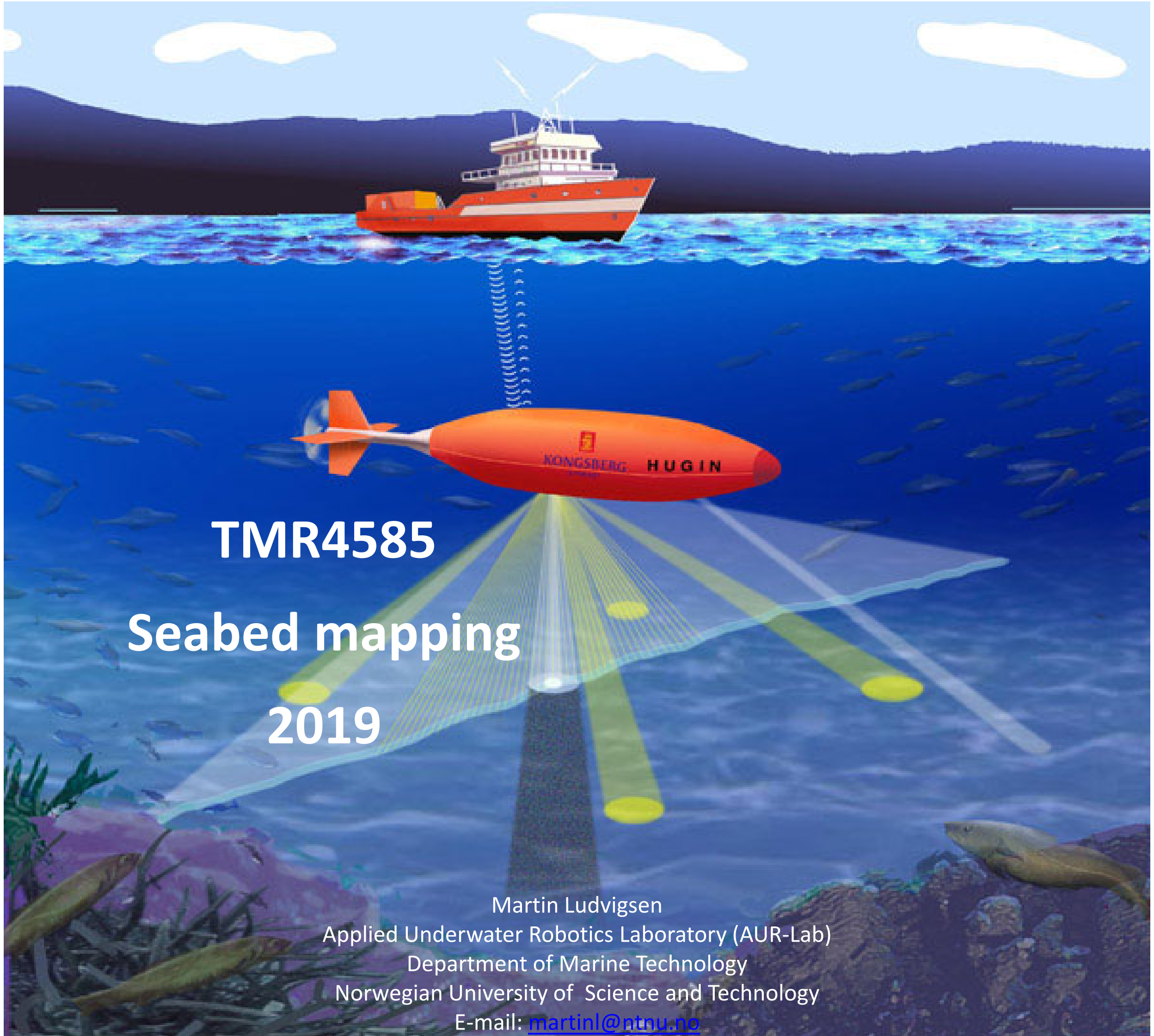


TMR4585

Seabed mapping

2019

Martin Ludvigsen
Applied Underwater Robotics Laboratory (AUR-Lab)
Department of Marine Technology
Norwegian University of Science and Technology
E-mail: martinl@ntnu.no

Kahoot

Learning objectives

- Basic acoustics (15 slides)
  - Sound propagation
  - Sonar equation
    - Source level
    - Scattering
    - Attenuation
  - Basic sonar principles
  - Doppler shift
- Sensor platforms (15 slides)
  - Vessel
  - Towed vehicle
  - ROV
  - AUV
- Sonars (15 slides)
  - Single beam
  - Multibeam
  - Sub bottom profiler
  - Side scan

Curriculum Seabed Mapping I

- Ludvigsen & Sørensen 2016
- Hansen 2012
- Bai et al 2012
- Lecture notes TMR4120

Online resource

https://dosits.org/

NTNU
Innovation and Creativity

Terms and defintions

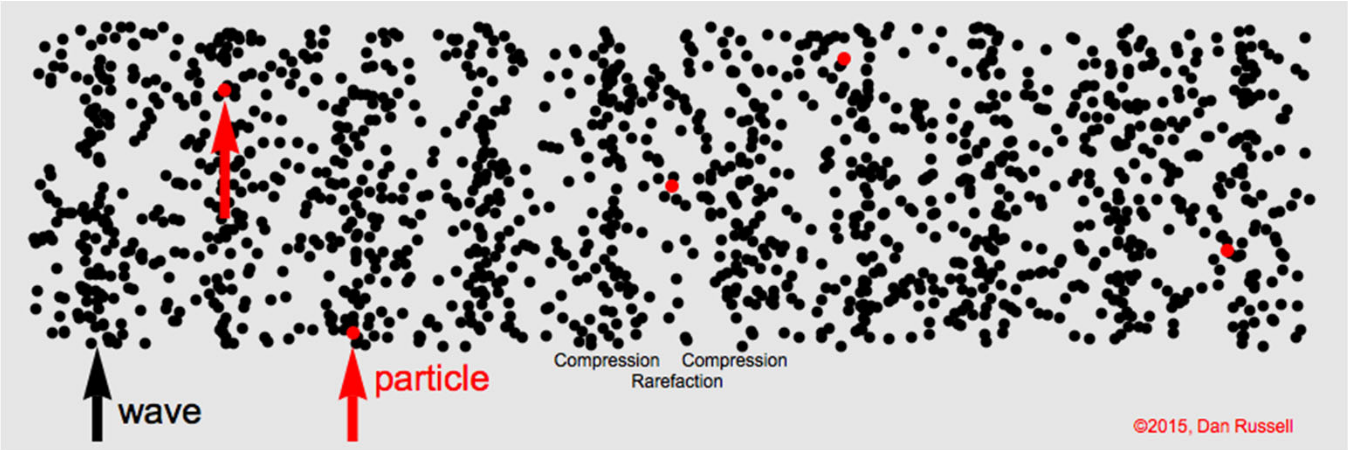
- Sound and sonars
  - Sound propagation
  - Sonar equation
  - Scattering
  - Attenuation
- Platforms
  - ROV
  - AUV
- Sonars
  - MBE
    - Beamforming
  - SBP
  - SSS
    - TimeVarying Gain (TVG)

Acoustics

The acoustic wave equation for fluids and gases is derived by the application of three simple principles:

- The continuity equation, or conservation of mass
- Newton’s second law: force equals mass times acceleration
- The equation of state: the relationship between changes in pressure and volume

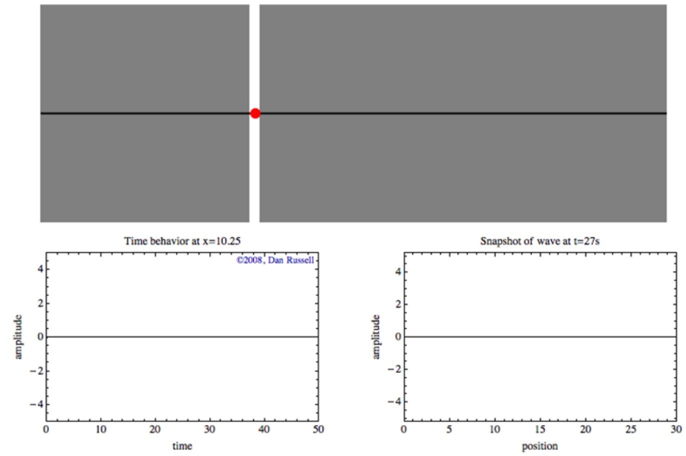
Longitudinal waves



https://dosits.org/science/sound/what-is-sound/

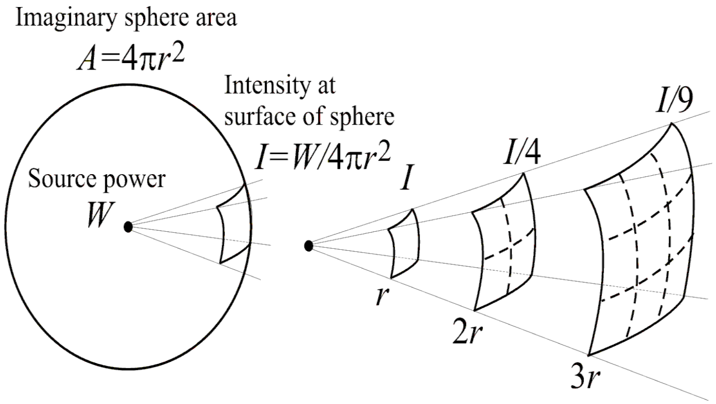
How to characterize sound

- Amplitude
- Frequency
- Intensity



Travel of sound

- Reflection
- Scattering
- Refraction
- Absorption
- Spreading



Acoustics

- We treat signals and waves with sine or cosine form, also called harmonic signals and waves. We move from the time domain to the frequency domain by using Fourier transformation. The angular frequency is:

$$\omega = 2\pi \mathrm{f}$$

- Where ω is in rad/s and frequency f in Hz. The acoustic wave number κ and the wavelength λ are defined by:

$$k = \frac{\omega}{c} = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{c}{f}$$

Sound velocity

- The propagation velocity of an acoustic wave is imposed by the characteristics of the propagation medium: it depends on the density ρ and the elasticity modulus
- $c = \sqrt{\frac{E}{\rho}}$
- *c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3+(1.34-0.01T)(S-35) + 0.016z*

Intensity and power

- Acoustic energy can be composed to kinetic (corresponding to particle movements) and potential components (corresponding to the work done by elastic pressure forces).
- Acoustic intensity

$$I = \frac{p_0^2}{2\rho c}$$

- Plane wave of amplitude p_0
- Acoustic power *P*
- Surface *S*
- $P = I \times S = \frac{p_0^2 S}{2\rho c}$

Decibel and Absolute Reference Level

- Acoustic values like pressure or energy are usually quantified on a logarithmic scale, and noted in decibels (dB)
- Acoustic intenist level:

$$10\log\left(\frac{P_1}{P_2}\right) = 10\log\left(\frac{p_1^2}{p_2^2}\right) = 20\log\left(\frac{p_1}{p_2}\right)$$

- A reference level is necessary if one is to give absolute pressure or intensity levels in dB. The intensity reference is often the intensity 1 m from the instrument.

Pulse length

- Acoustics in underwater applications are often used as sound pulses

$$l_p = n\lambda = n\frac{c}{f}$$

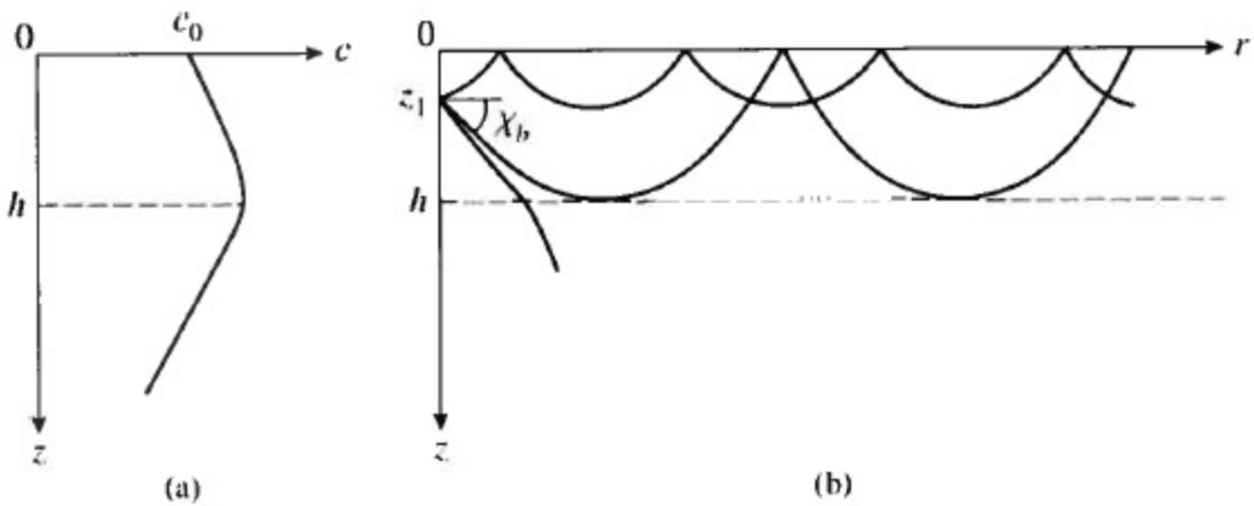
- Longer pulse lengths are used for devices and instruments that will be used in long-range applications, rather than those for short-range applications

Ray bending

- The path can be calculated according to Snell's law, where Θ_1 is incident angle for the sound path and Θ_2 refraction angle. c_1 and c_2 represents the two levels for speed of sound.

$$\frac{\sin(\Theta_1)}{c_1} = \frac{\sin(\Theta_2)}{c_2}$$

Surface channel



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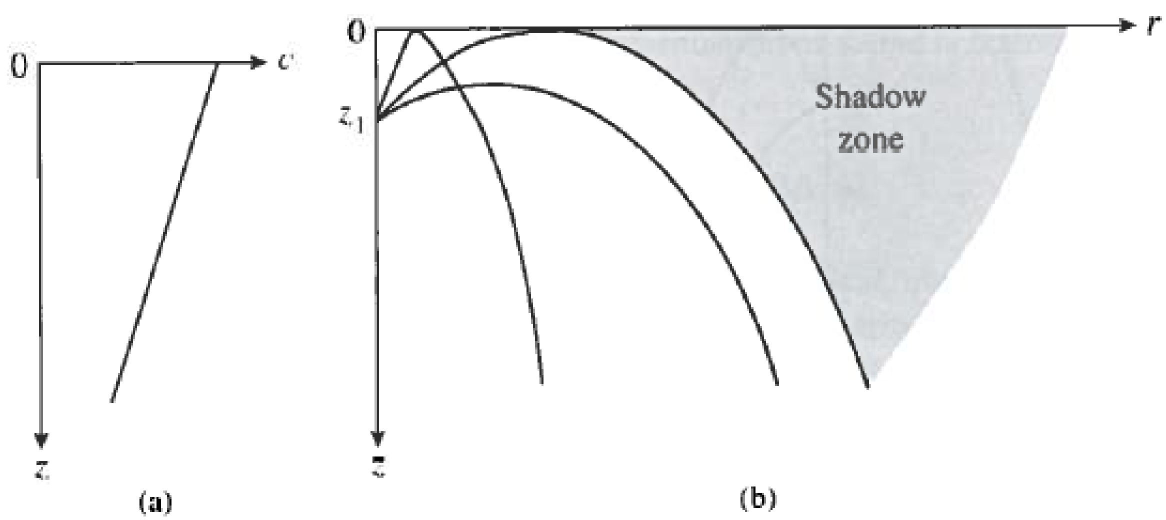
Shadow zones



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Doppler effect

- The Doppler Effect corresponds to a shift of the apparent signal frequency, due to a change in the duration of the source receiver paths during transmission time
- The Doppler Effect complicates the processing of signals.
- It can be used to determine the speed of a vehicle relative to the bottom or the water column
- If can be used to measure the direction and magnitutde marine currents

Sonar equation

- The sonar equation expresses the intensity EL (Echo Level) of the echo received by the sonar system after backscattering

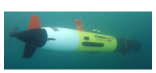
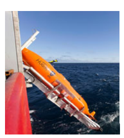
$$EL = SL - 2TL + TS = SL - 40\log(R) - 2\alpha R + TS$$

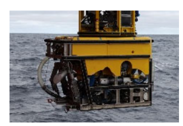
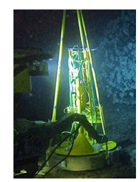
$$EL \geq NL + DT$$

- DT (Detection Threshold)
- The lower the noise, the lower can be the EL and, with a determined target and equipment, it is possible to increase TL and thus R.

Categories of underwater platforms

- Underwater vehicles
  - Manned submarines
  - Unmanned underwater vehicles
    - AUVs
      - Gliders
      - Remus
      - Hugin
    - ROVs
      - Eyeball
      - Observation class
      - Work class
    - Landers

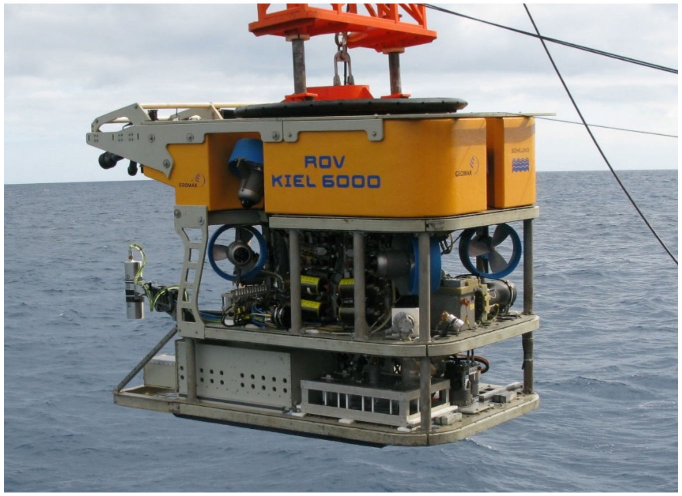



ROV categories

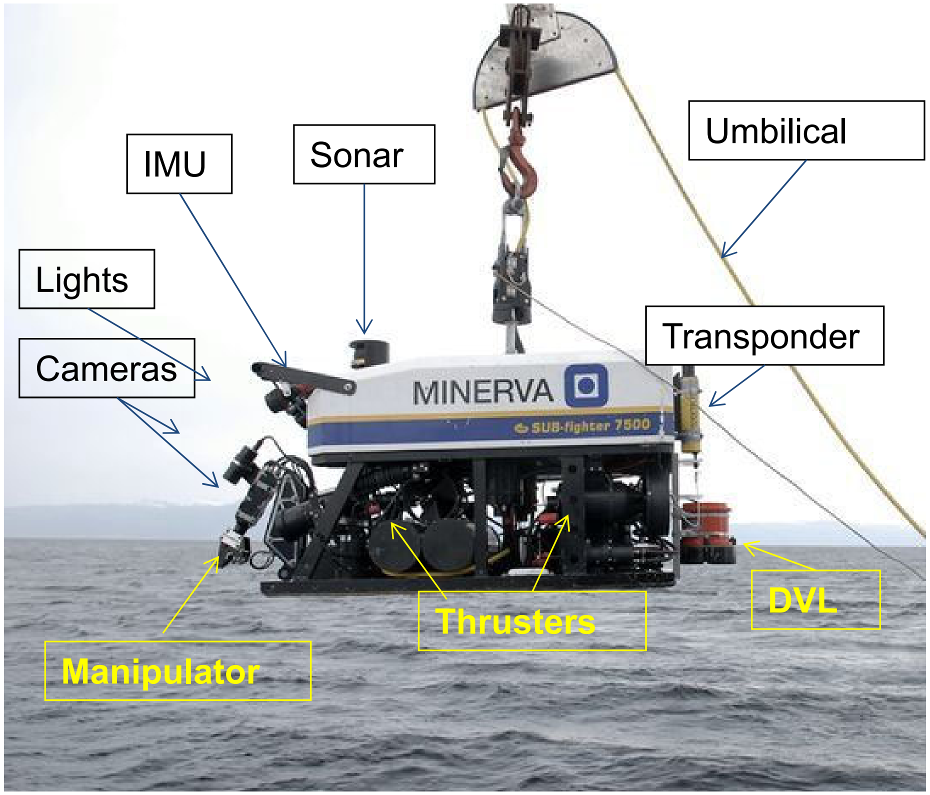
Class I – Pure observation

Class II – Observation with payload option

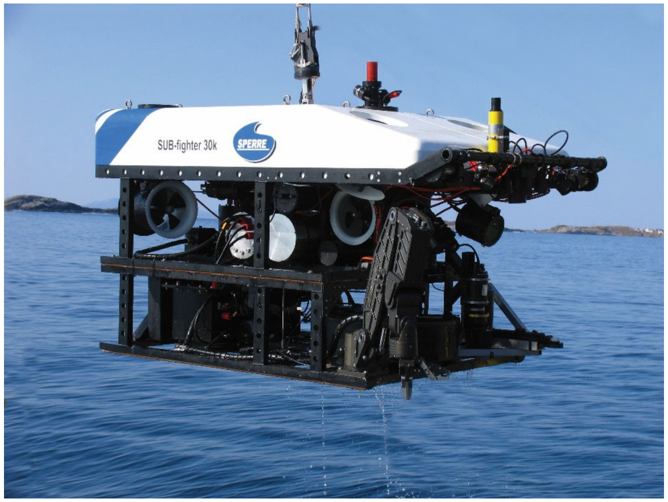
Class III – Work class vehicles



Components and sub systems

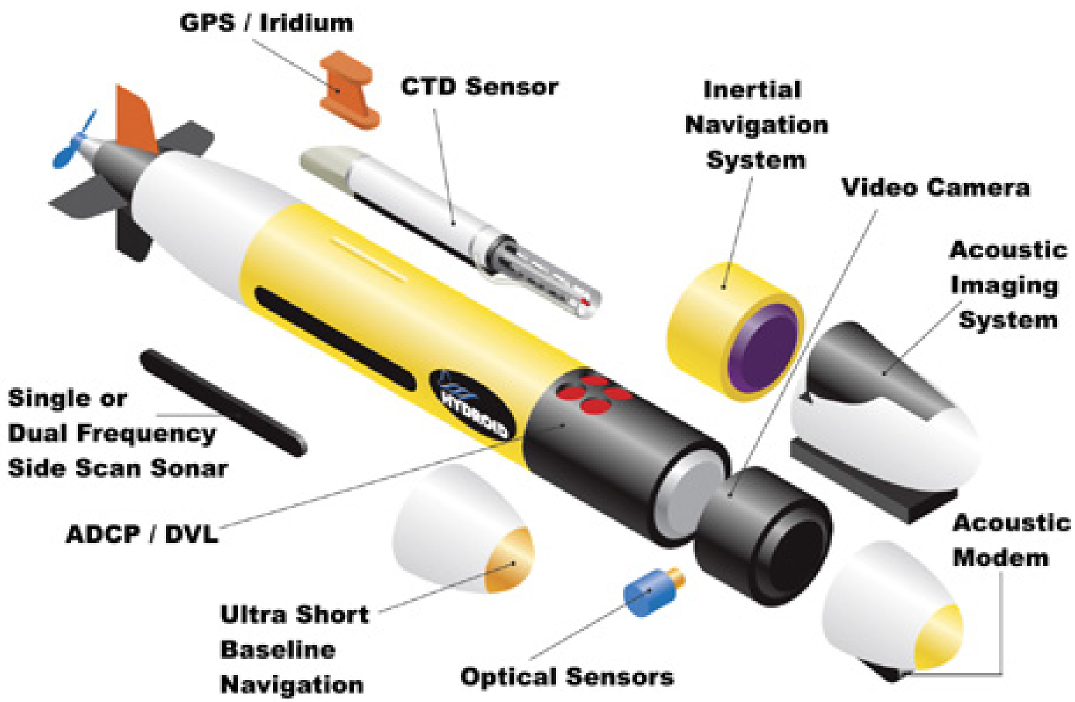


Components and systems

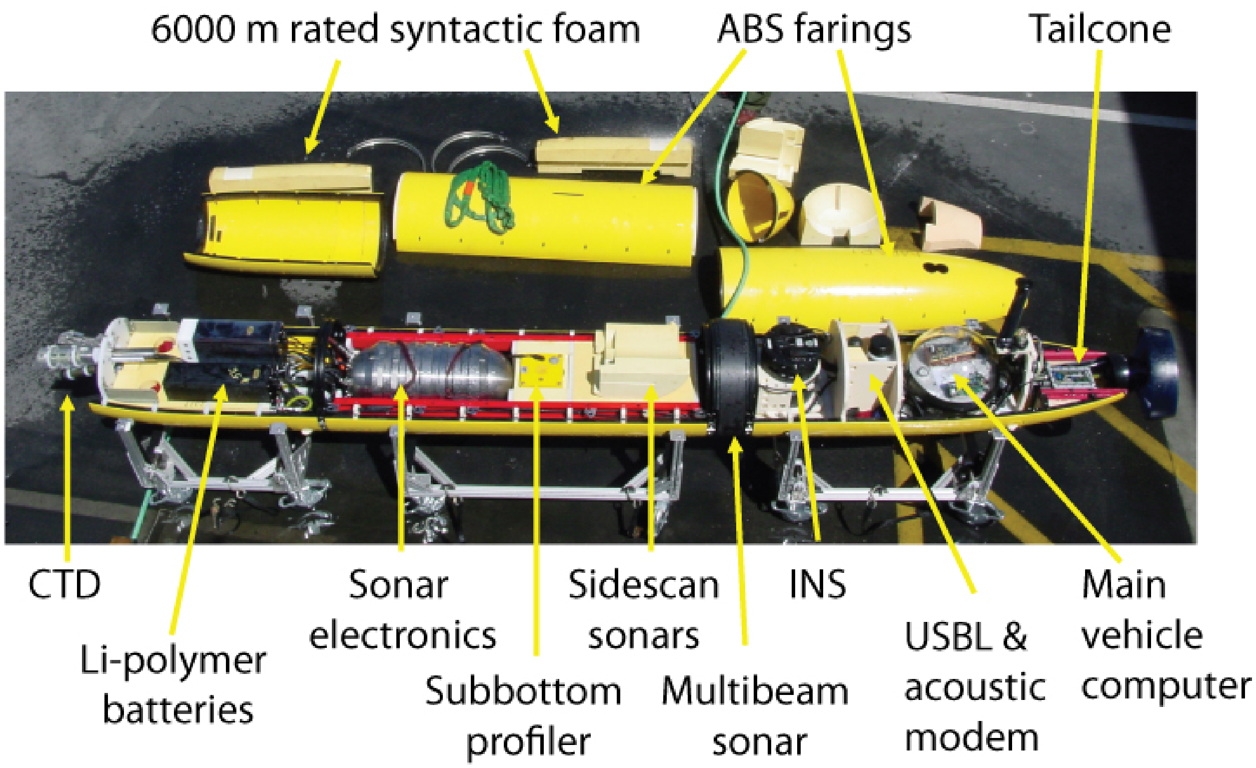


- Navigation
  - Sonar
  - IMU
  - DVL
  - Transponder
- Lights and camera
- Power systems
- Propulsion systems
- Hydraulic system
  - Manipulator and HPU
- Payload system
  - Mappings sonars
  - Samplers
  - Pipetracker
  - etc

AUV REMUS 100

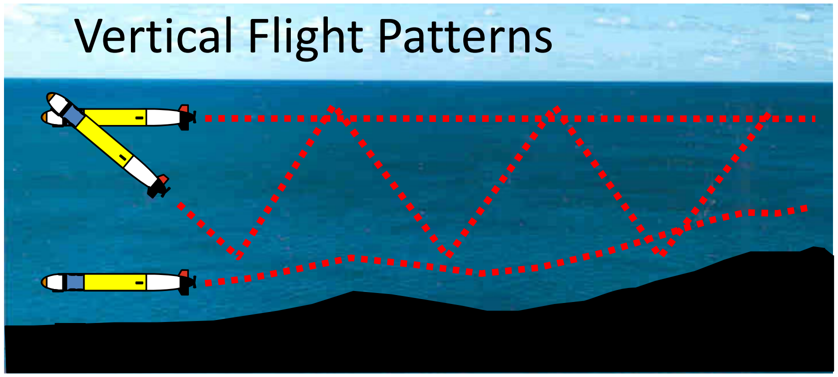


AUV - Components

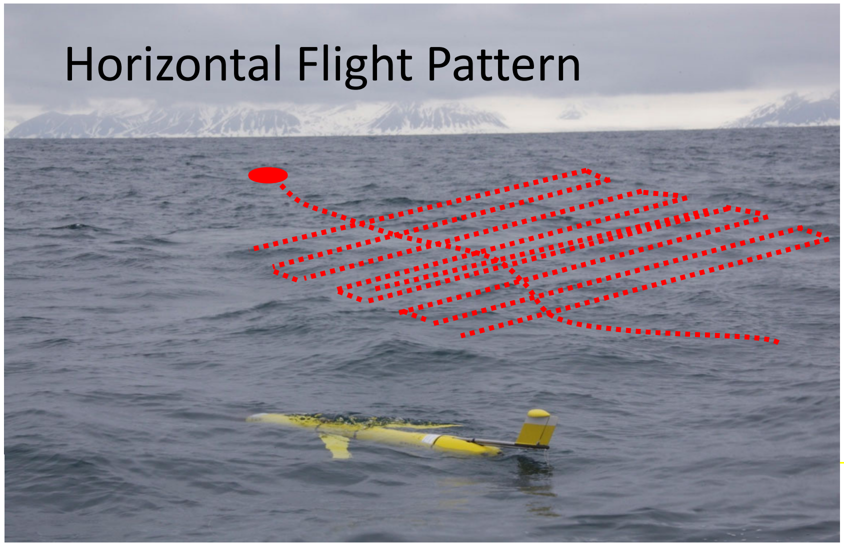


AUV flight patterns

Depth
Undulate/Seesaw
Altitude

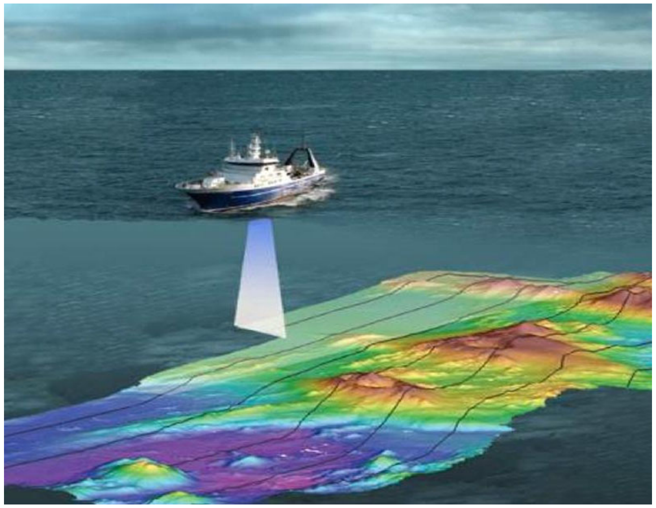


Transects
Grids
Drifting



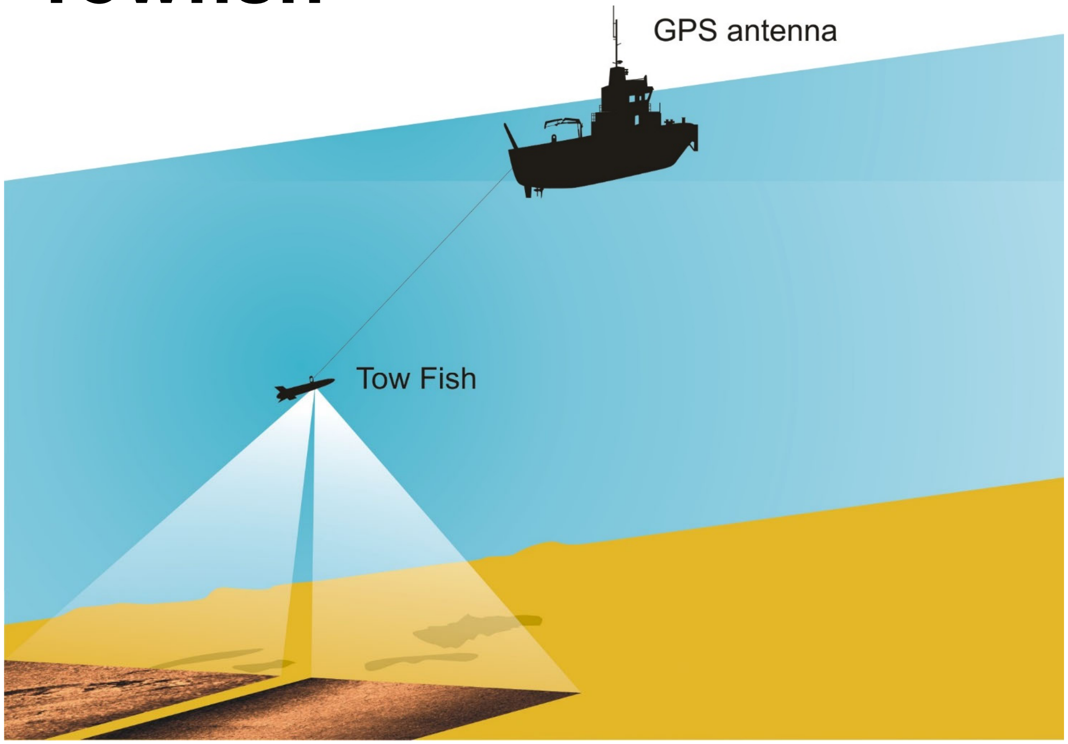
Survey vessel

- DGPS surface positioning system
- USBL subsurface positioning system
- North seeking gyro & motion sensor
- Dual head scanning profiler system
- High resolution sonar system
- Temperature / salinity probes



- On-line survey and navigation computer system
- Off-line data processing and charting computer system

Towfish



http://ets.wessexarch.co.uk/

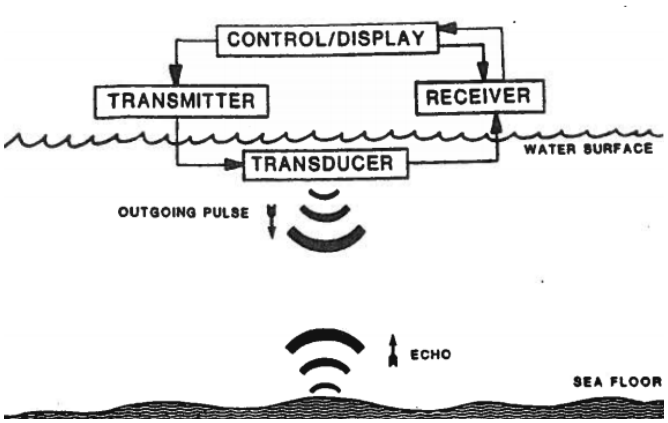
Sensor platforms

Platform	Capacity	Pros	Cons
Vessel		Control Navigation Communication	Cost vessel Personnel Distance to seabed
Tow fish		Cost Simplicity Robustness	Navigation Manuovering Altitude control
ROTV		Cost Altitude control Manuovering	Navigation Vessel dependent
AUV		Seabed coverages Manuovering Speed efficiency	Cost Risk Navigation
ROV		Direct control High resolution/control	Vessel dependent Low speed/efficiency

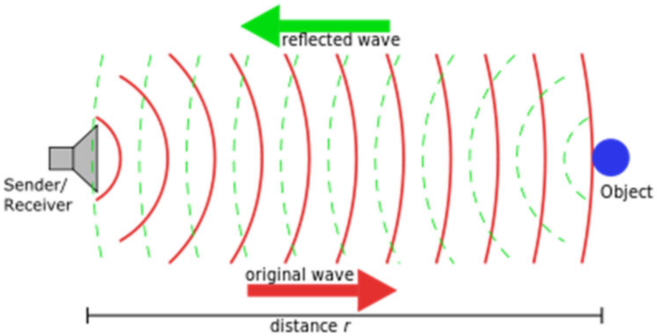
Sonars

- Sonar concept
- Multibeam echosounder
- Sub bottom profiler
- Side scan sonar

Sonar concept

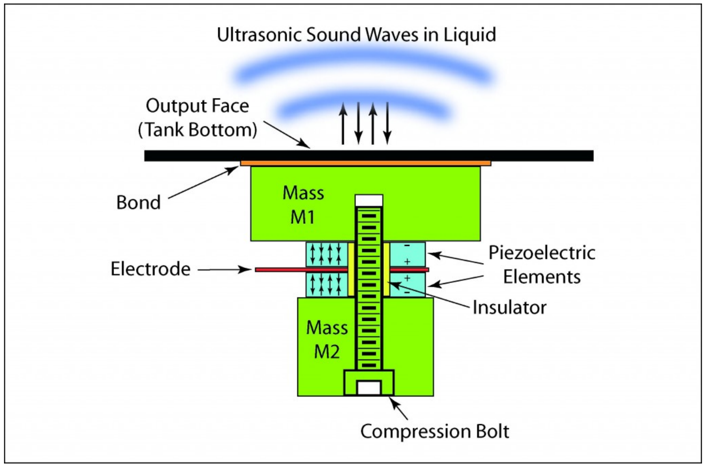


Mazel 1985



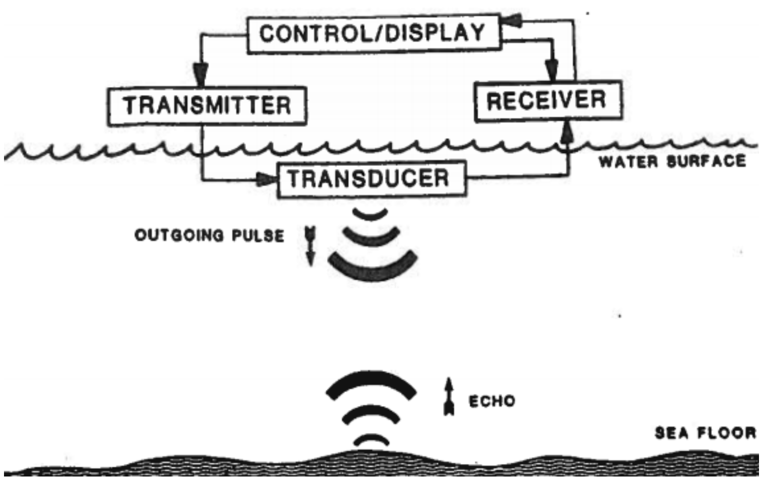
Transducer

- Transforms electric energy to acoustic energy and vice versa (similar to load speaker and microphone)
- Can be the same physical unit
- Receiving units are called hydrophones
- Piezo electro elements
- Designed for specific frequencies and beam forms
- Beam forming can provide directivity

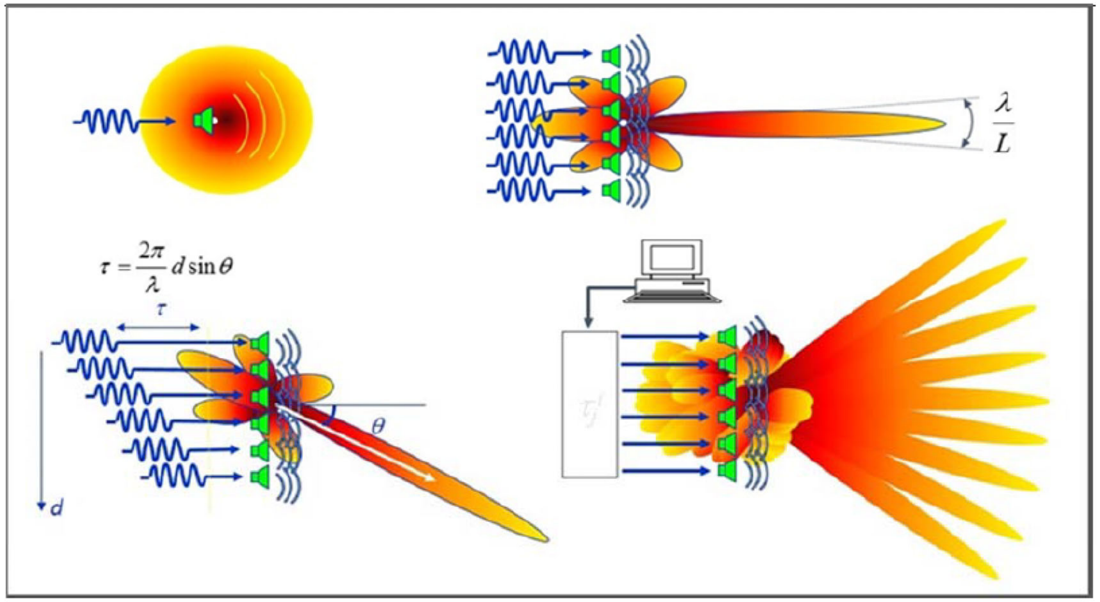


Transmitter

- Provides oscillating electric field for the transducer
- Provides the desired frequency (and phase for arrays)



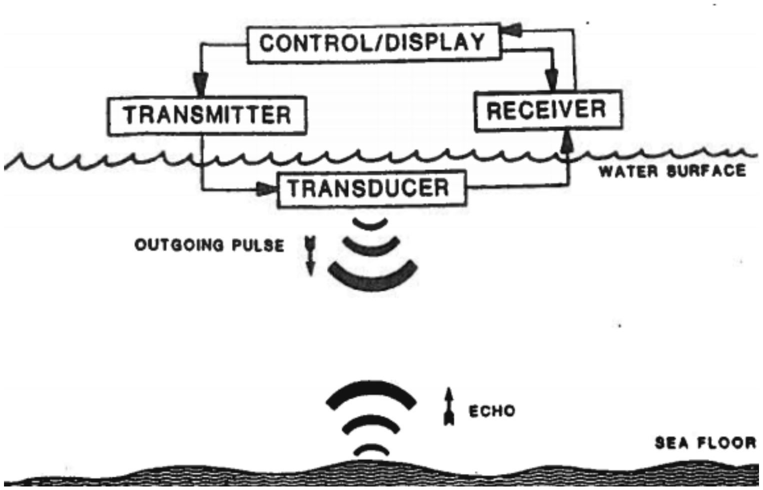
Beamforming



Xavier Lurton and Geoffroy Lamarche. Backscatter Measurements by Seafloor-Mapping Sonars. GeoHab Working Group, May 2015

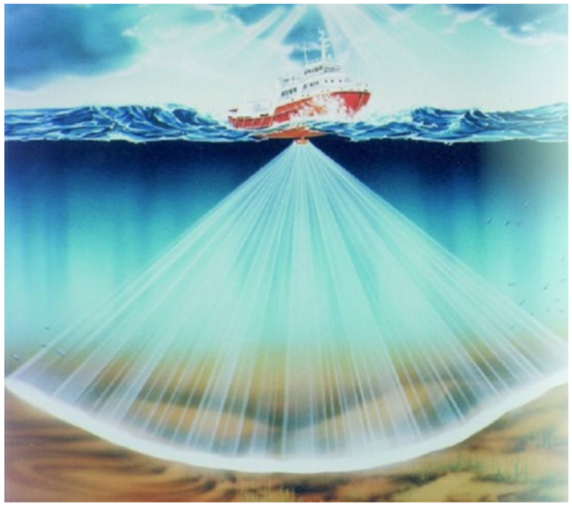
Receiver

- Converts the analog electric signal to data
- Signal amplification (several thousand times)
- Gain control -> amplification
- Time Varying Gain (TVG)

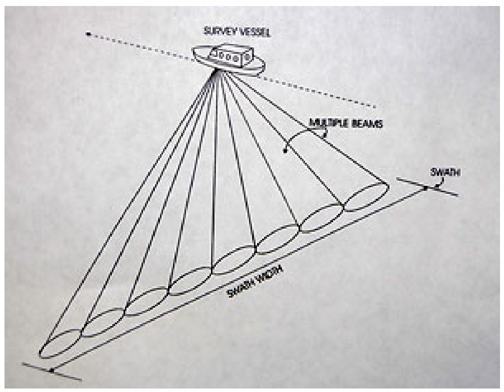


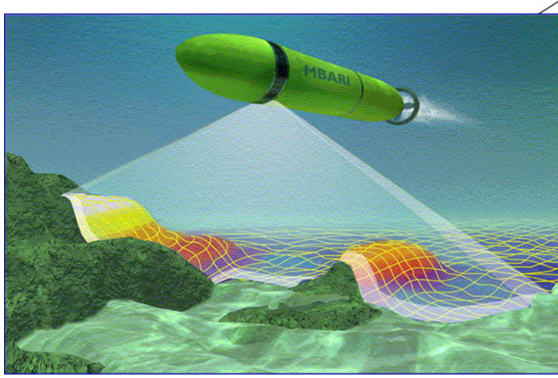
Multibeam echosounder

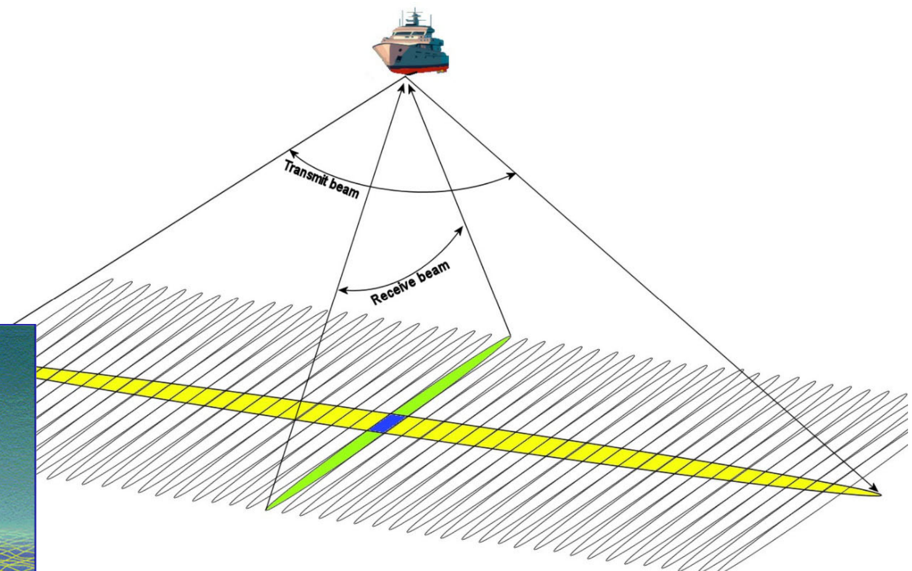
- Beamforming
- Direction
- 100-400 beams
- Beams
  - 1,5° x 1,5°
- Range
- Backscatter



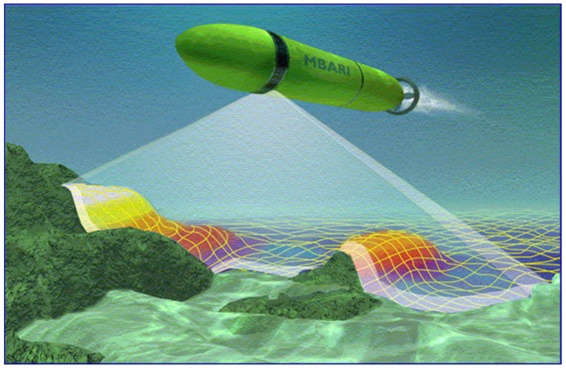
Multibeam echosounder



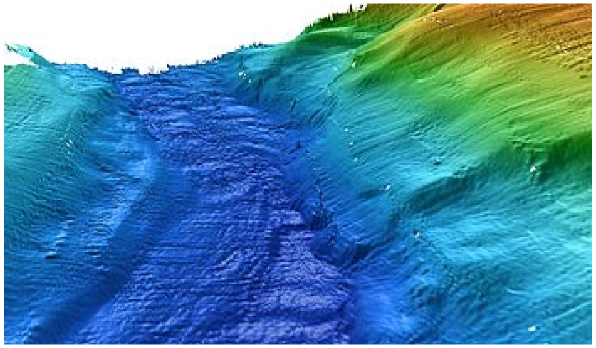




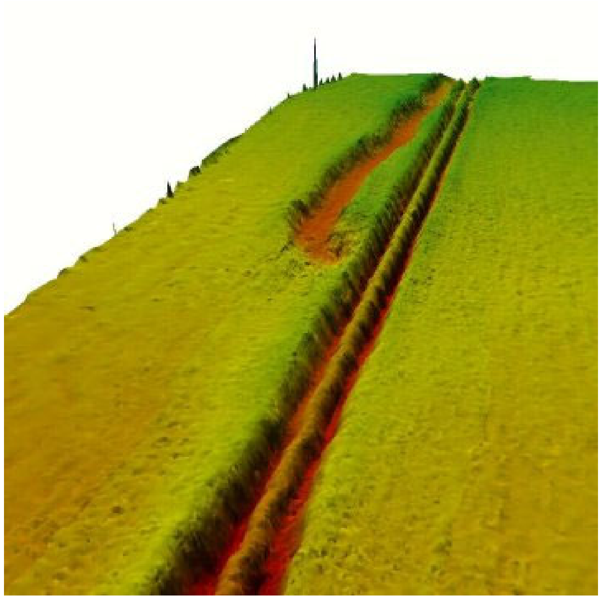
Multibeam sonar



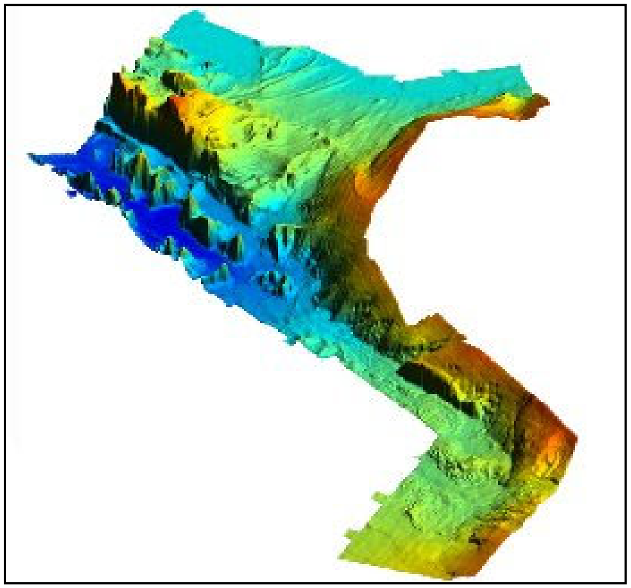
- Require high accuracy navigation
- Bathymetry (topology)



Multibeam Data Examples

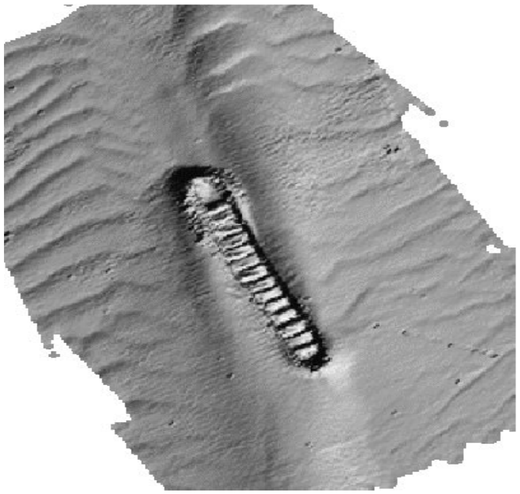


High Resolution

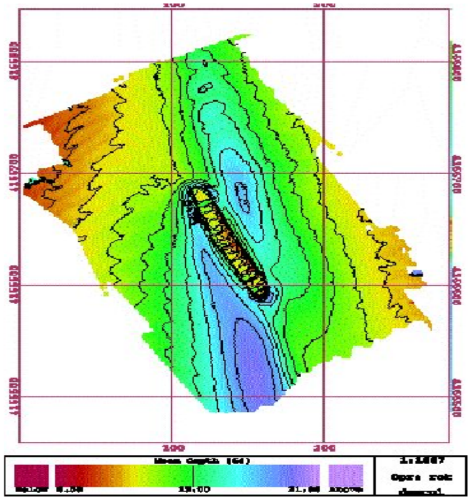


Low Resolution

Presentation of Multibeam Data



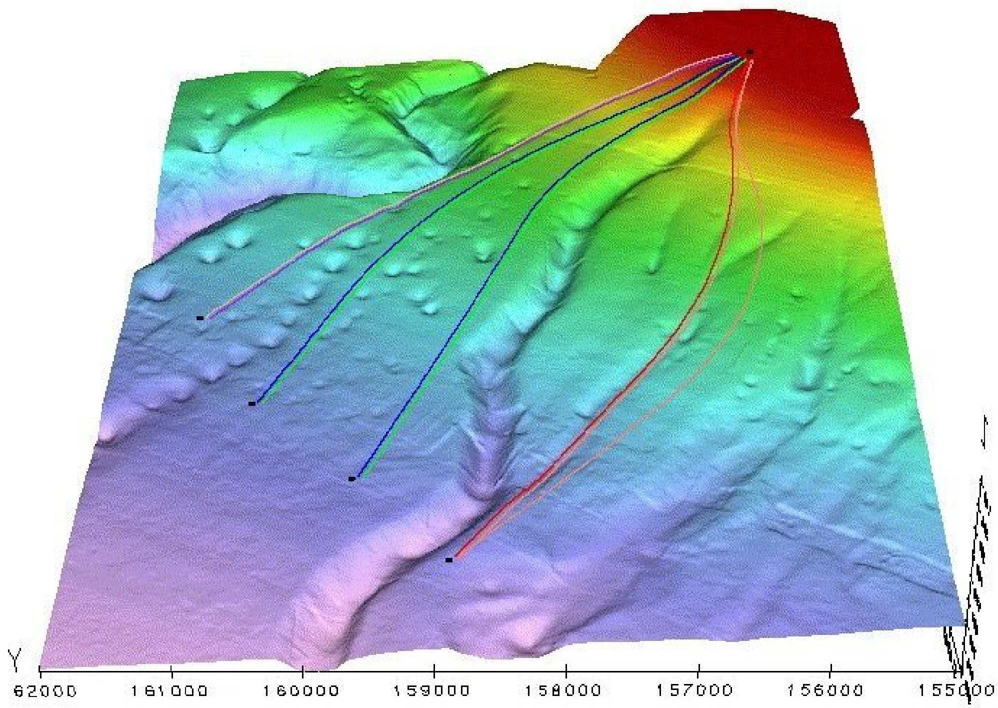
Shaded mean depth presentation



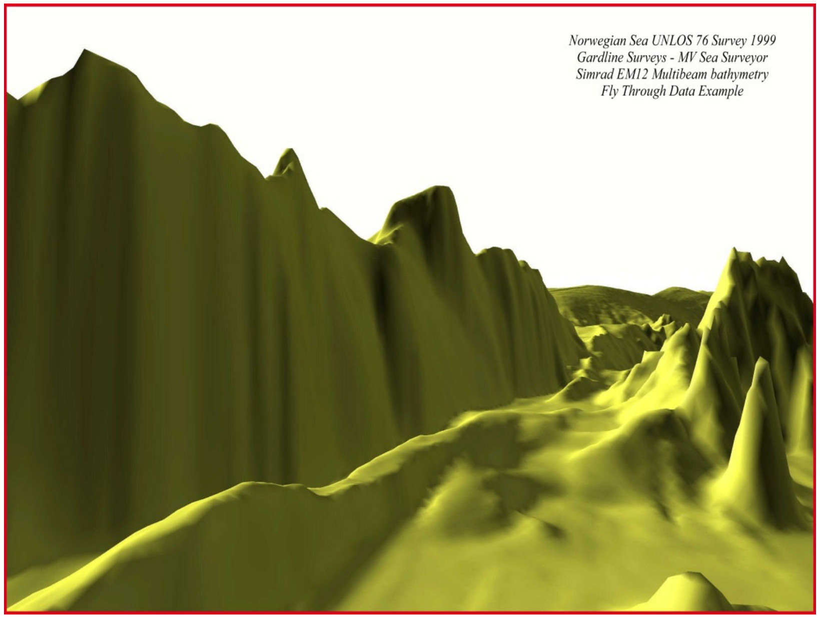
Colour coded depth presentation

with contour lines

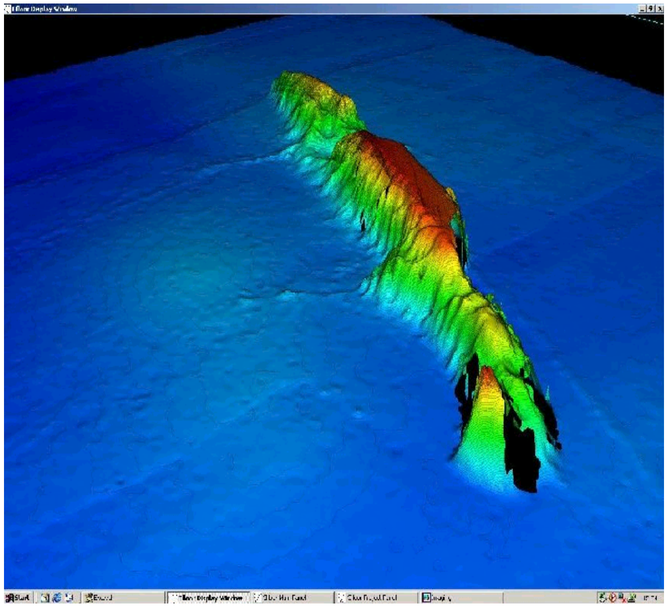
Digital Terrain Model – West Africa, 10 x 10m DTM



Multibeam Data Visualisation



Low Frequency EM12



Medium/High Frequency EM2000

Multibeam sonar

- Applications
  - Coverage and overlap
  - Shading
- Corrections
  - Motion and position
  - Speed of spound profiles
  - Tide
- Calibration (patch test)
  - Roll, pitch yaw
  - Latency

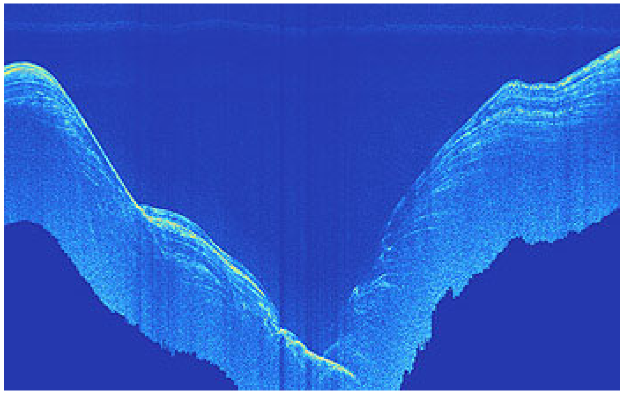
Sub Bottom profiler Systems

Geoacoustics Boomer

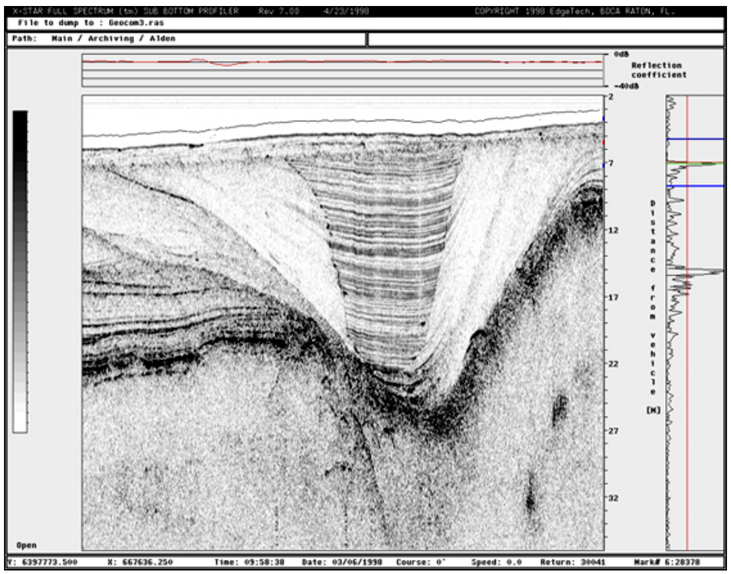
Geoacoustics Chirp Profiler

Sub bottom profiler

- High power
- Low frequency
- Separate transmitter and receiver
- 50 m into seabed
- 10 cm vertical resolution



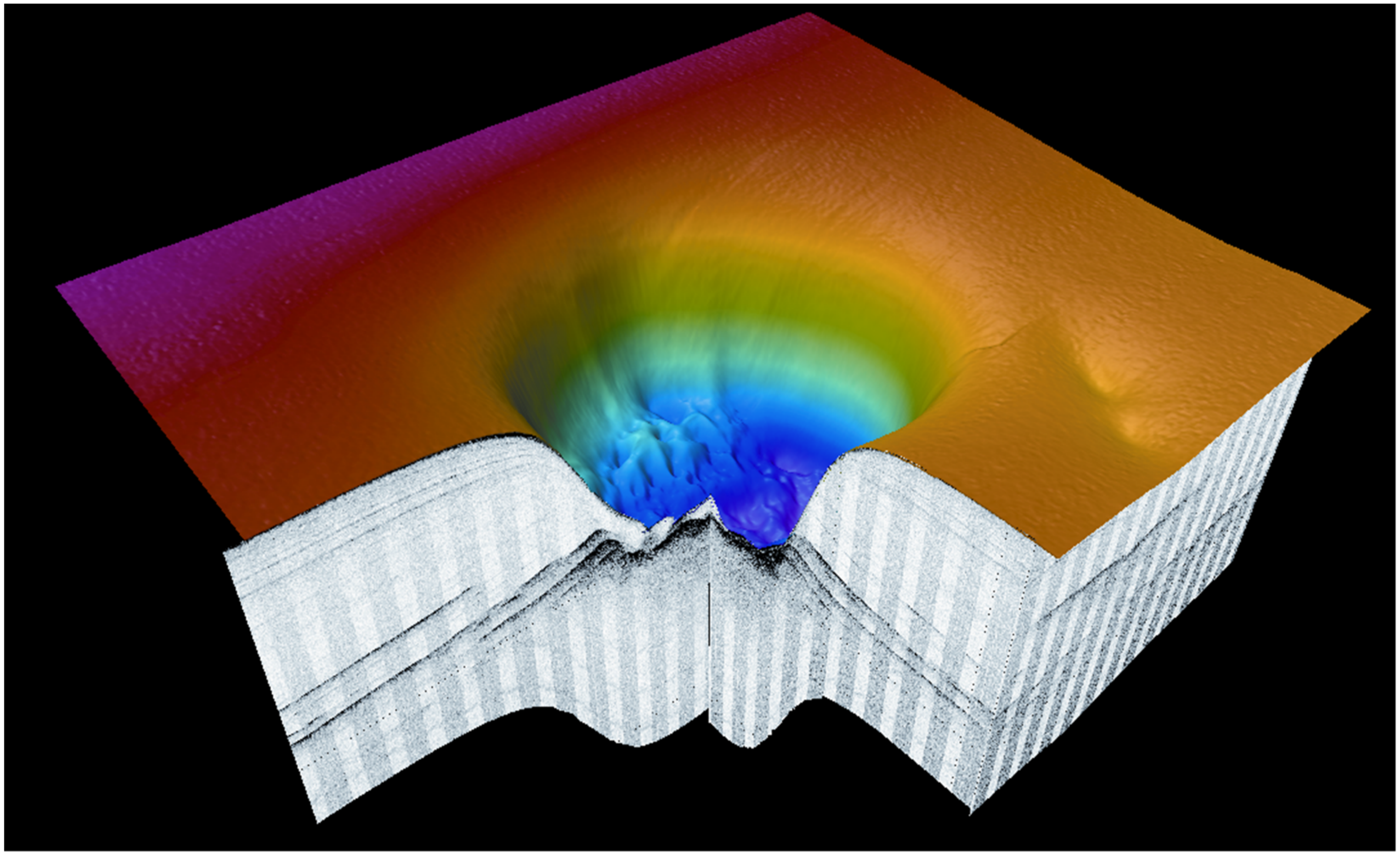
Sub-Bottom Profiler



Two main applications

- Geological structure below the seabed
- Sunken or buried objects

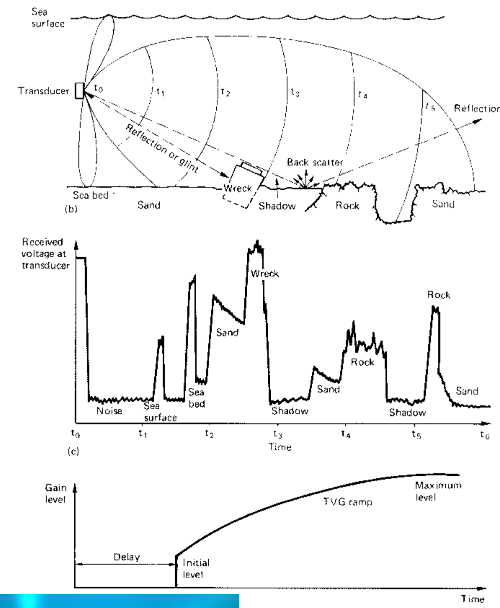
Swath Bathymetry and Sub-Seabed Imagery, West Africa



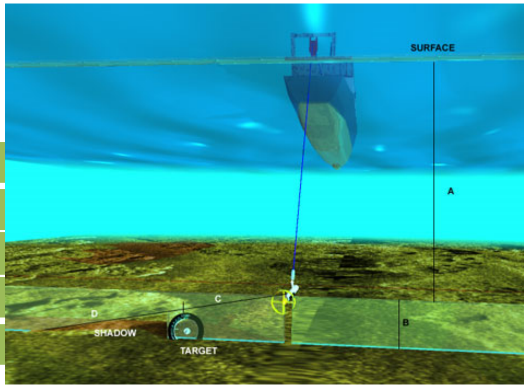
Side scan sonar

$$\Delta x = \frac{c}{2} \cdot \frac{L}{\cos\theta} = \frac{c}{2B}$$

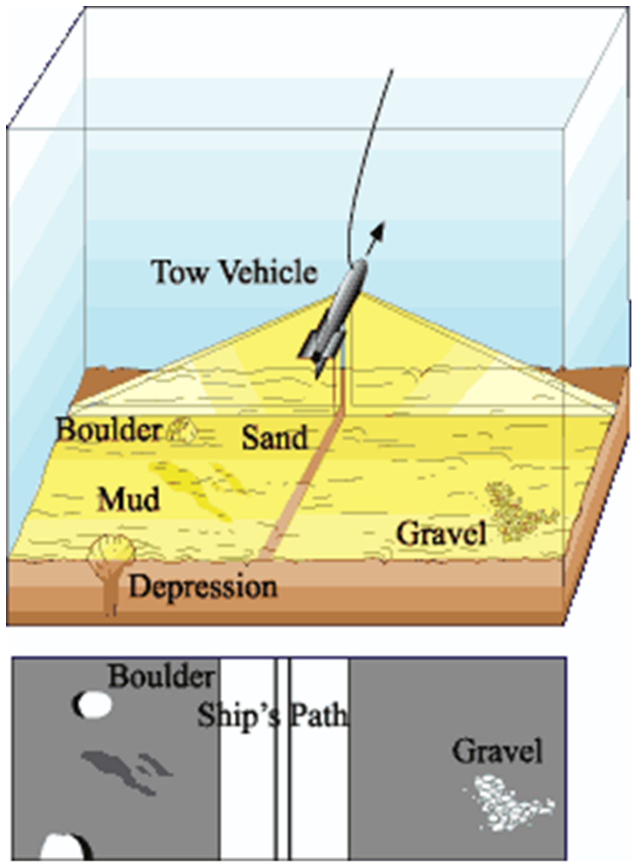
- L Pulse length (seconds)
- c Speed of sound
- θ Inclination angle
- B Signal bandwith



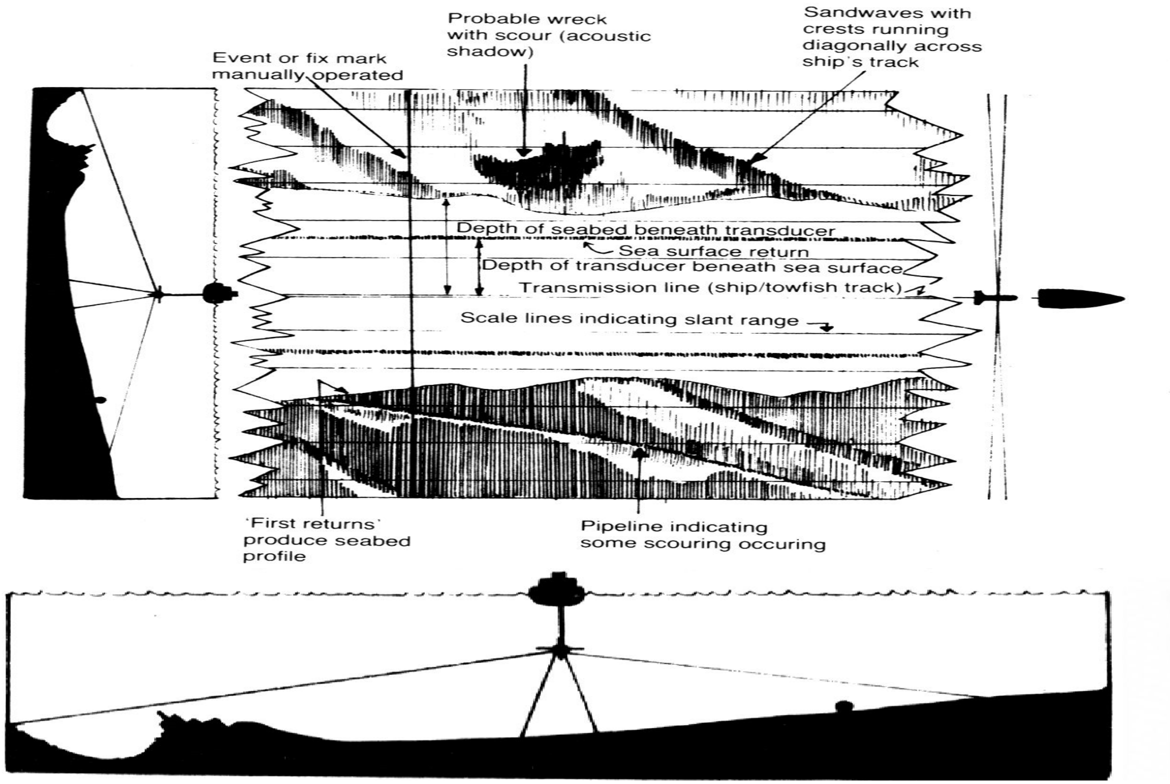
Frequency	Resolution	Range
30 kHz	Low	3 – 6000 m
100 kHz	Medium	500 – 1000 m
300 kHz	Good	150 – 500 m
600 kHz	Very good	75 – 150 m



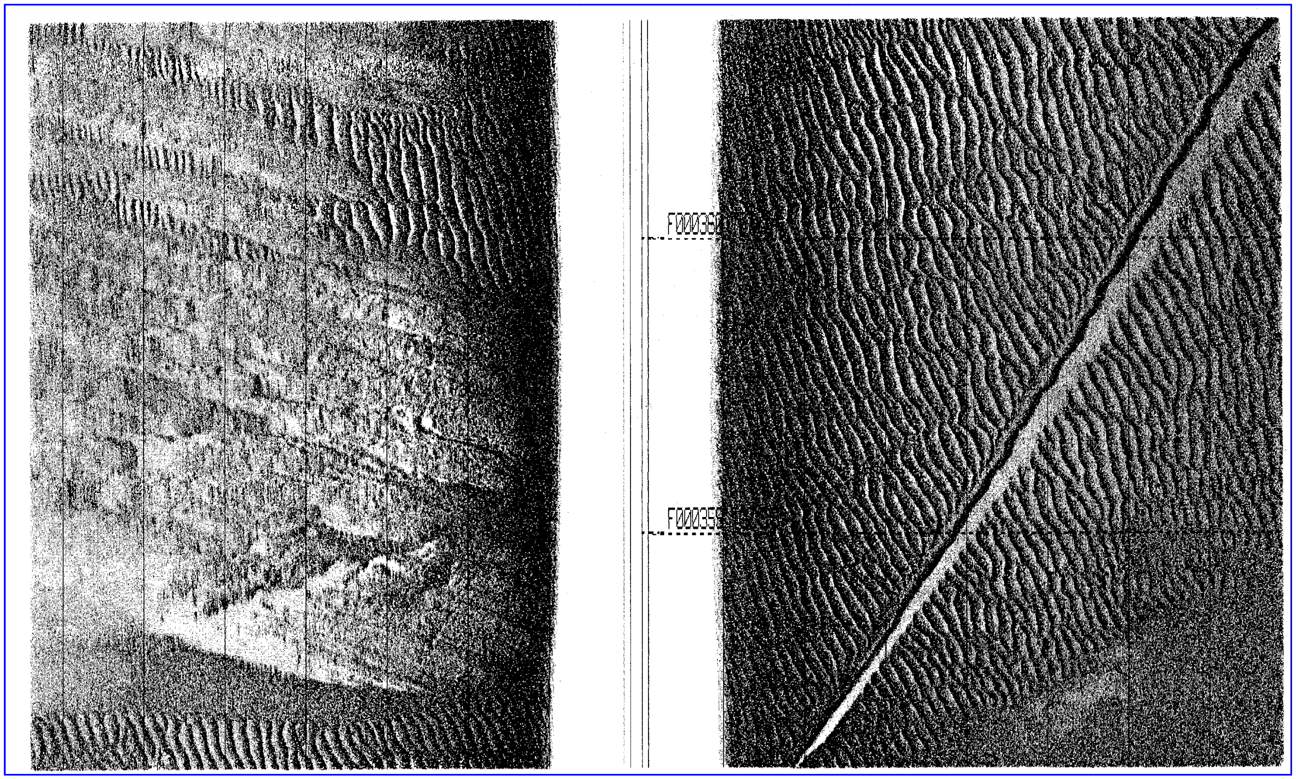
Side scan sonar



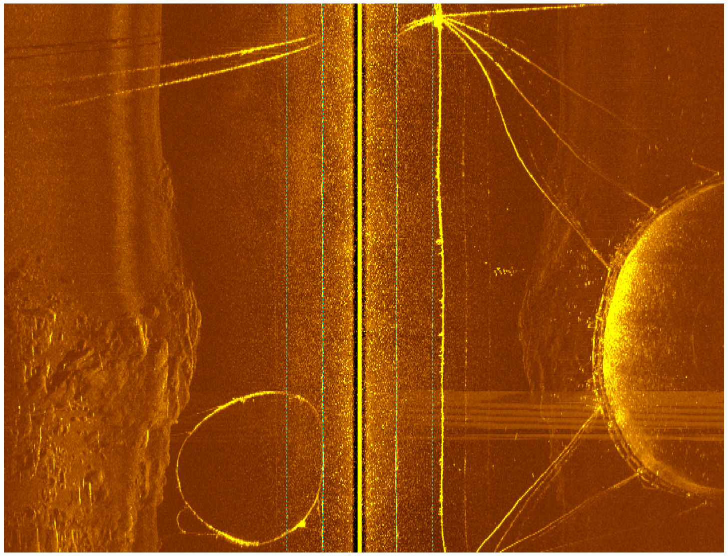
Sidescan Sonar Trace

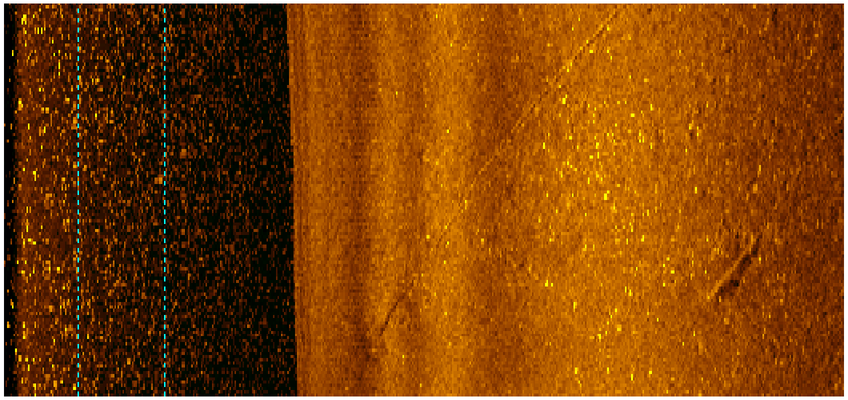


Typical Sidescan Sonar Trace

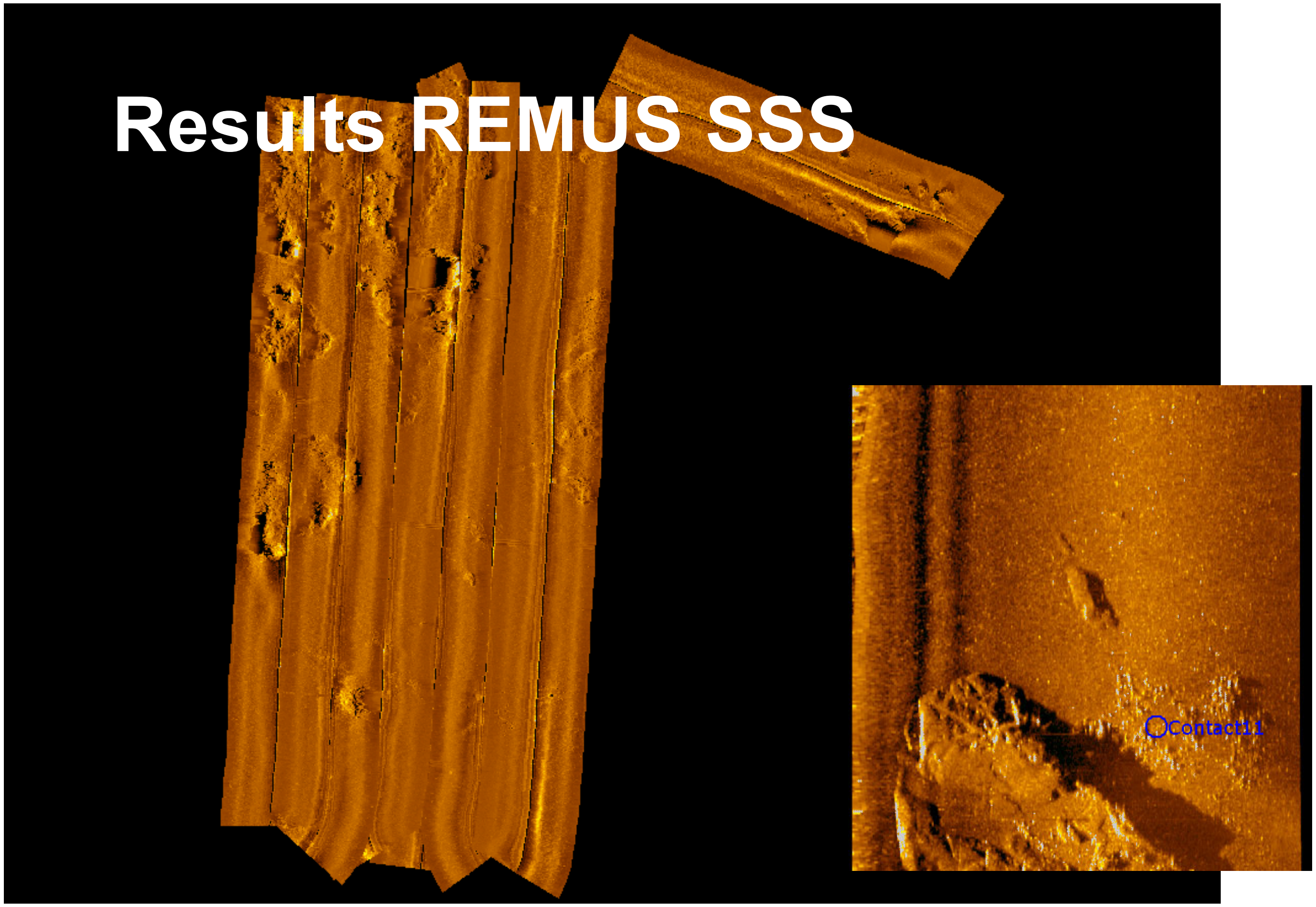


Sonarimages Aquaculture installation

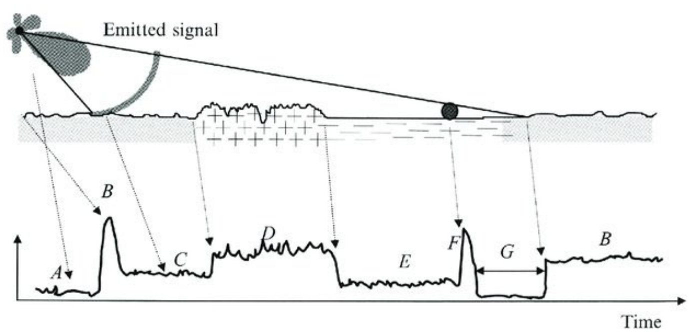


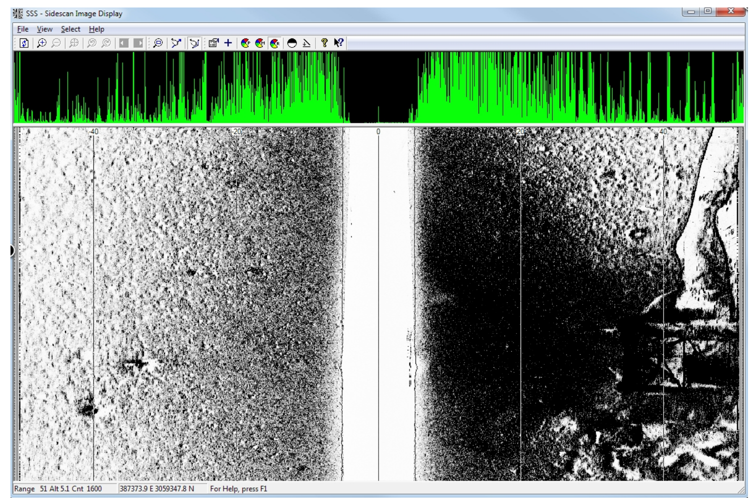


Results REMUS SSS



Time varying gain (TVG)





Summary

- Basic acoustics
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