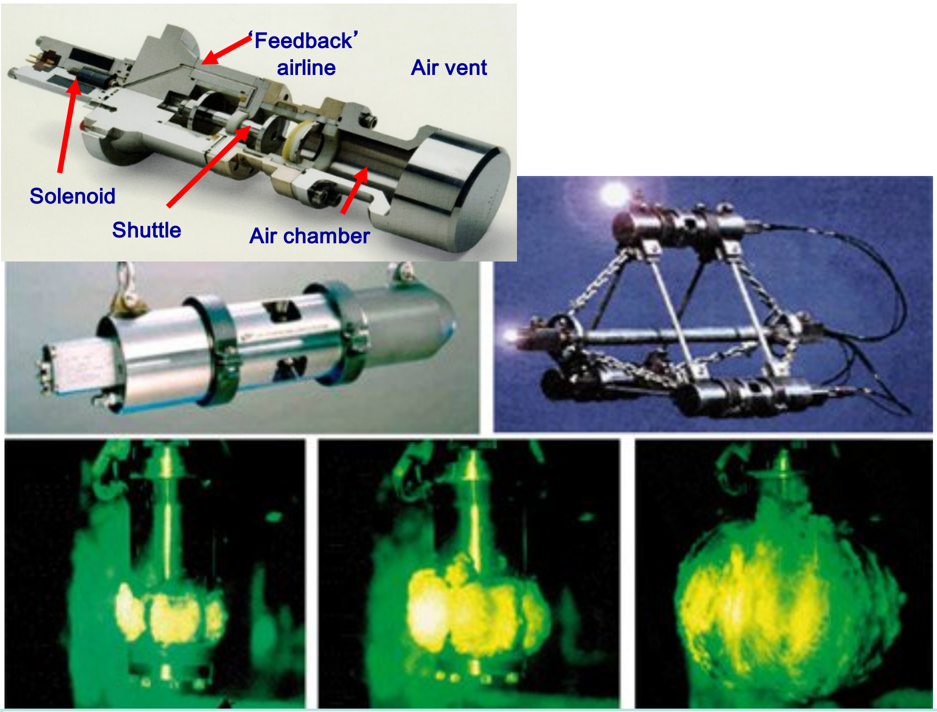
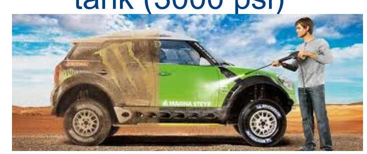
Compressed Air Sound Source, aka Air "Gun"

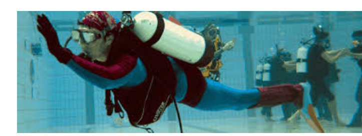


http://www.geoexpro.com/articles/2010/01/marine-seismic-sources-part-i
Llandrø M. and L. Amundsen. 2010. GeoExPro v. 7 (1)

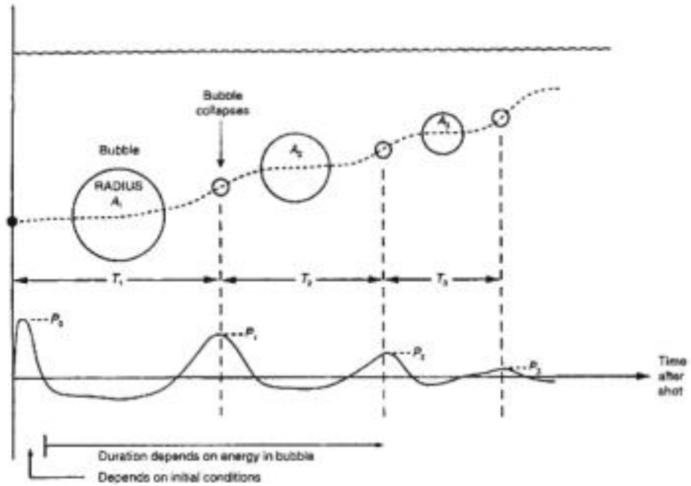
A typical element ranges in size/volume:
- 10 – 800 cubic inches or …..
- 0.15 – 13 liter or ……..
- A disappointingly small beer to a daypack

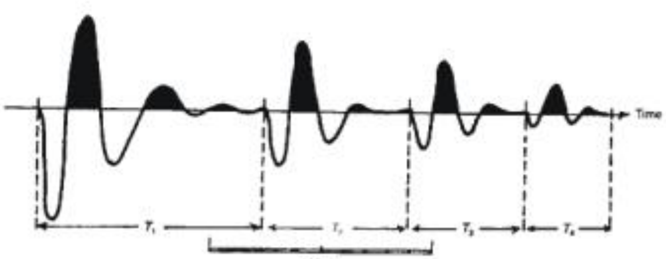
Typical air pressure is
- 2000 psi or 14 Mpa or 140 Bar or ……..
- Somewhere between a household pressure washer (1500 psi) and a scuba tank (3000 psi)

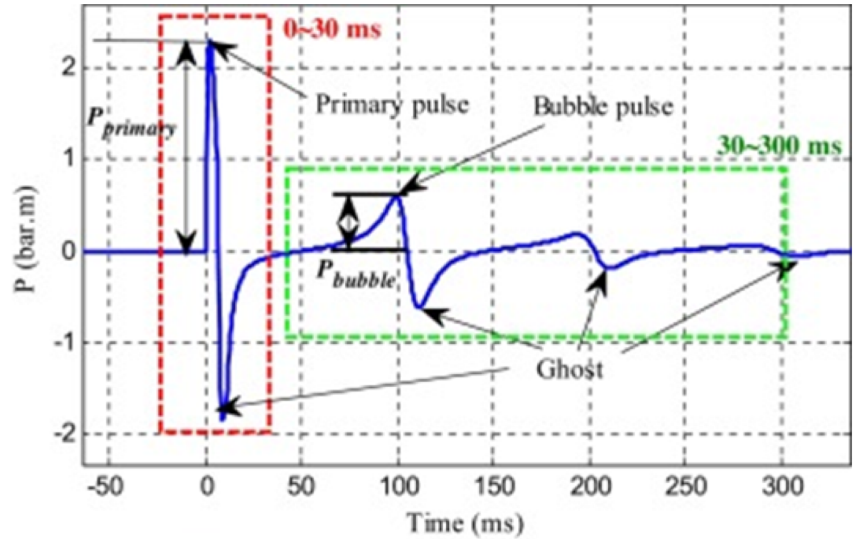


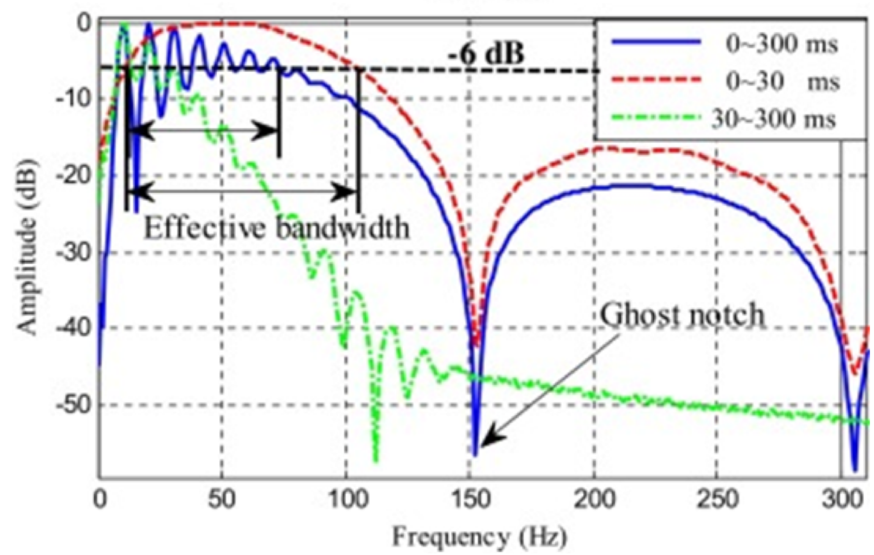


Bubble Pulse









Zhang et al, 2017

Alternative Sources

- Bolt e-Source

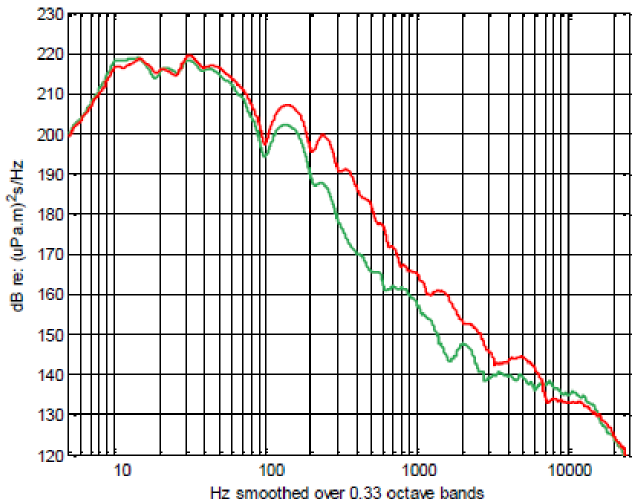
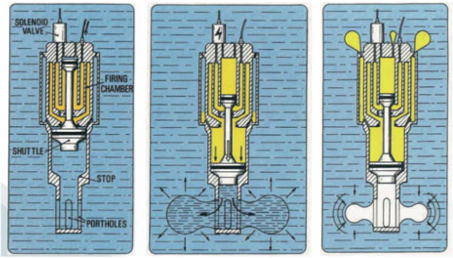


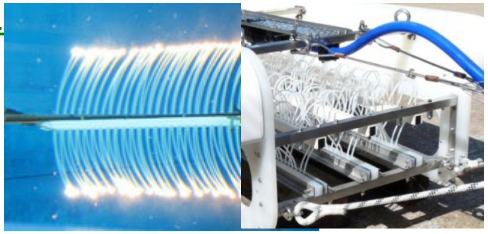
Figure 5: Example vertical far-field energy spectra of a 3,300 in^3 array (simulated from near-field measurements) of: air-guns with the new design (green) and standard air-guns (red) with the same mix of volumes and the same firing pressure. The source arrays are at a depth of 7.5 m. Note that the spectra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

- Water gun



- Sparker

www.appliedacoustics.
www.marine-seismic-equipments.net

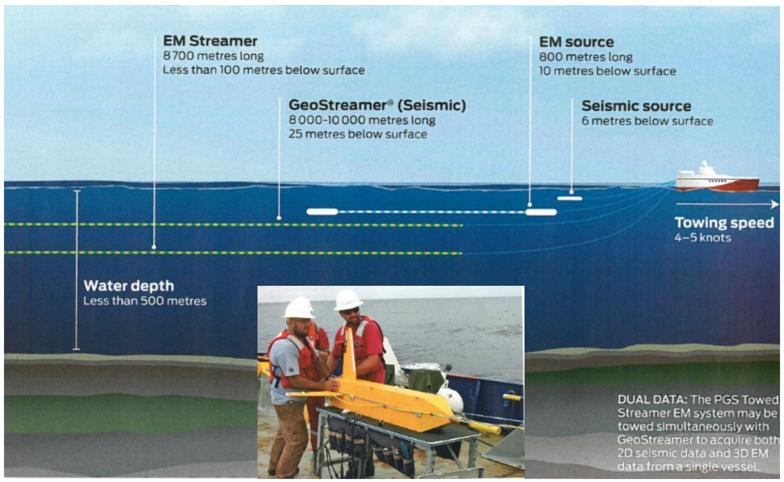


- Explosives

(www.dosits.org)

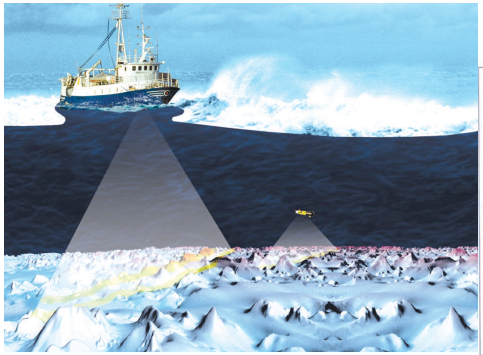
Alternative Sources

- Electromagnetic (EM)
  - LF pulsed electric dipole
  - Oil saturated rock is less resistive
  - Exploration? Or during drilling?
  - Issues of cost/benefit

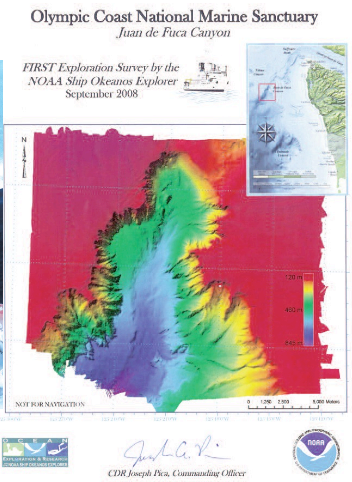


Upstream Technology (1) 2016

- Multibeam Echosounders
  - Narrower frequency, lower SPL
  - Aka Sub-bottom Profiler
  - Less depth penetration, equal or greater SEL (continuously on)
  - Has been implicated as a possible cause of stranding



www.Kongsberg.com



Vibratory/Tonal Sources

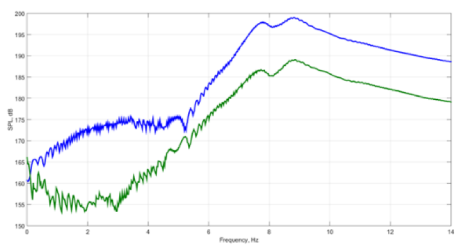

Distributed Seismic Source™ – the new gun in town?

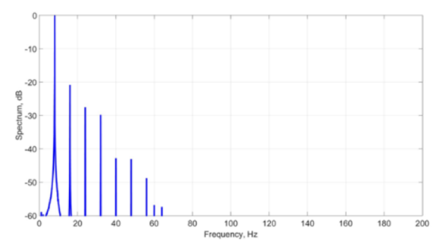
GPUSA President Jim Andersen explains how the company's Distributed Seismic Source™ for marine and downhole applications shatters conventional wisdom

GPUSA DSS in InnovOil August 2015; Nov 2015

Exxon, Chevron, Total MVJIP

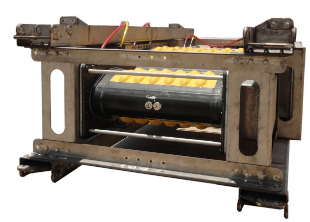
- Three protoptypes in various stages of testing
- Petroleum Geo-Services (PGS) flex-tensional shell
- Applied Physical Sciences (APS) piston driven
- Teledyne-Webb Research (TWR) pneumatic bubble resonance.



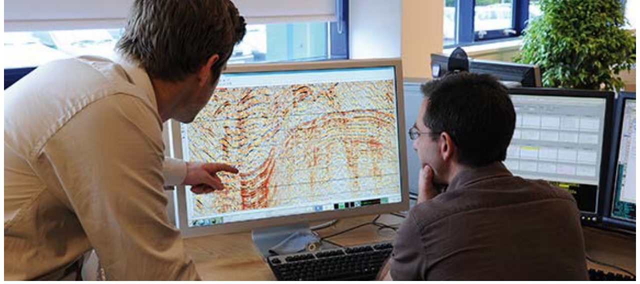


Geokinetics AquaVib™

- At-sea performance test 2015
- Flextensional transducer



- Sources produce a range of frequencies
- Typically within 5-300 Hz
- Typically 5-20 s duration
- May be swept, hyperbolic or coded sequences
- Lower peak SPL but similar SEL with little or no 'quiet' time between pulses.



Seismic Array

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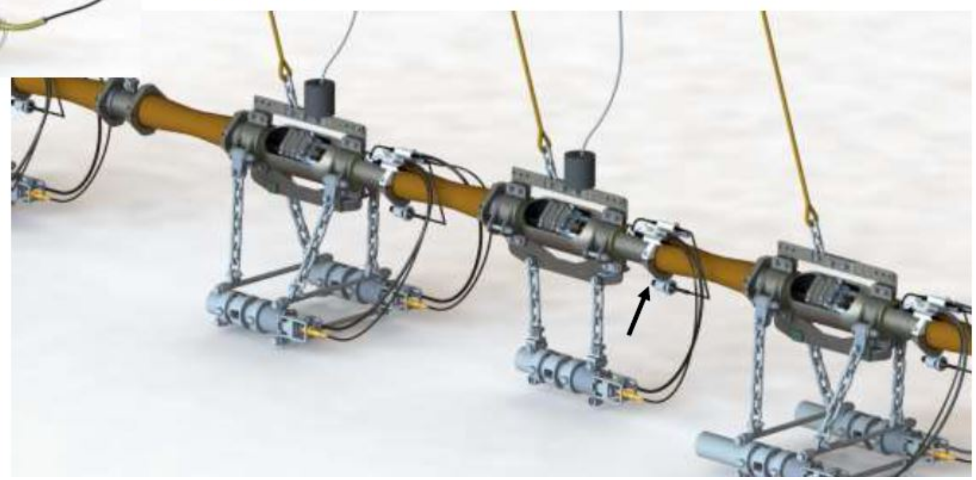
+1 281 702 4201

Configuration of source array

- Each air ‘gun’ is actually a cannister of compressed air that releases the air through a port every 10 seconds.
- Considerable engineering effort given to precise control of the firing signals.
- Considerable engineering effort given to real time measurement of the output from every air gun location.

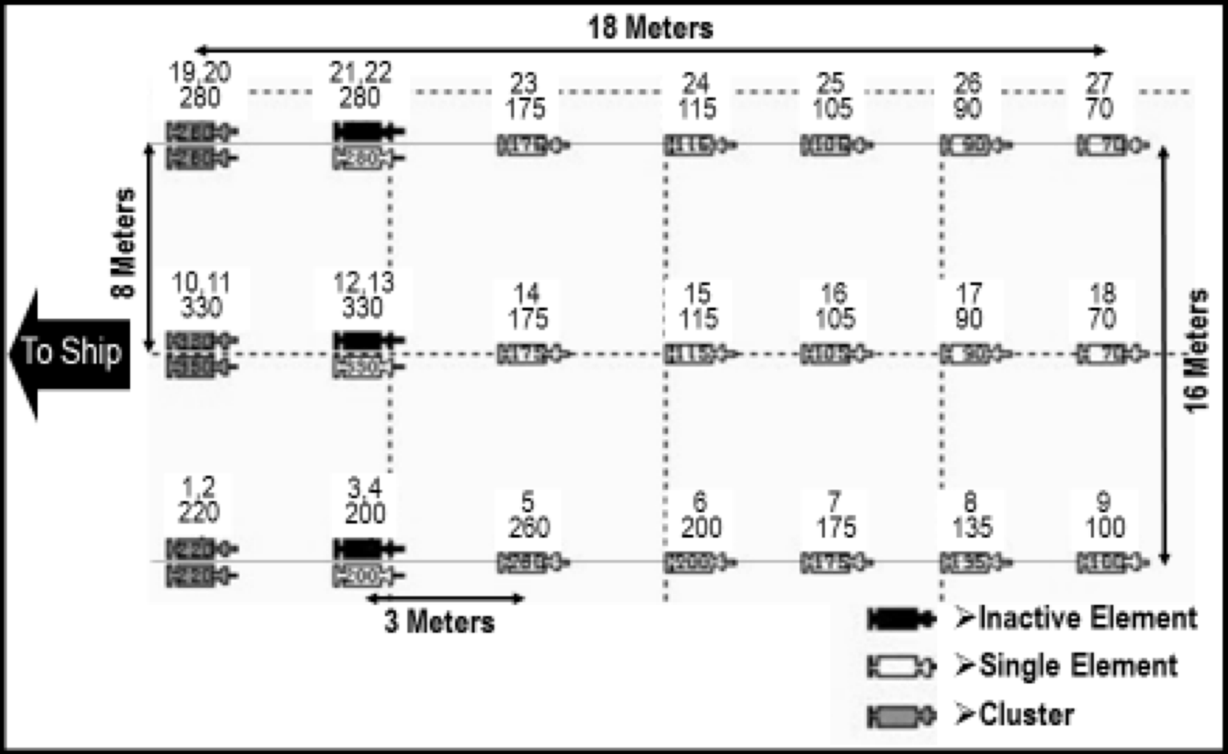


- Near field hydrophones mounted 1 m above each air gun.
- Also measure air-line pressure and water temperature, atmospheric pressure, acoustic position of each air gun, etc.

8

Courtesy Andrew Long PGS

Geometry of 24 Element, 4450-Cubic Inch Array



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Why An Array? Two Reasons.

You can increase the source level of the array more readily by adding smaller individual elements than making one big single element.

BECAUSE:

1) The output of multiple elements adds up in linear proportional to the number of elements in the array (i.e., all else being equal, a 30-element array will generate twice the amplitude of a 15-element array)

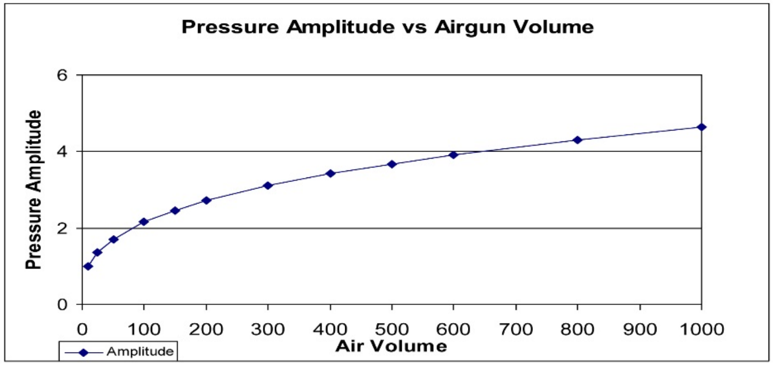
2) linearly proportional to the air pressure of the array (a 4000-psi array will have twice the amplitude of a 2000-psi array)

3) But only proportional to the cube root of the air volume.

In other words:

To double the amplitude obtained from a single 125 cubic inch element:

- We can either add a second 125 cubic inch element, or
- We can replace the 125 cubic inch element with a 1000 cubic inch element.



Things to keep in mind:

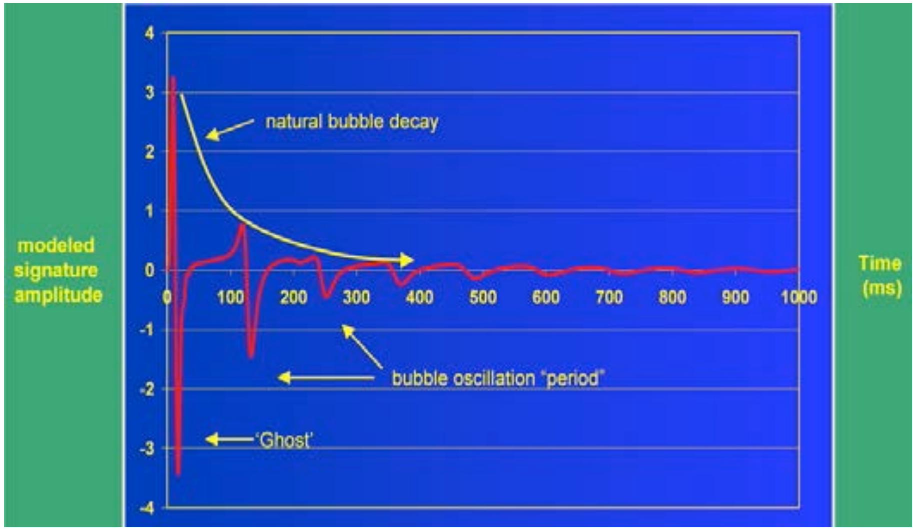
Source SPL or Intensity expressed as dB is a LOGARITHMIC scale.

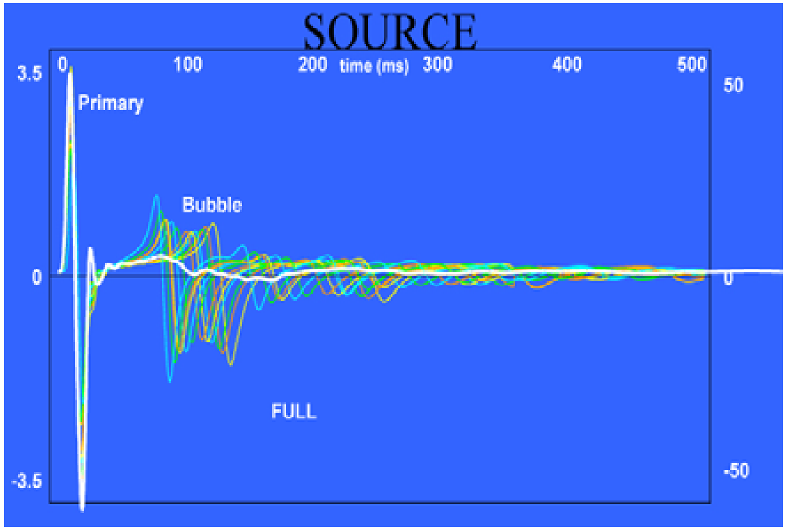
Pressure is a 2 dimensional phenomenon (a surface), while the bubble is a 3 dimensional phenomenon (a sphere)

Why An Array? Second Reason

Getting rid of bubble oscillations:

1) For signal processing purposes, one single, clean pulse is preferred
2) But as the pressure equalizes between the water and the bubble
3) The bubble keeps producing sound (at reduced levels) for several oscillations before it rises to the surface





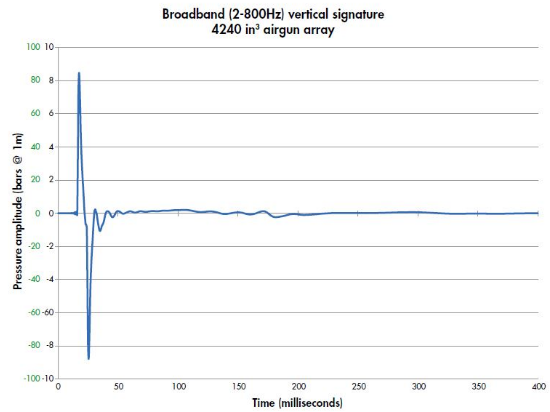
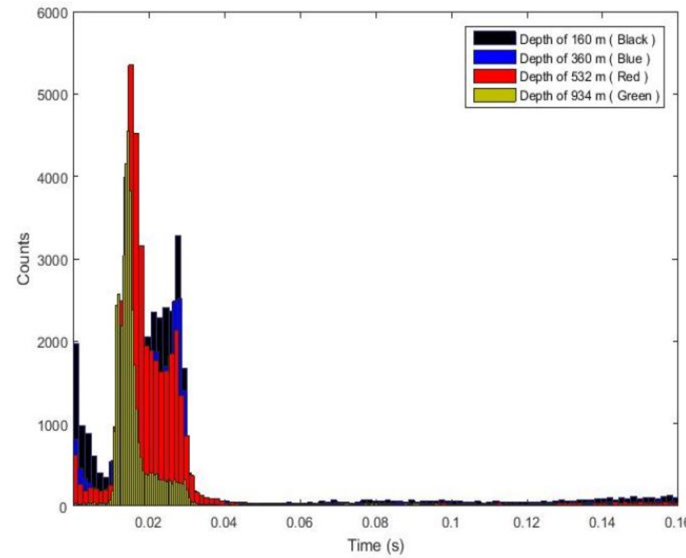
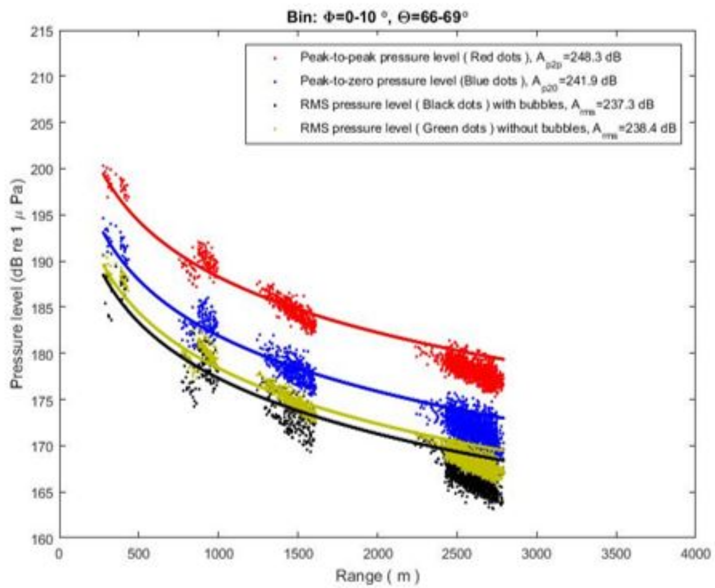


Figure 19a *(credit: Polarcus)*

This shows the time-series (amplitude versus time) display of an airgun signal from a 4450 in³ array that has 33 active guns. The green numbers are the theoretical back-calculated values for this array if one could measure the full output at 1m from the center, thus the units bars at 1m. The black numbers are the actual maximum values in bar-meters that one would measure given the array dimensions of about 14m by 14m.





Seismic pulses are very consistent

- Pulse duration <01 s
- Peak-to-peak SPL is SPL_{peak} +6 dB
- RMS SPL is SPL_{peak} -6 dB
- SEL is SPL_{peak} -16 dB

Propagation Effects

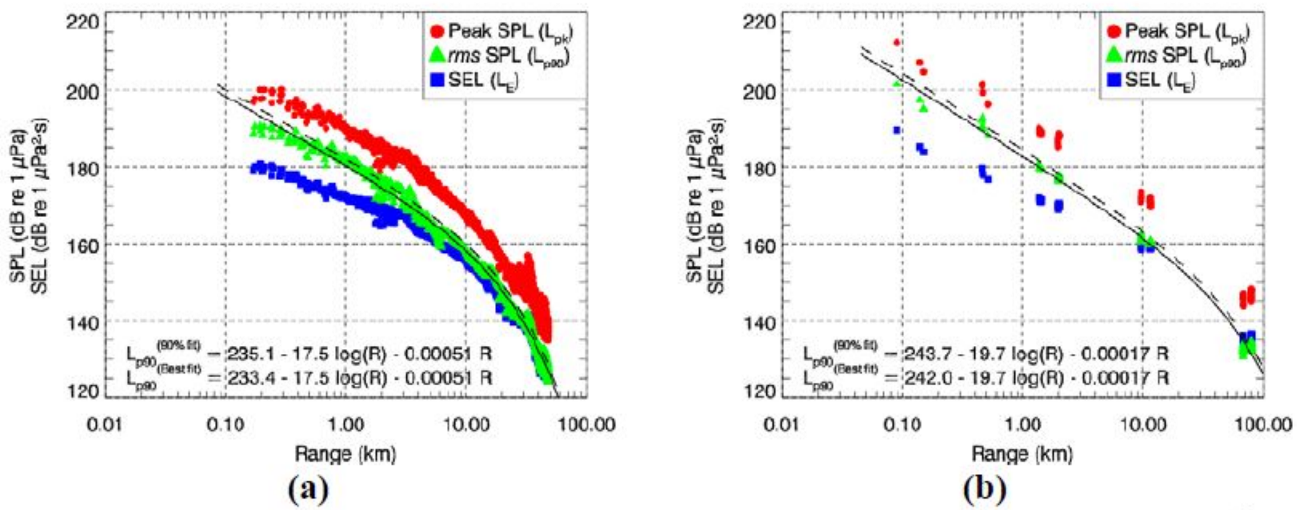


FIGURE 3.5. Peak SPL, *rms* SPL, and sound exposure level (SEL) versus range for 3000 in^3 array airgun pulses at the SSV site: (a) endfire on OBH A1, and (b) broadside on OBH A1, B, and C. Solid line is best fit of the empirical function to SPL_{rms90} values. Dashed line is the best-fit adjusted to exceed 90% of the SPL_{rms90} values.

Blees et al 2010. JASCO Chukchi

Array Directivity

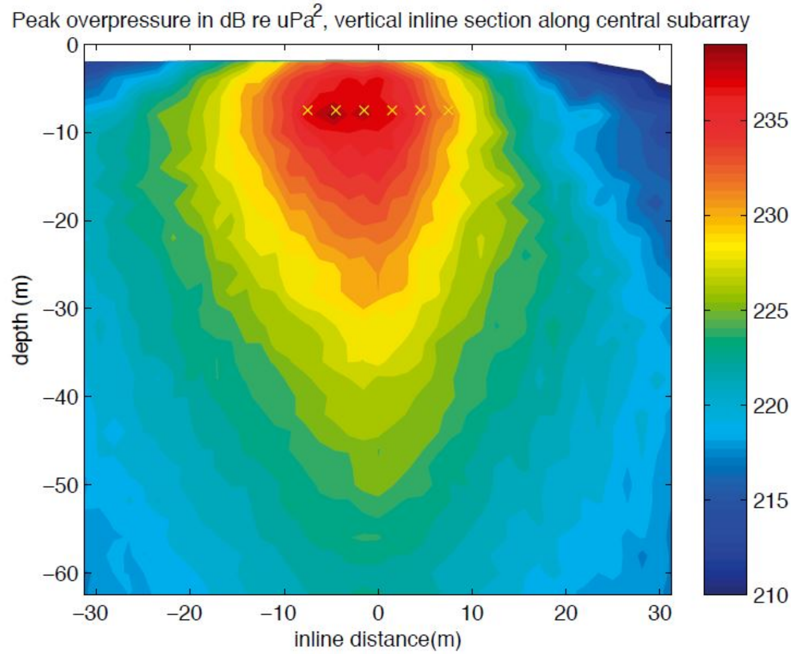


Figure 23b *(courtesy IAGC)*

This shows the modeled sound pressure (zero-to-peak) on an inline vertical slice through the centre of the array. The depth of the array is 7.5 metres, and the total frequency band used is 0-400 Hz. It has 18 elements arranged in three subarrays each 15 metres long and separated by 7.5 metres. It has a total volume of 5205 cubic inches and is charged to 2000 psi. The elements at the front (left) of the array are larger and this accounts for the inline asymmetry. The yellow crosses indicate positions of the source elements. Contours are shown from 210dB re μPa^2 upwards.

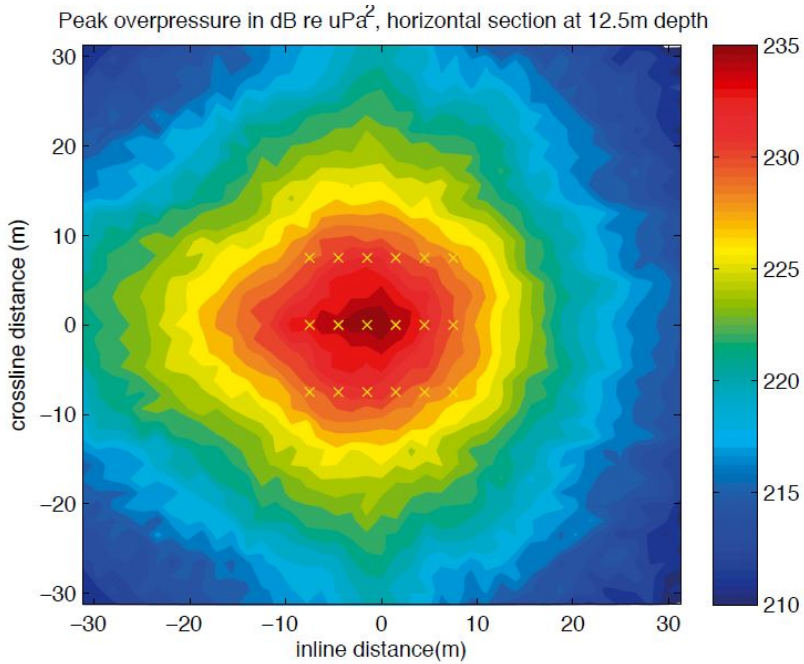


Figure 23a *(courtesy IAGC)*

This shows the modeled sound pressure (zero-to-peak) on a horizontal slice at a depth of 12.5 metres. The depth of the array is 7.5 metres, and the total frequency band used is 0-400 Hz. It has 18 elements arranged in three subarrays each 15 metres long and separated by 7.5 metres. It has a total volume of 5205 cubic inches and is charged to 2000 psi. The elements at the front (left) of the array are larger and this accounts for the inline asymmetry. The yellow crosses indicate positions of the source elements. Contours are shown from 210dB re μPa^2 upwards.

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Why Sources Need The Umph They Have

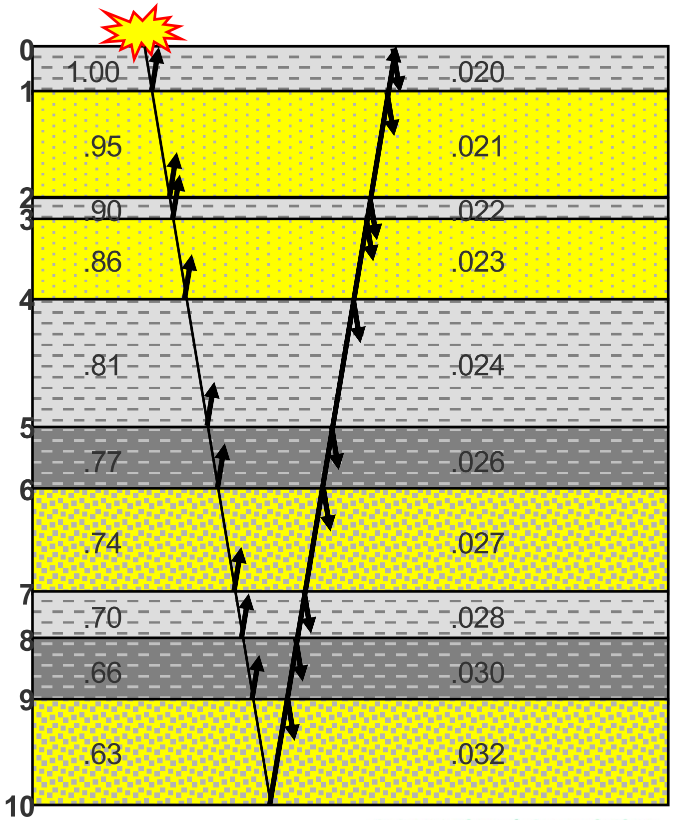
At each layer, 5% of what hits that boundary gets reflected.

Just from reflections, amplitudes are down ~ 34 dB.

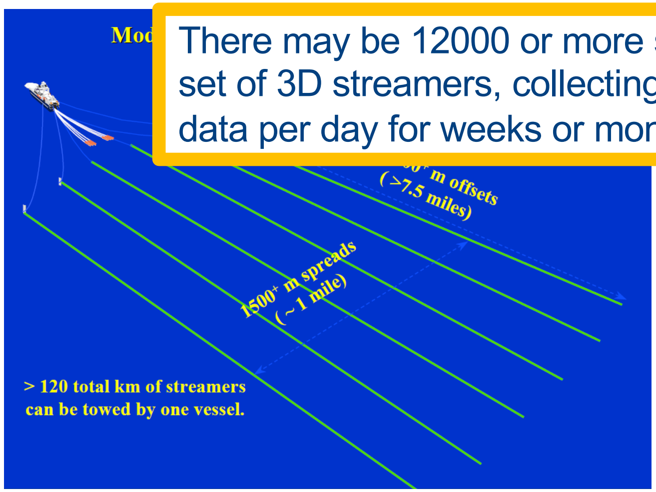
Amplitude decreases directly as the distance increases, so after 1000 meters, amplitudes are down 60 dB from that alone.

Together, the 2 effects mean amps are down more than 94 dB if these 10 reflectors go down 500 meters.

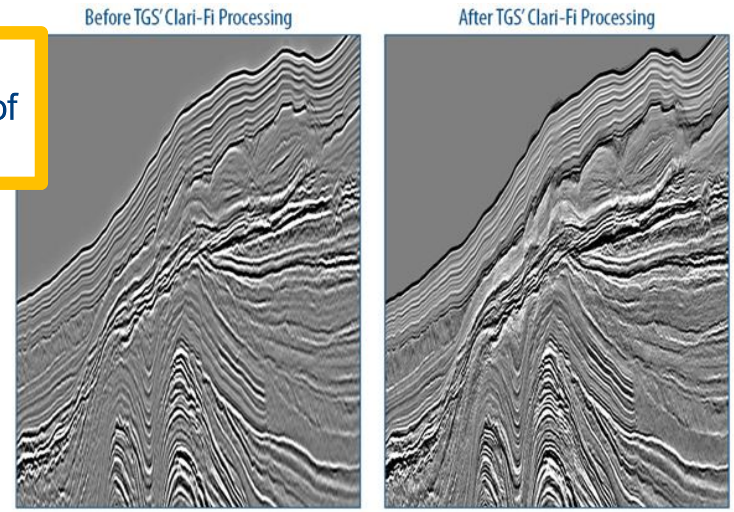
Add to this the Earth's attenuation, which is a few dB, and not much amplitude is left.



The technologies for collecting data have not changed as much as the technologies for getting more out of the data



There may be 12000 or more sensors in a set of 3D streamers, collecting petabytes of data per day for weeks or months

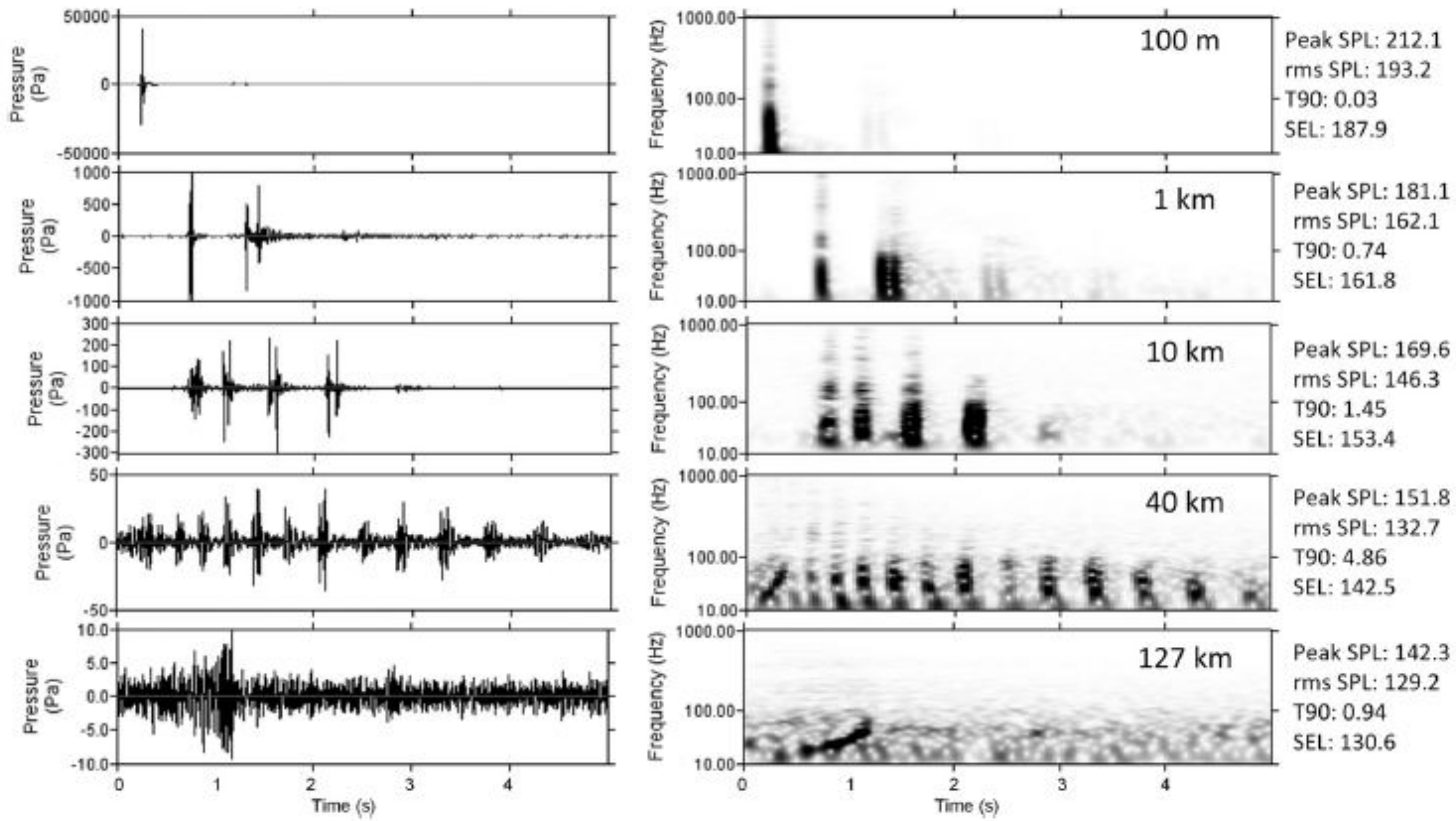


Total's latest supercomputer, Pangea built by Silicon Graphics (SGI), was upgraded from its original 2.3 petaflop capacity installed early in 2013 to 6.7 petaflops, placing it among the top ten of the Top500 ranking (Nov 2015), and first in the industry category of the list.

The main drivers for such IT investment are to:
• Improve the accuracy of subsurface imaging,
• Optimise the development and production of Total's producing fields, and
• Time saving, by shortening the study duration.

Propagation Effects

Propagation Effects



Martin et al 2017 Greenland

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Performing a Survey

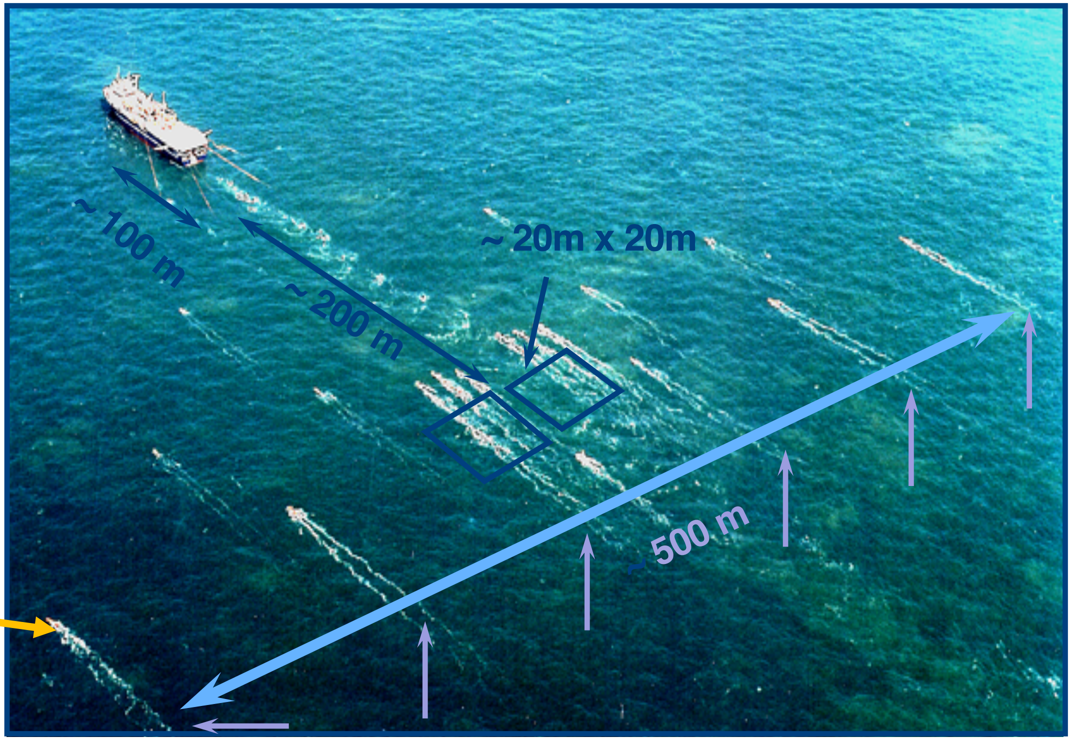
Equipment

The Fleet

- A typical fleet for 3D seismic consists of:
  - The seismic vessel acquiring the geophysical data.
  - 1 or 2 chase boat that:
    - Guard the in sea equipment
    - Ward off fishing vessels and other vessels
    - Scout ahead of the seismic vessels (ice, obstructions, shallow water)
  - A supply vessel to:
    - Bring out supplies and fuel
    - Take refuse
    - Take data back to port
    - Occasional transfer of crew members.

Aerial View of Seismic Vessel in Operation

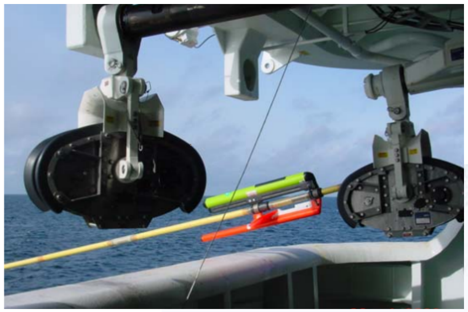
Paravane deflector



Courtesy of Peter Seidel - TGS

Seismic Survey Vessel Schematic (not to scale)

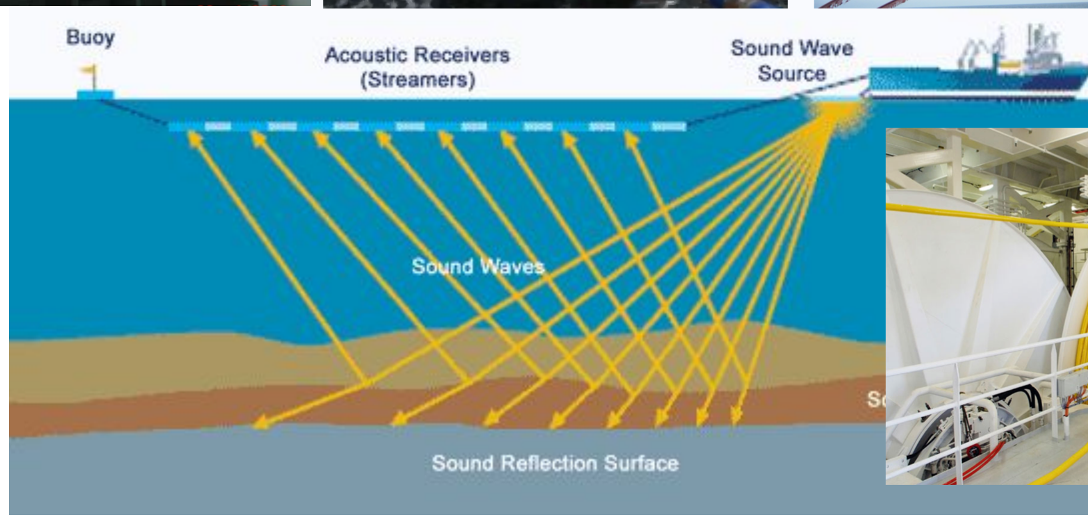
Streamer leveling unit ("bird")



Streamer deflectors

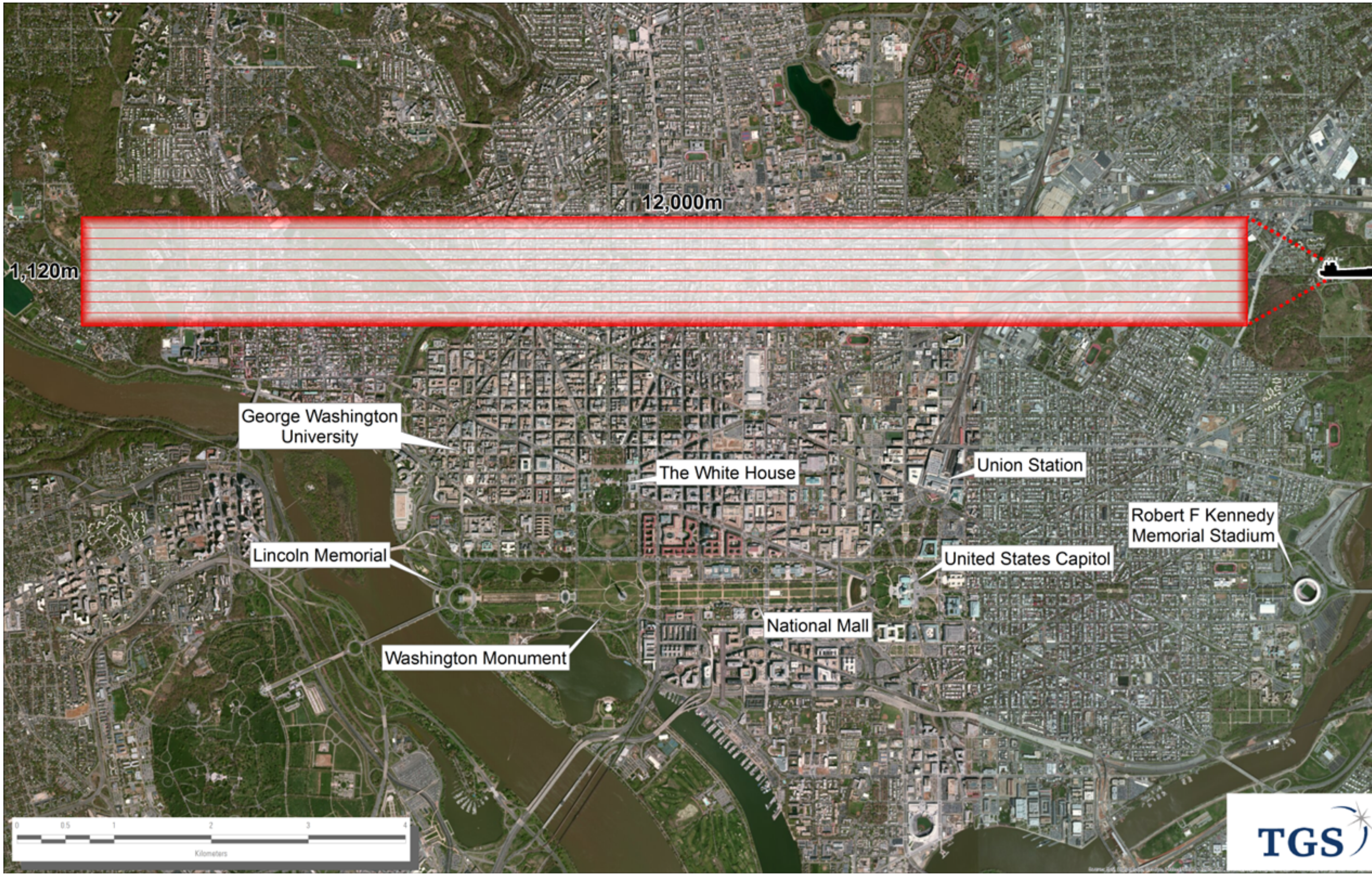
Streamer tow points

Tail buoy



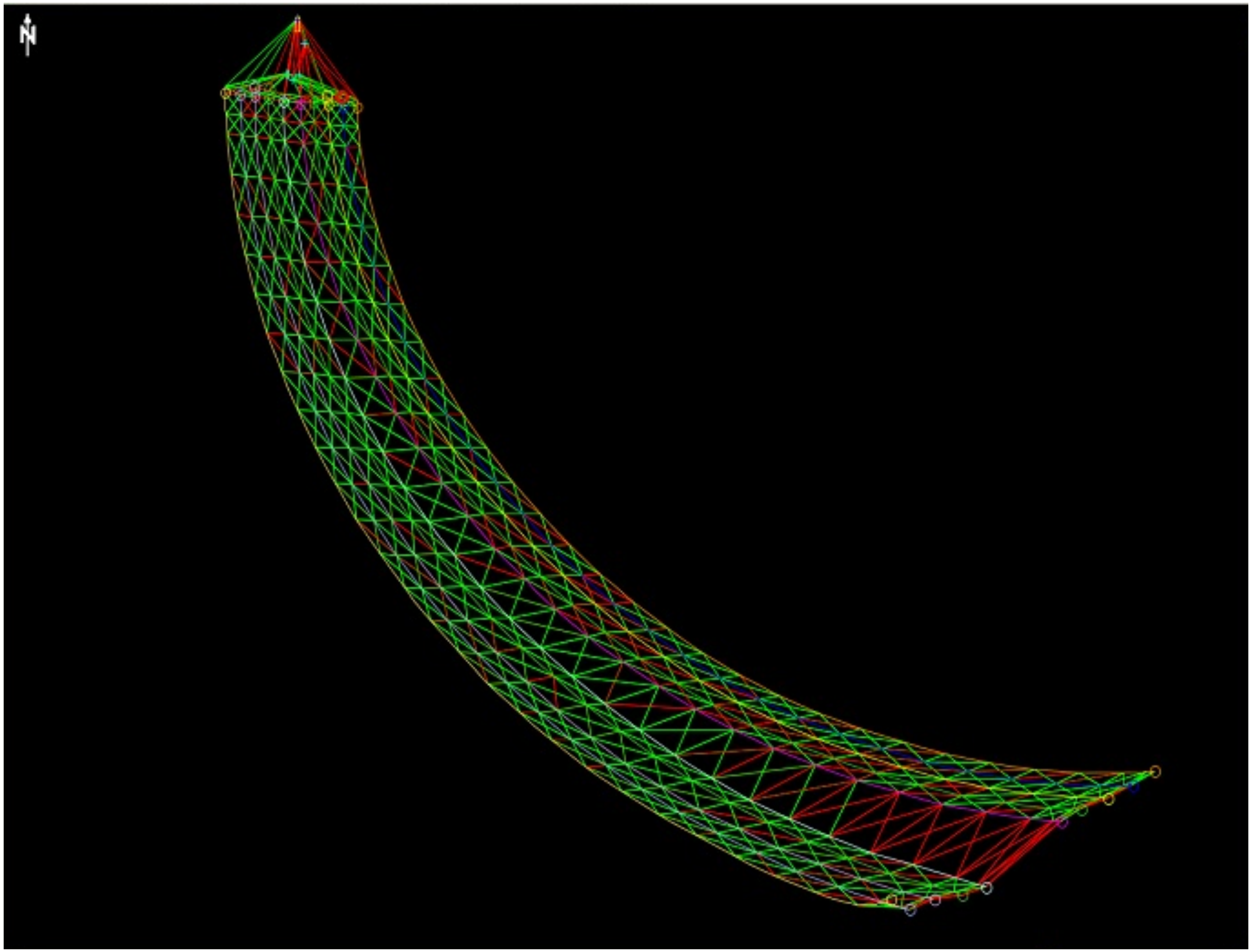
Streamer reels

Courtesy of Peter Seidel - TGS



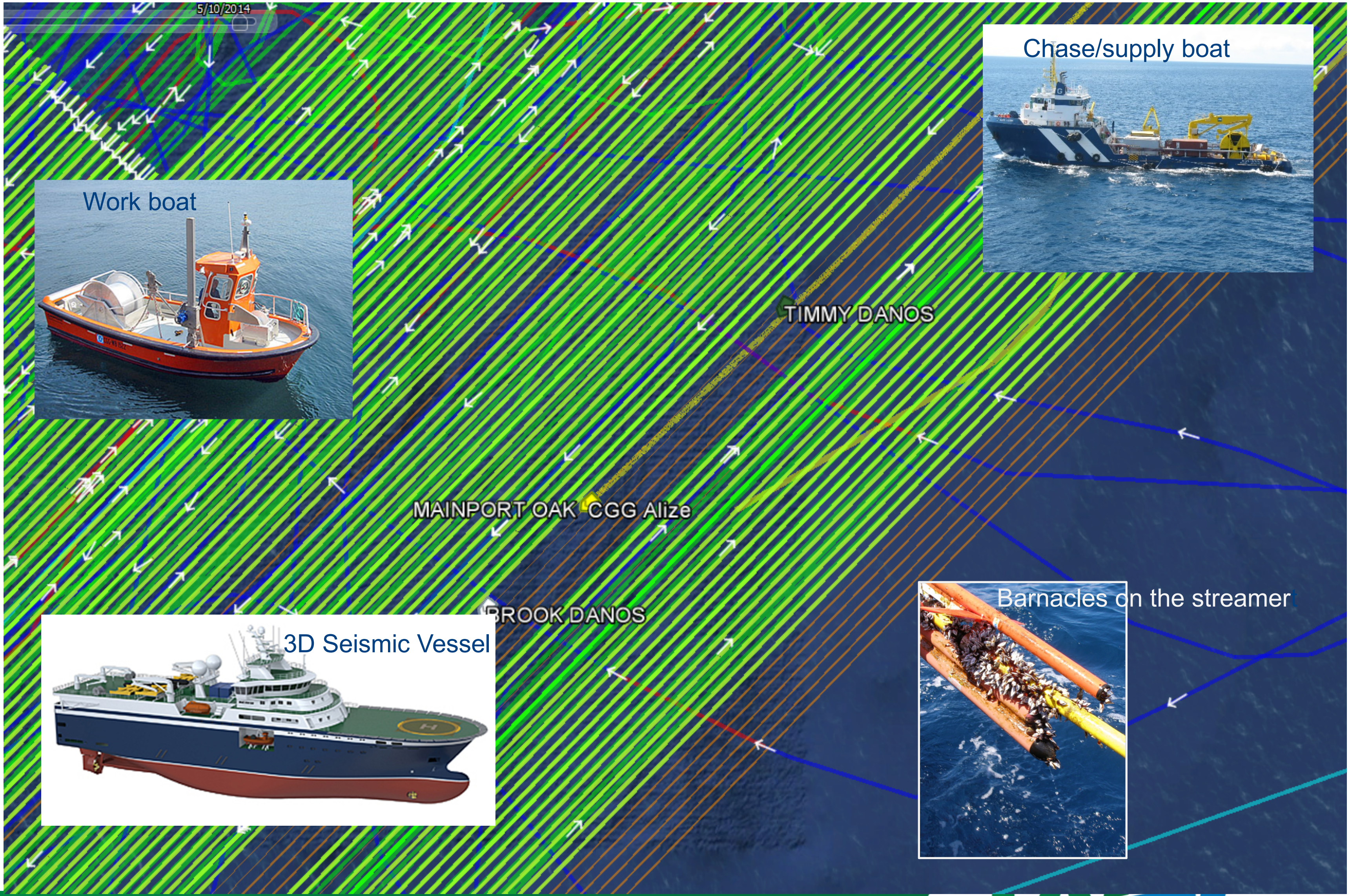
Courtesy of Peter Seidel - TGS

Keeping Track of In-Sea Equipment



Vessel Operations

Support Vessels (not to scale)



Deployment and Retrieval

- Deployment and retrieval times are dependent on many variables including the length of streamers and weather conditions.

- Typical times are:
  - 8 X 12 km streamers = 6 days to deploy – 3 days to retrieve
  - 12 X 6 km streamers = 4 days to deploy – 2 days to retrieve

  - (Source deployment or retrieval is about 3 to 4 hours)

Circle and Line Change Times

- Line change and circle times have many variables but are predominantly determined by streamer length.
- Some typical line change times are:
  - For 12 km streamers - 7-8 hours
  - For 8 km streamers - 3-4 hours
  - For 6 km streamers - 2.8 -3.5 hours

- Some typical circle times are:
  - For 12 km streamers - 10 hours
  - For 8 km streamers - 5 hours
  - For 6 km streamers - 4 hours

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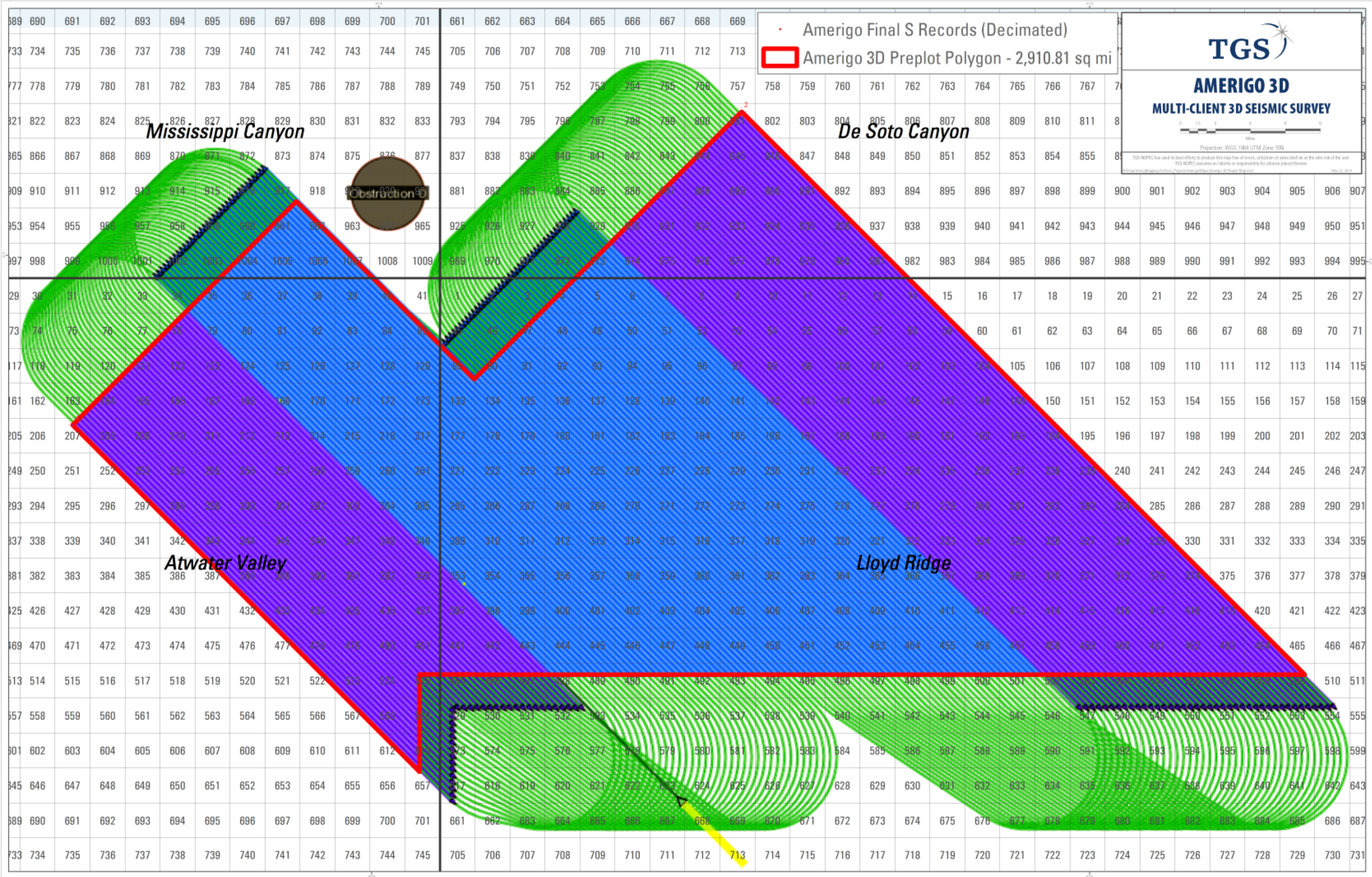
Planning



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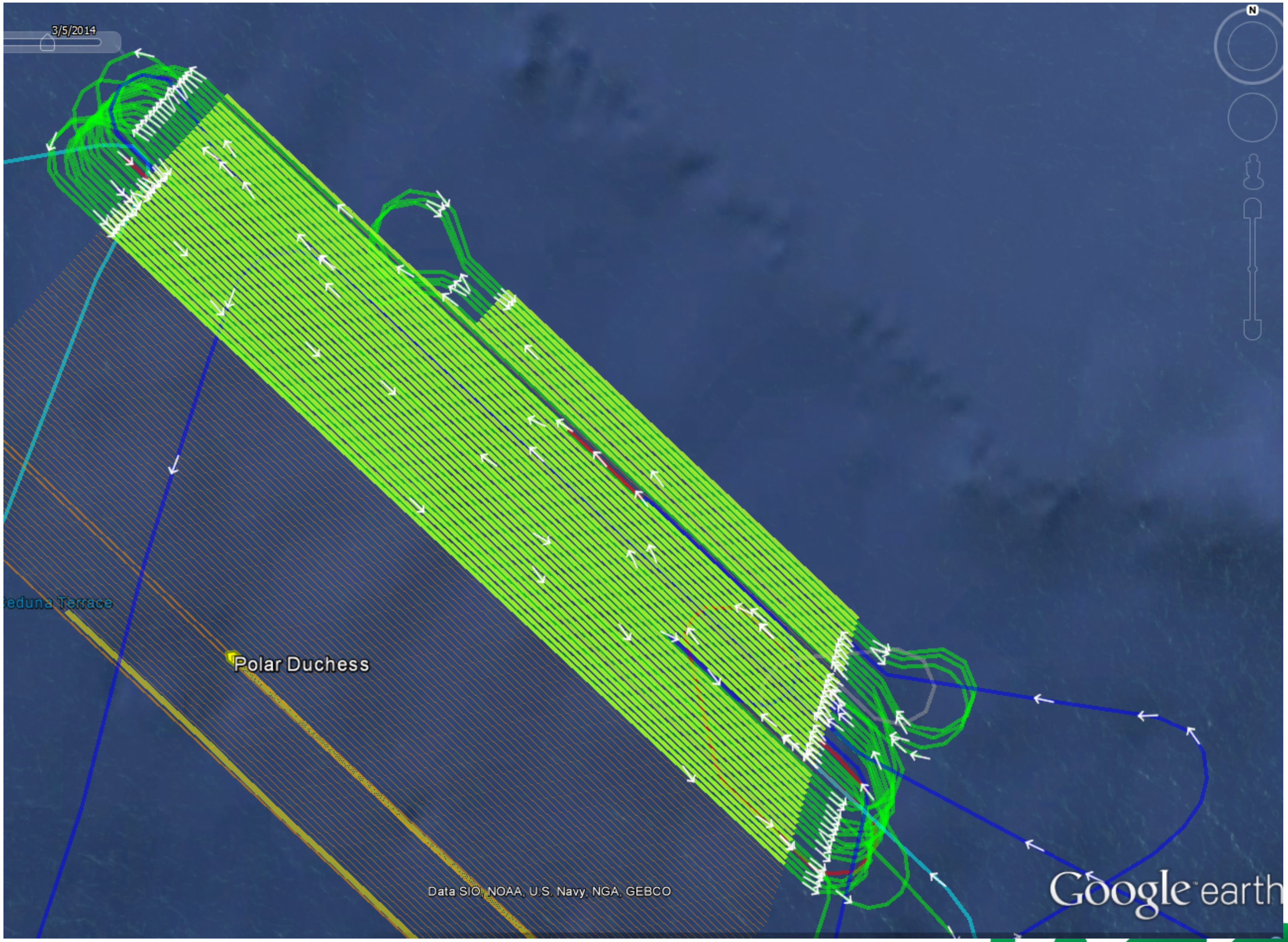
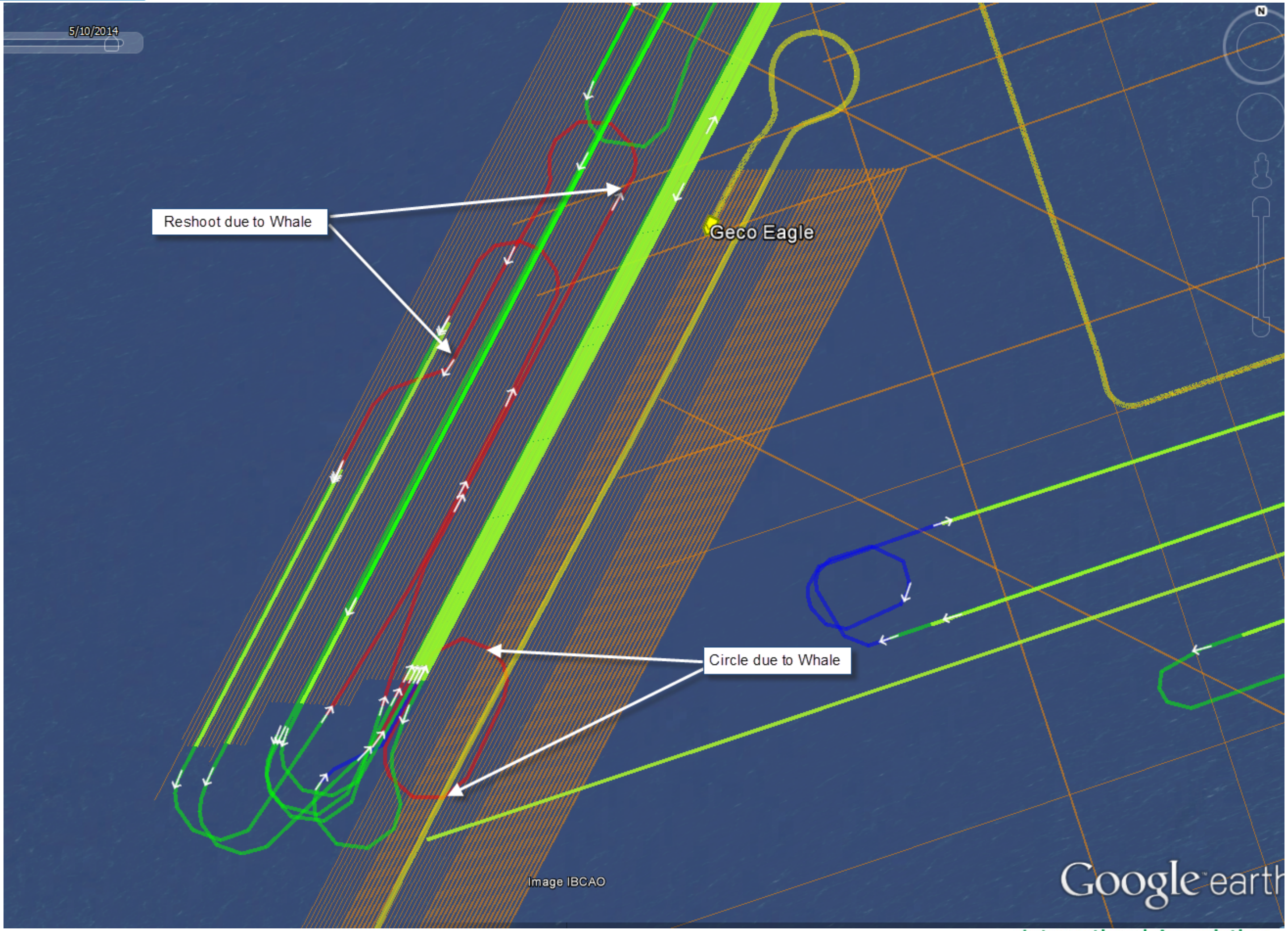
Teardrop Line changes



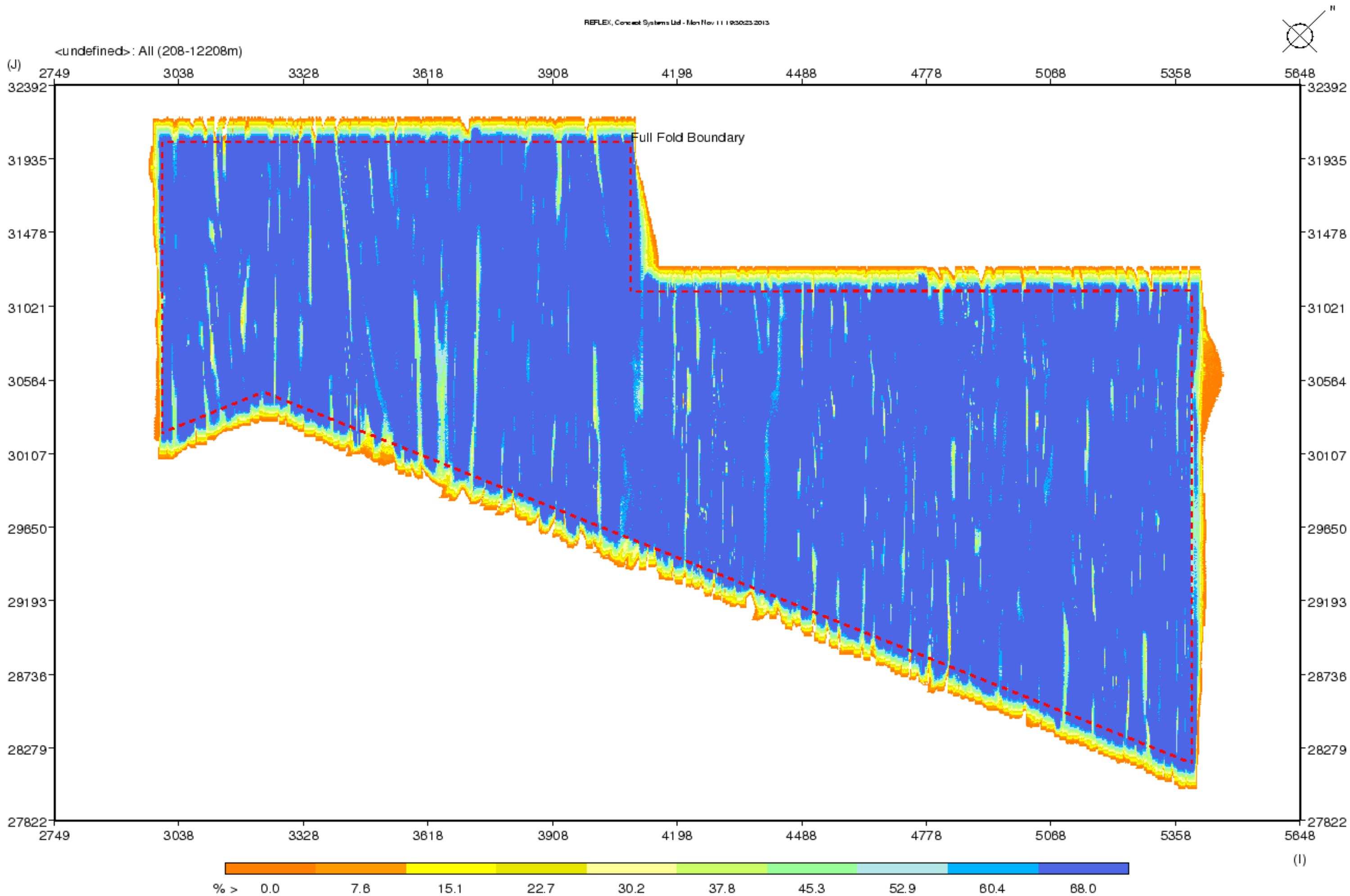
Shutdowns for Mammals



THE VOICE OF THE GEOPHYSICAL INDUSTRY SINCE 1971

International Association IAGC of Geophysical Contractors

Coverage with downtime (10-20%)



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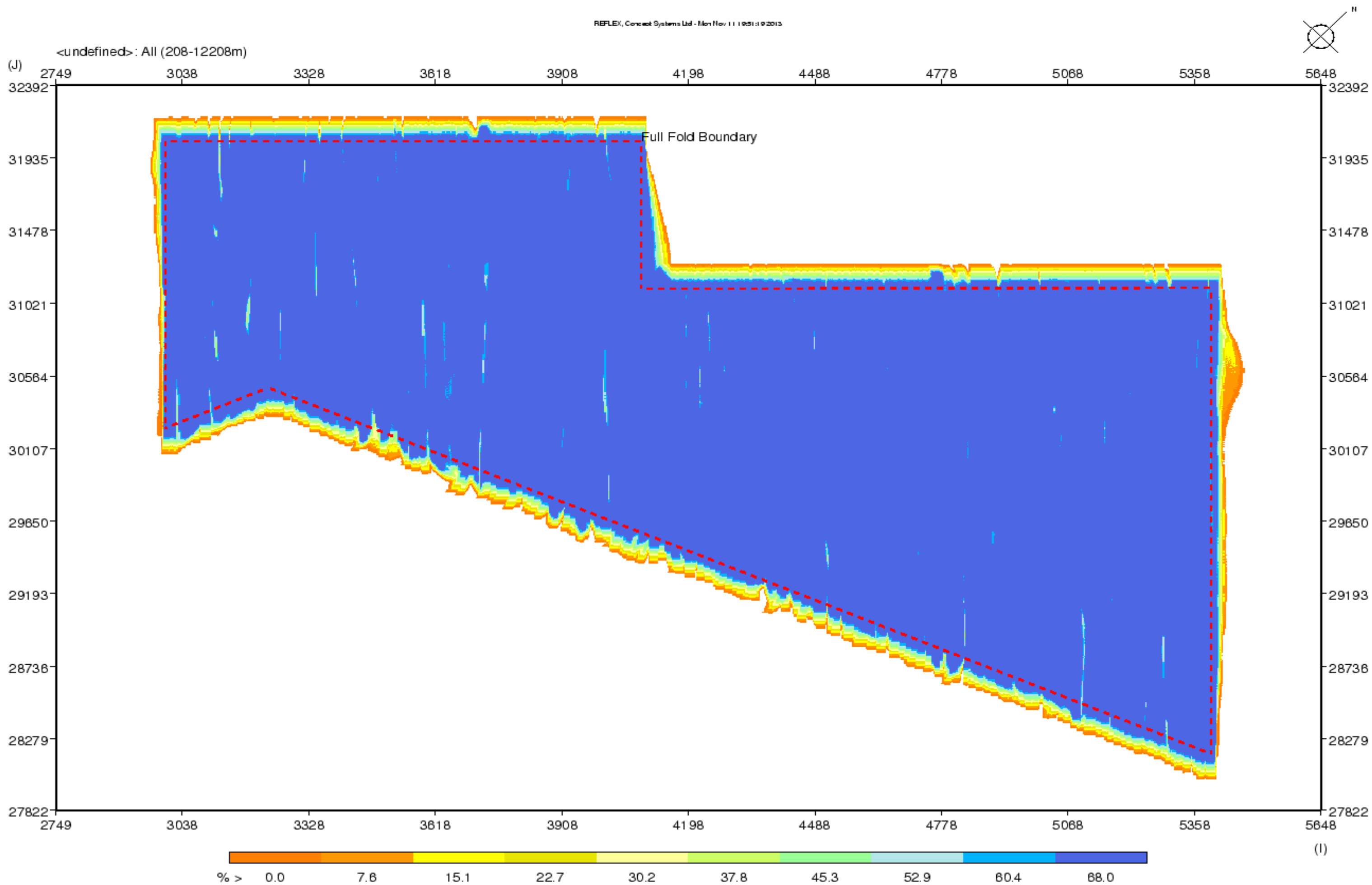
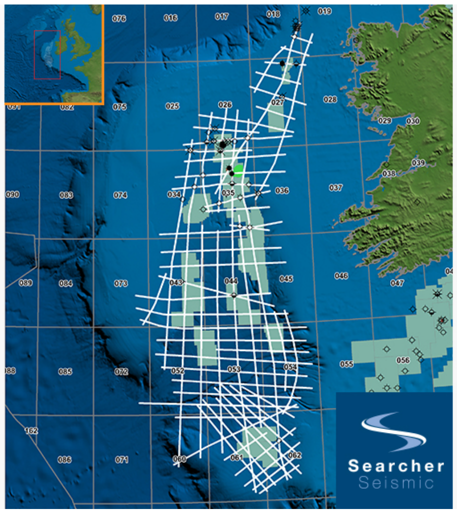
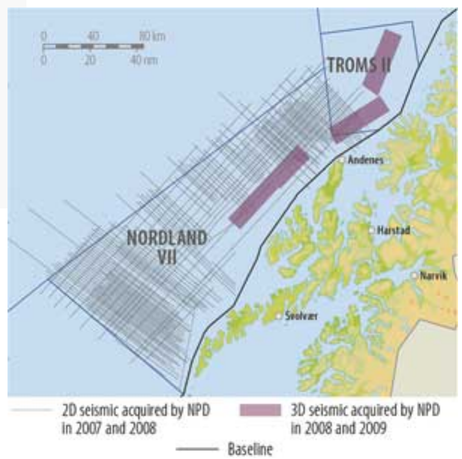
Coverage after backfilling missed lines

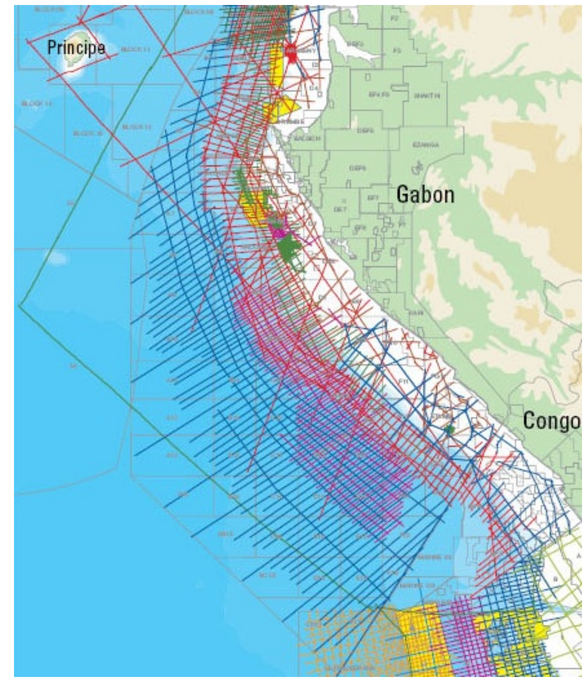


Types of Surveys

2-D surveys tend to be coarser scale over larger areas while 3-D surveys cover smaller areas with more densely spaced lines to resolve detailed features of interest.



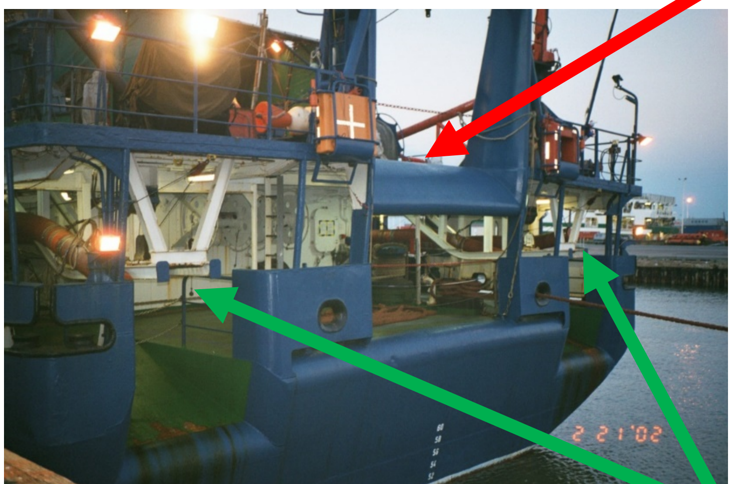




geophysics Rocks!

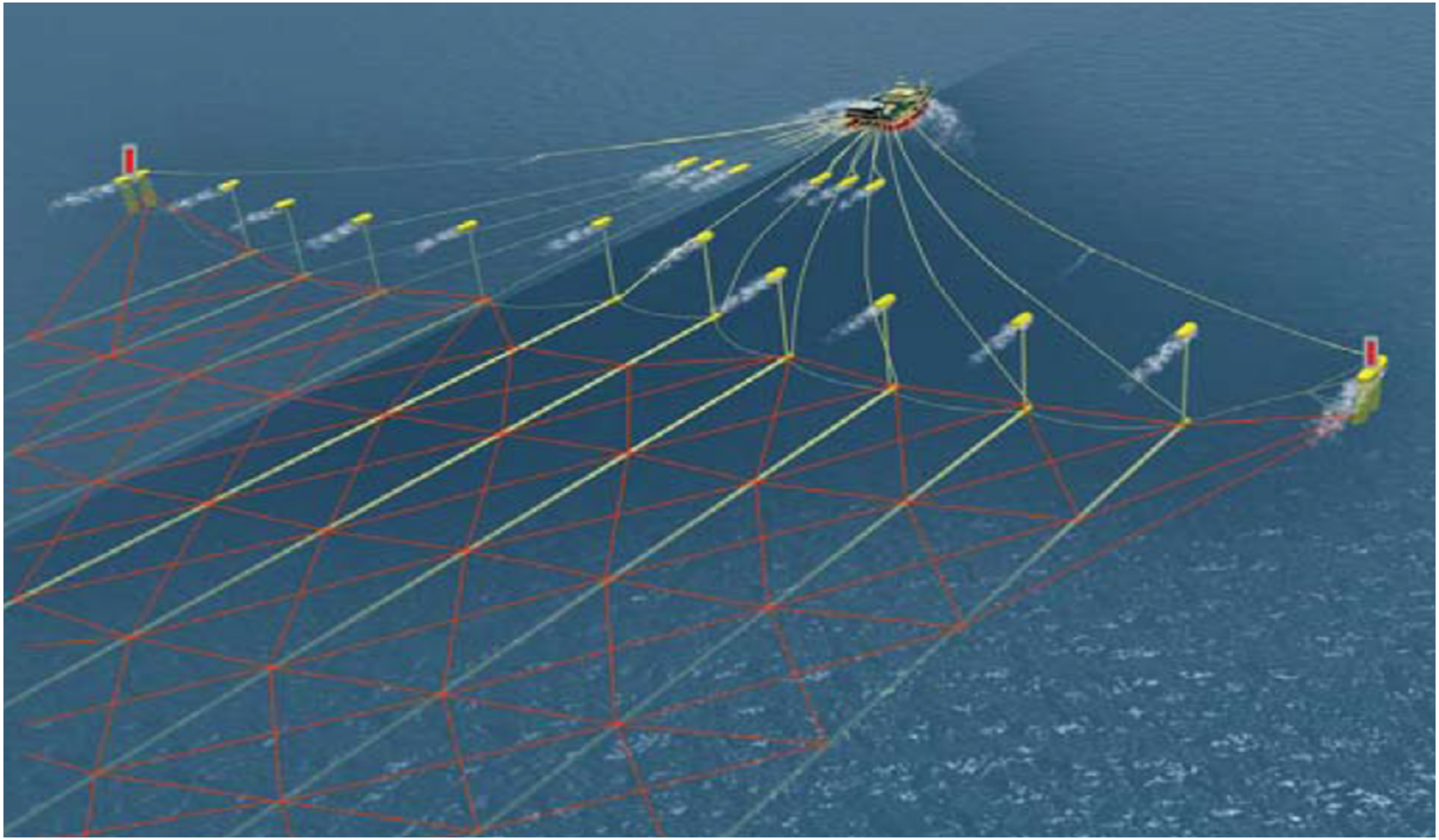
2-D surveys use one receiving streamer; 3-D surveys used multiple receiving streamers

Receivers



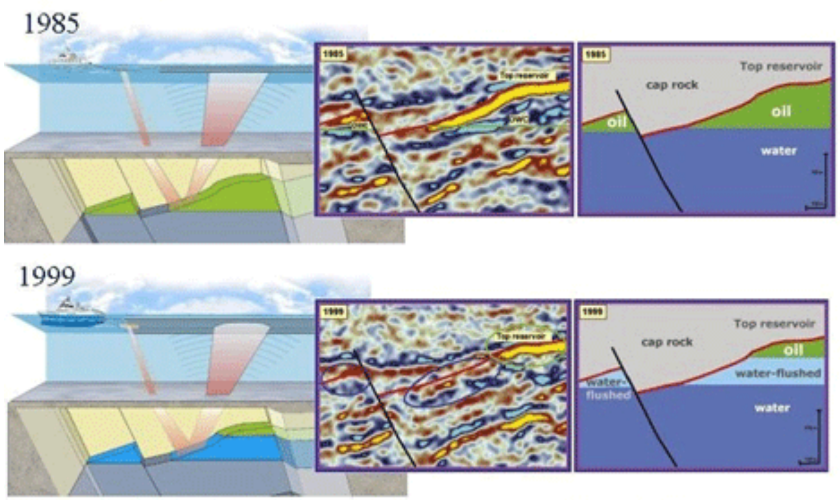
Source arrays – 2, alternating

A 3D array



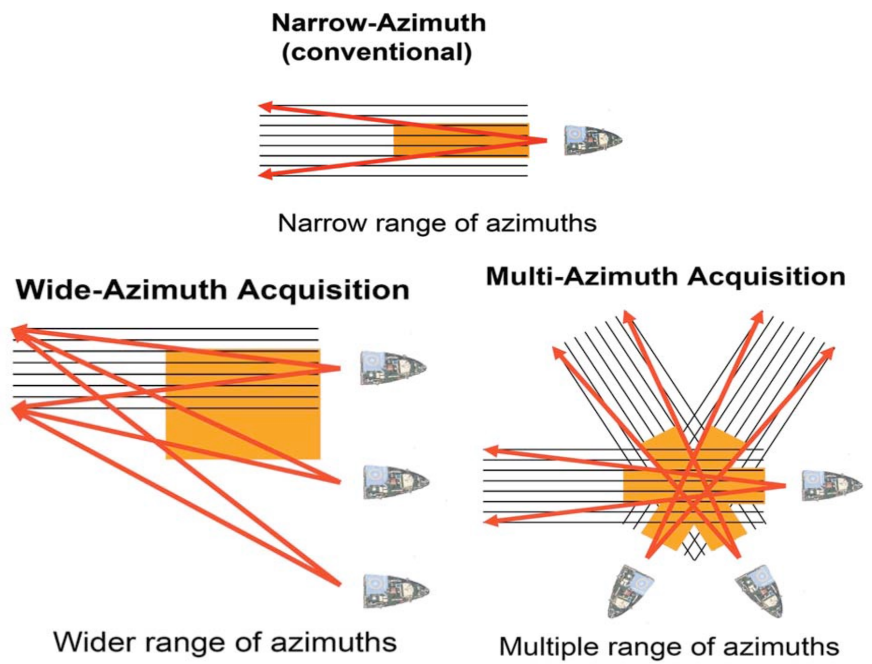
Variants on 3-D

- WAZ and RAZ – one or more sources; two or more receive arrays.
- 4-D – multiple 3-D surveys over time to monitor progress of extraction



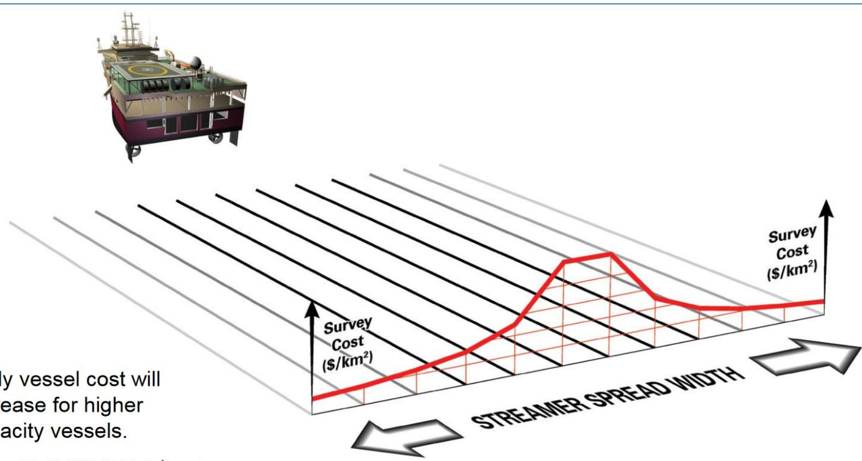
Principle of 4D acquisition

Gullfaks field



Bigger Ships = Reduced Cost, Reduced Time, Reduced Fuel and Reduced Sound

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



Daily vessel cost will increase for higher capacity vessels.

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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

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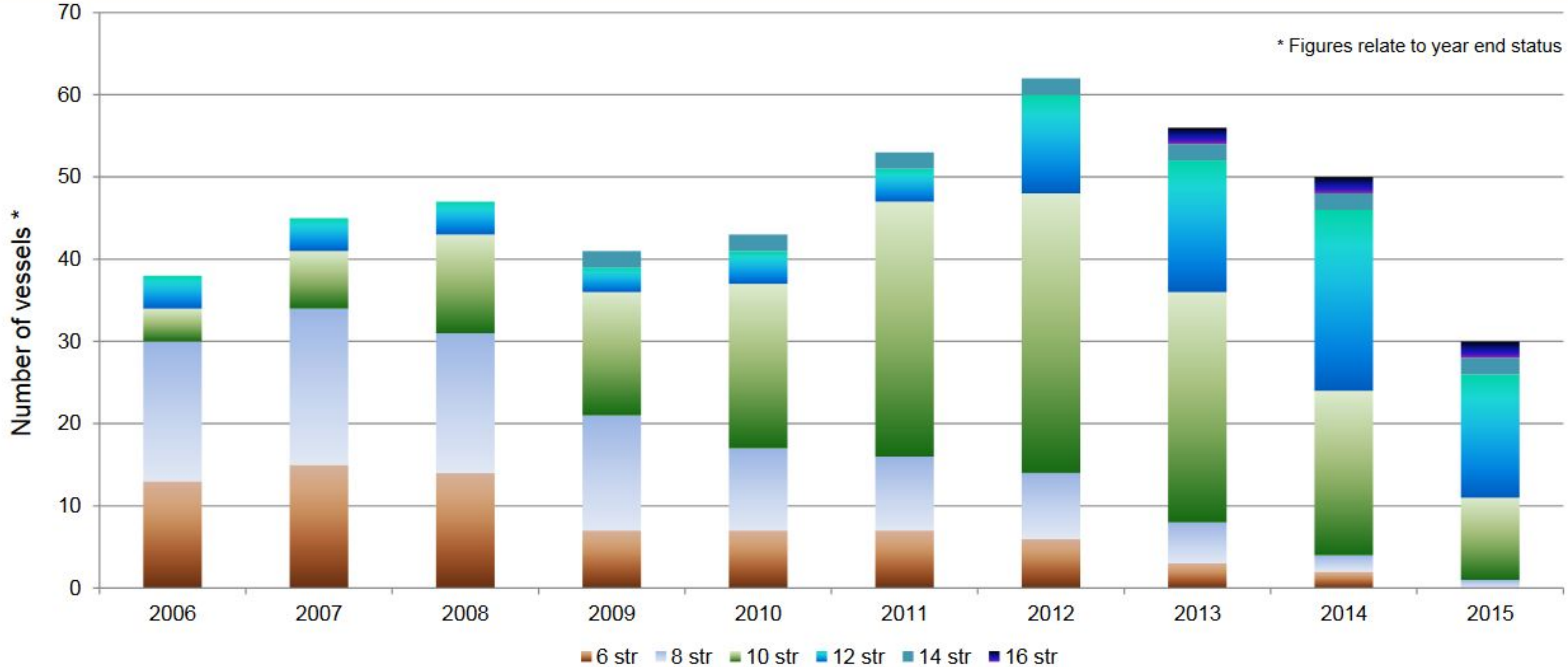
A Quick Word About the Business Model for Seismic Surveys

- Sole Source
  - A seismic company collects data under contract to one client.
  - The contract usually results in the data belonging to the client
  - There are intermediate contractual relations where the seismic operator might contract with two or more clients and data rights could vary
- Multi-Client
  - A seismic company may contract with multiple clients or package multiple data sets for sale as a bundle.
  - The data belong to the seismic company; the customers have limited rights
  - “SPEC” data
    - The seismic operator collects the data on “speculation” that there will be customers for the data
    - The risk falls on the seismic operator
    - Multi-client spec data collection has increased rapidly in the last 20 years or so: customers like the reduced risk burden, seismic companies like the potential for better profits.

Re-processed Data: Companies may buy, sell and bundle libraries of data sets. They may “get more out of the data” through new proprietary data processing algorithms

Fleet Reductions Since 2014 Downturn

Seismic Vessel Count and Renewal



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

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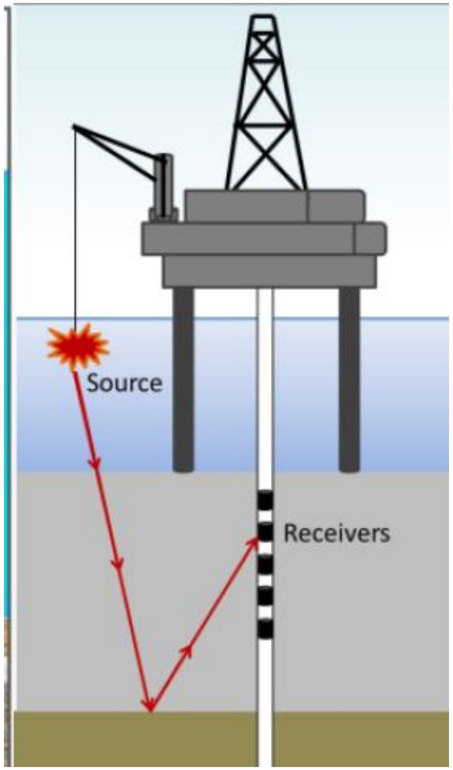
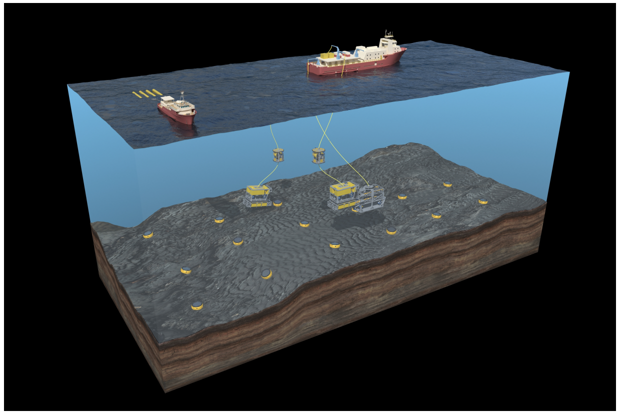
Other seismic methods



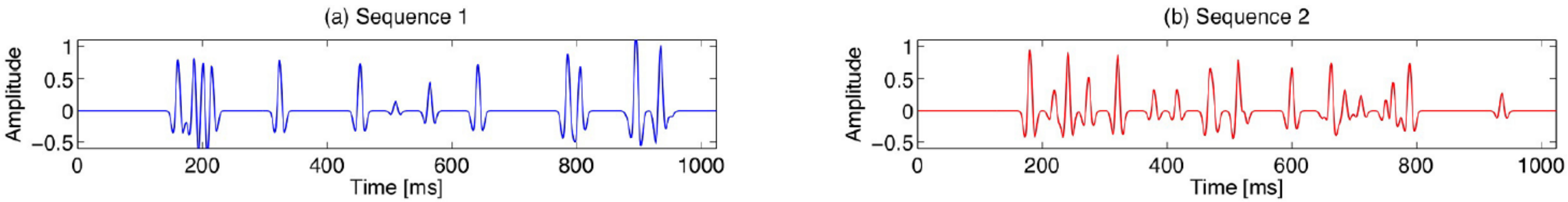
Vertical Seismic Profiling (VSP), aka "borehole seismic"



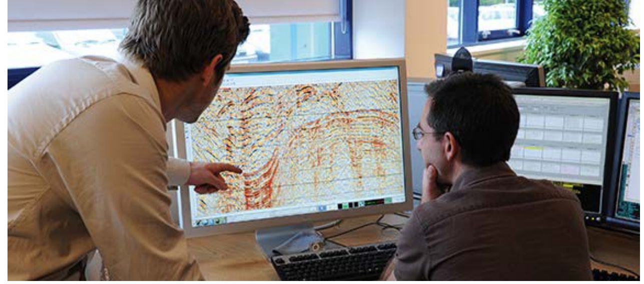
Magseis-Fairfield Nodal

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


Uses of Seismic Surveys

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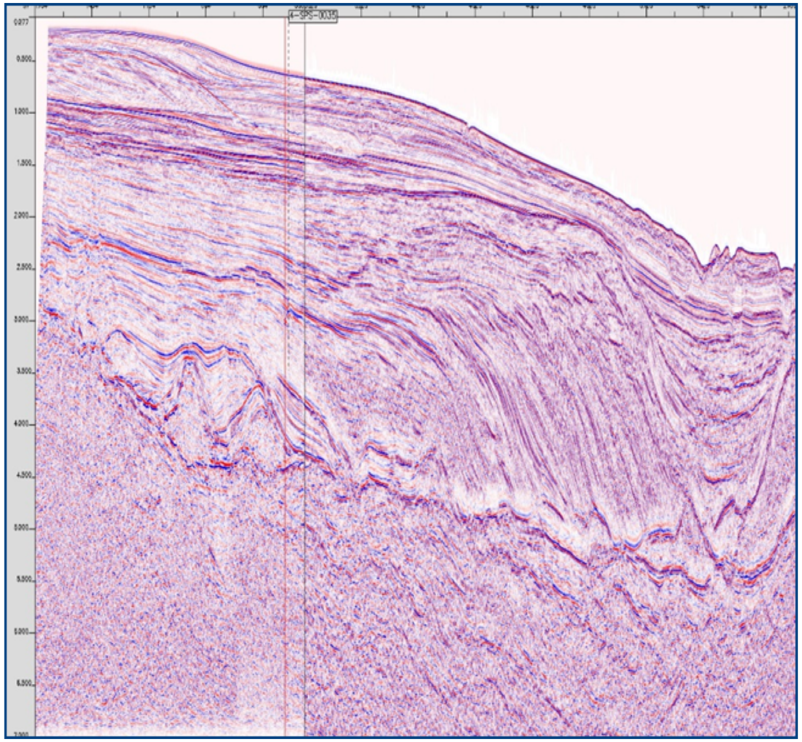
Marine Geophysical Exploration

Purpose

- Image the subsurface
- Evaluate the acreage
- Identify potential hydrocarbon accumulations



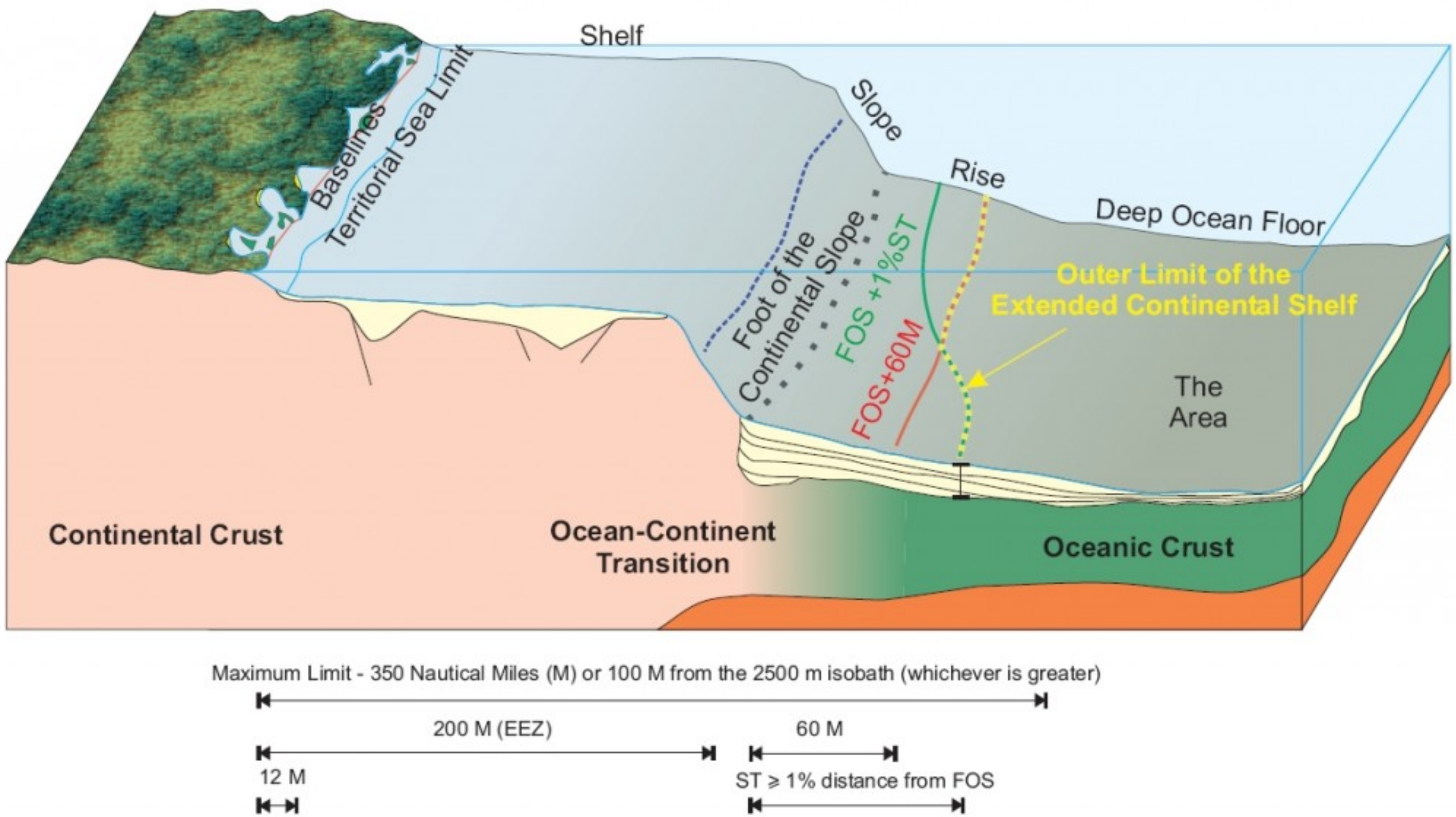
Reducing footprint – fewer wells

- Condemns non-prospective areas
- Replaces drilling as an exploration tool
- Delineates reservoir boundaries

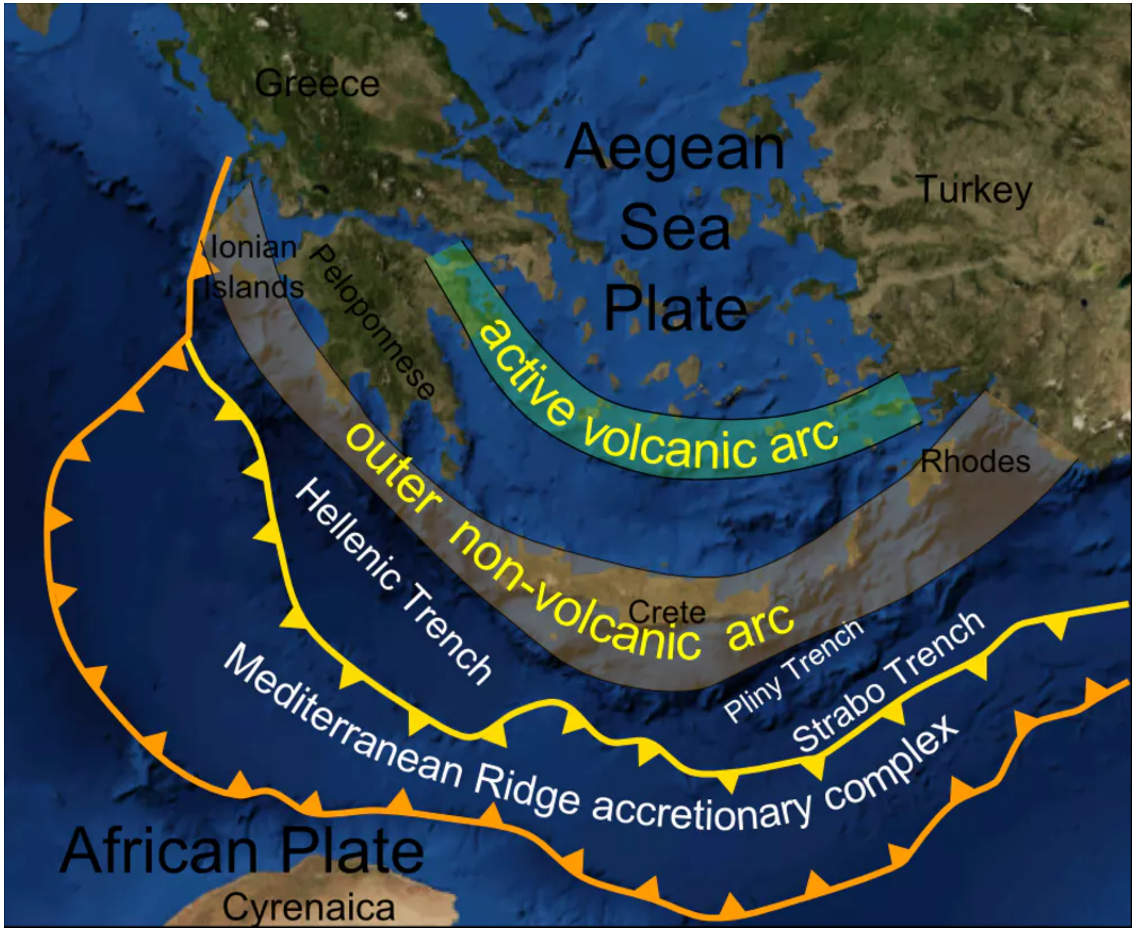
Reducing risk – drilling hazard prediction

- Ensure load-bearing ability of substrate. Seismic surveys help to avoid:
  - High pressure shallow gas/hydrates, etc.
  - Pore pressure prediction – shallow and deep
- Prolong the life of the asset

Making a Case for Expanding a Nation's EEZ

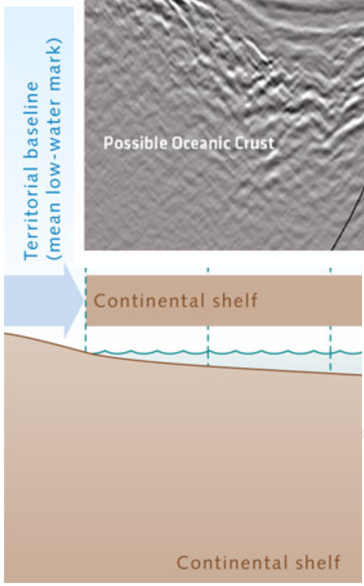


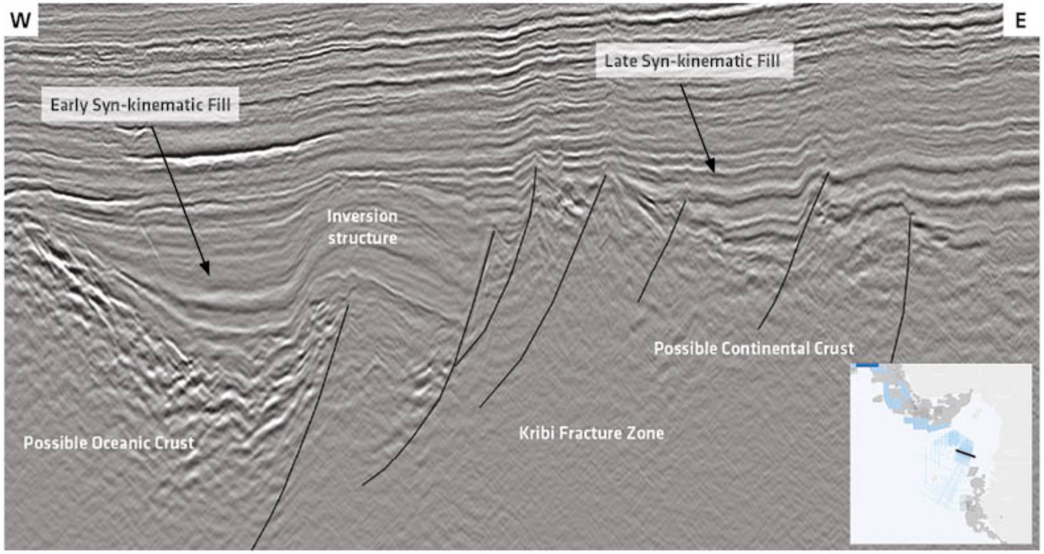
Mediterranean Earthquake and Tsunami Risk Mapping

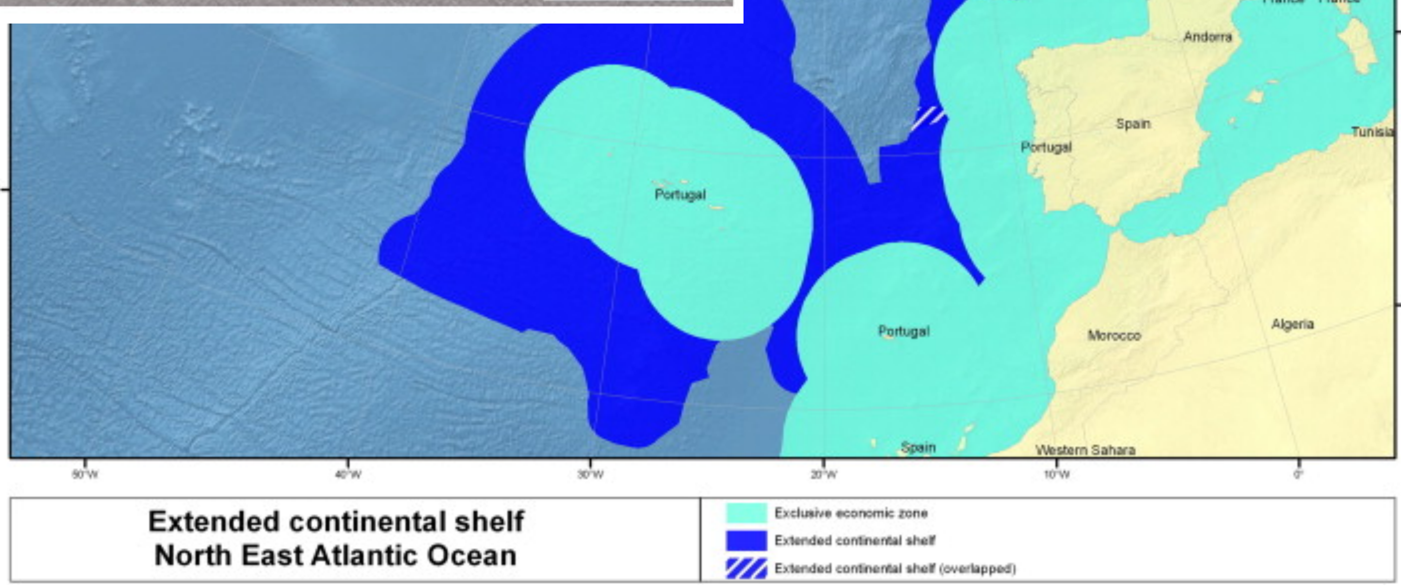


Source: U.S. Geological Survey
MARK NOWLIN / THE SEATTLE TIMES

Making a Case for Expanding a Nation's EEZ







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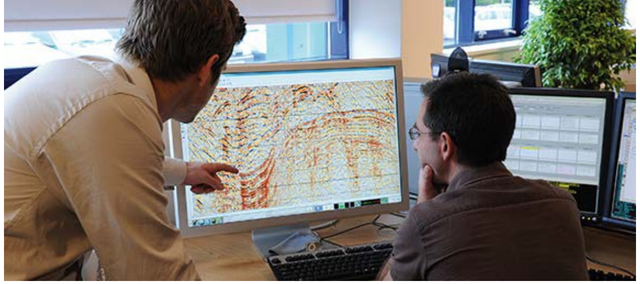
Any mistakes, however, are completely my own.



Questions?

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