

Navigation of Remote Undersea Vehicles

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Outline

- * Requirements for undersea position and time measurements
- * ROVs and AUVs
- * Ocean acoustics
- * Short and long baseline acoustic navigation
- * Seafloor geodesy for crustal deformation
- * Time measurement in acoustics and seismology

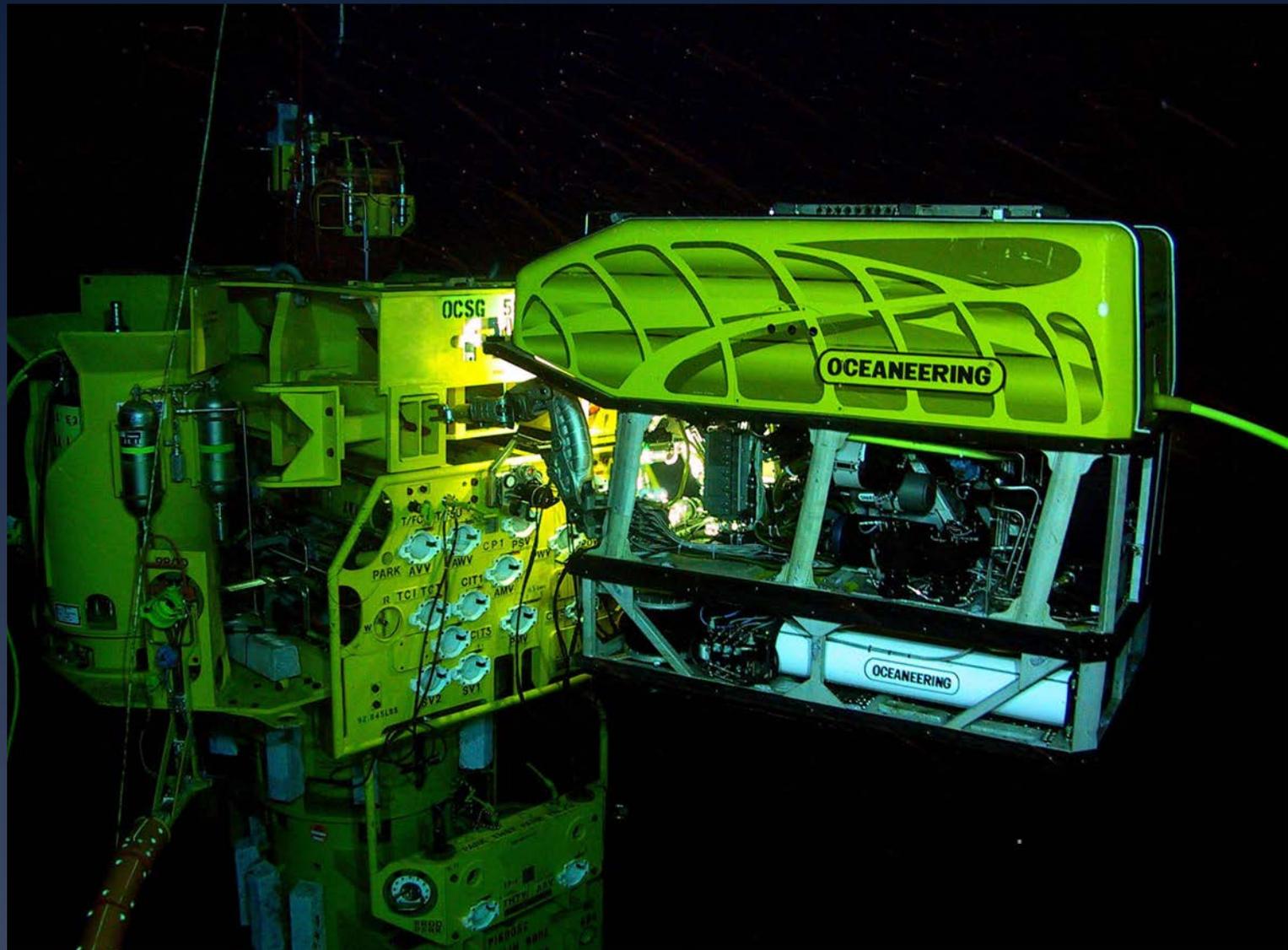
Requirements for undersea positioning and time

- * Seismic velocity is between 3 and 5 km/s, and acoustic velocity is 1.5 km/s
- * Positions of seismometers and acoustic receivers are generally controllable to around 1 meter
- * Cameras won't see things much further away than 10 m
- * 0.1 to 1 ms in time and 0.1 to 1 m in position are desirable goals

Remotely Operated Vehicles

- * Tethered to the ship all the time
- * Umbilical provides power and video link
- * Consumes tens to hundreds of kilowatts of power for propulsion, lights, cameras, hydraulic manipulator arms
- * Remain within a few km of a ship

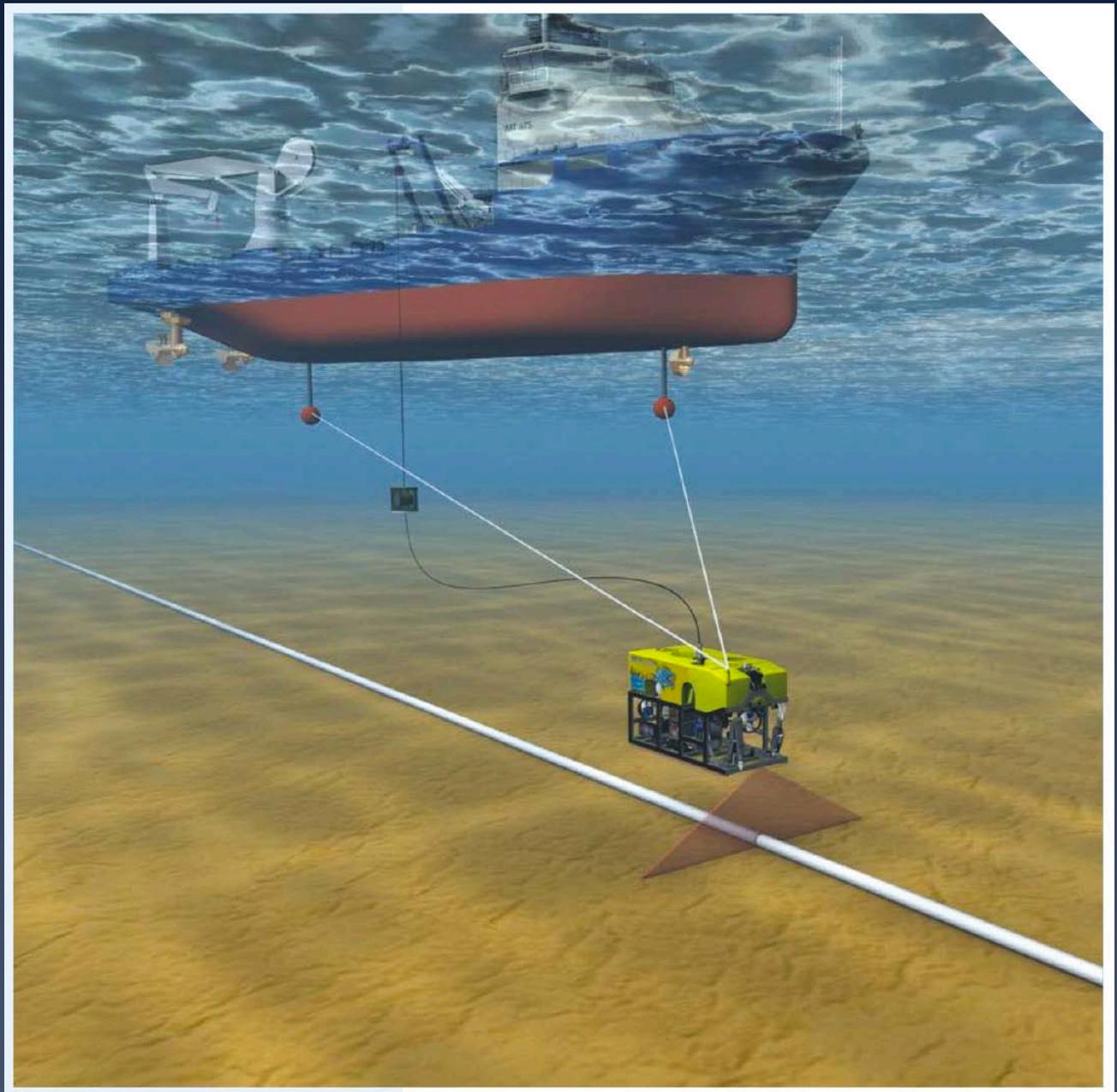






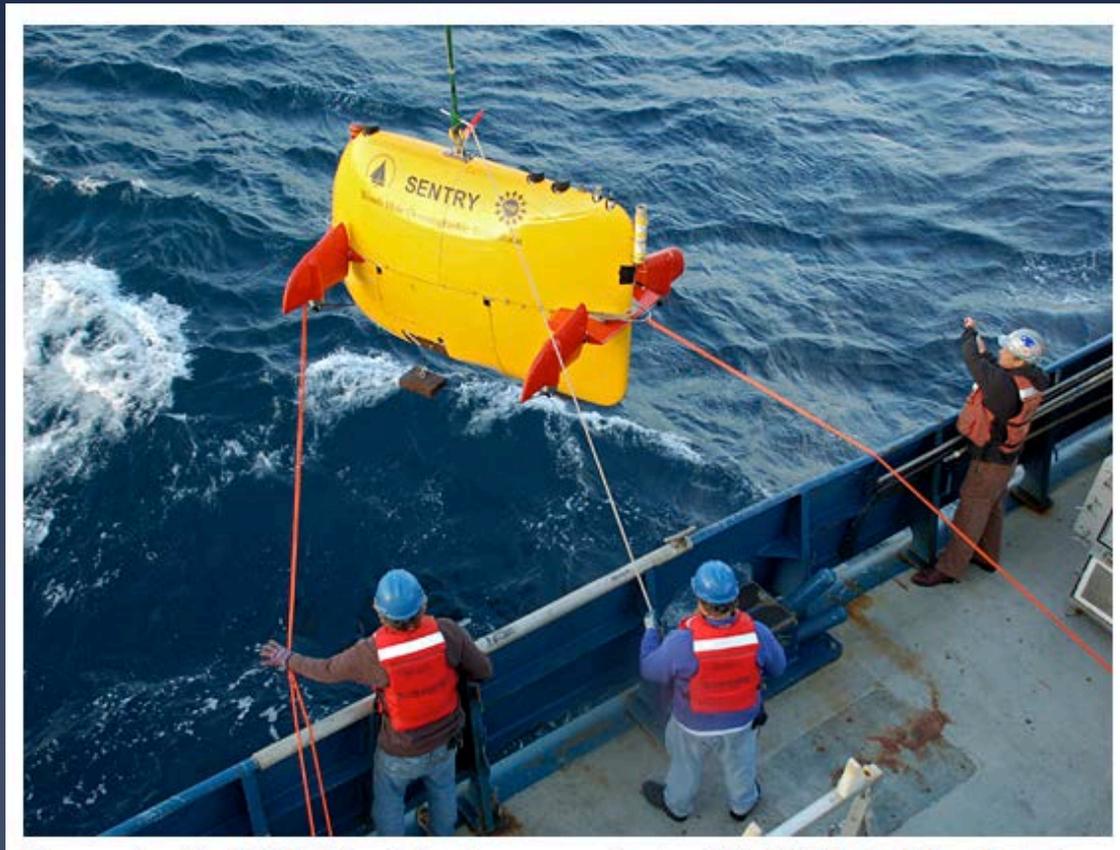
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Autonomous Under Vehicles

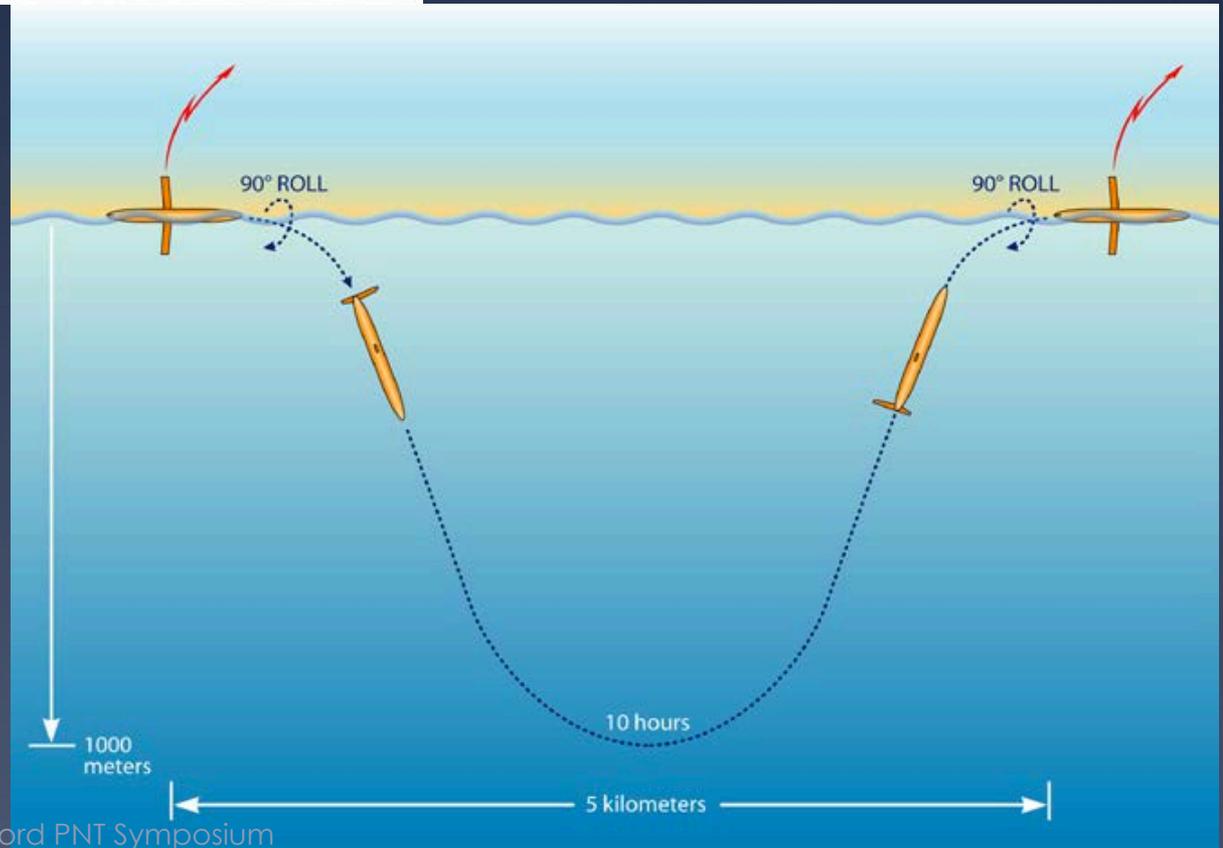
- * Autonomous: means not tethered to a ship
- * Run on batteries, so low power required
- * May travel for many tens of hours at speeds of a few knots
- * Used for
 - * high resolution bathymetric mapping
 - * cable and pipeline route surveys
 - * archaeological surveys



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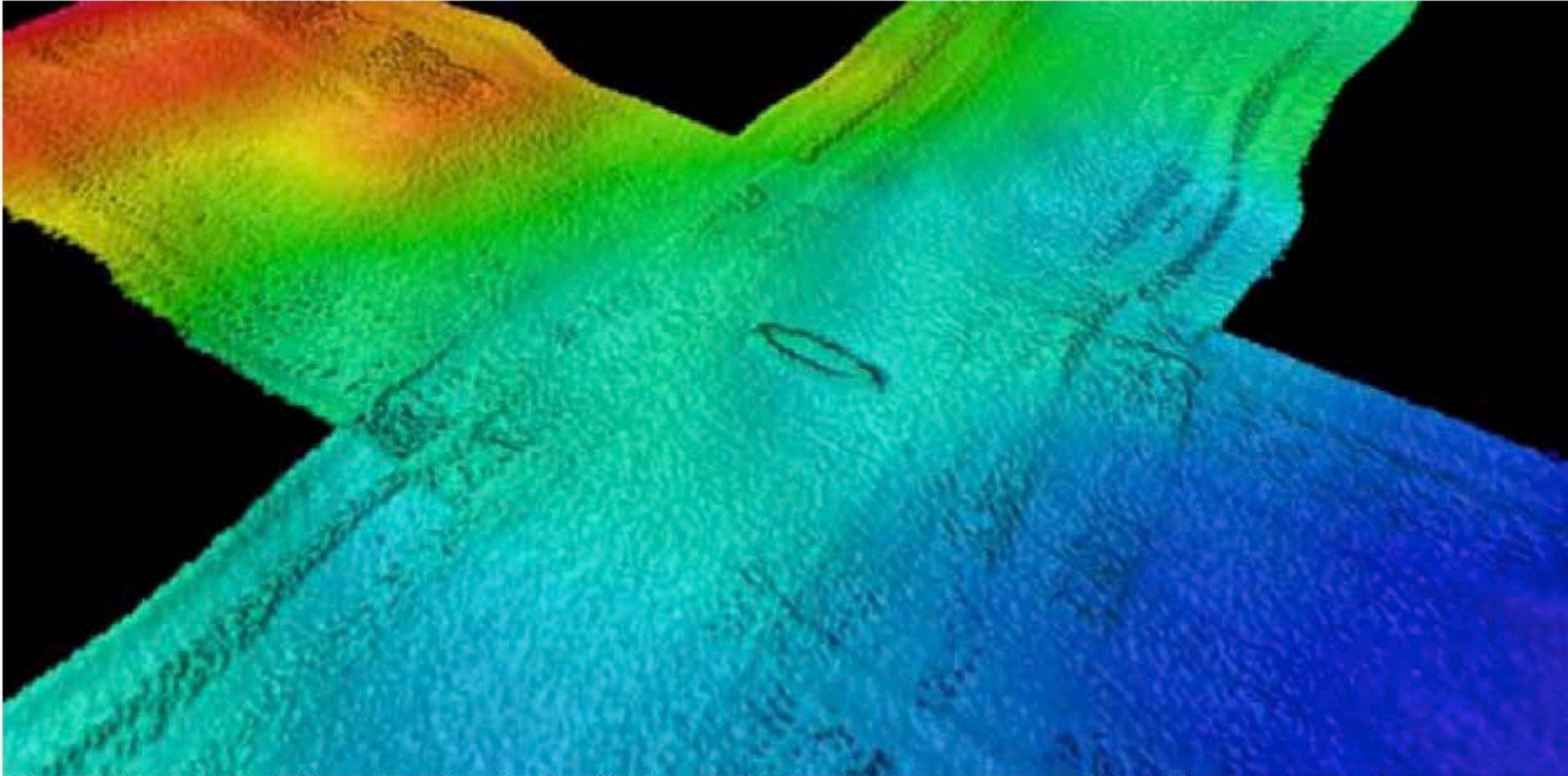
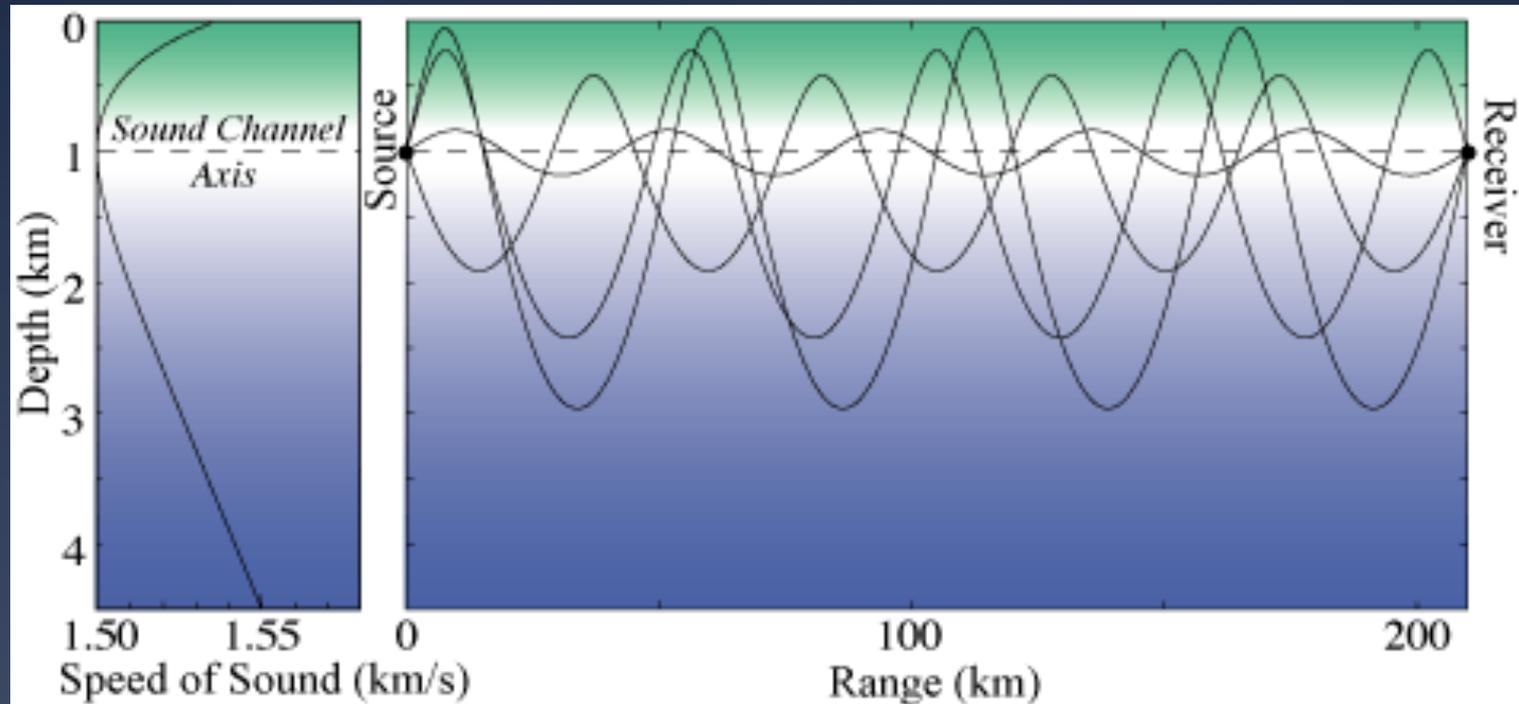
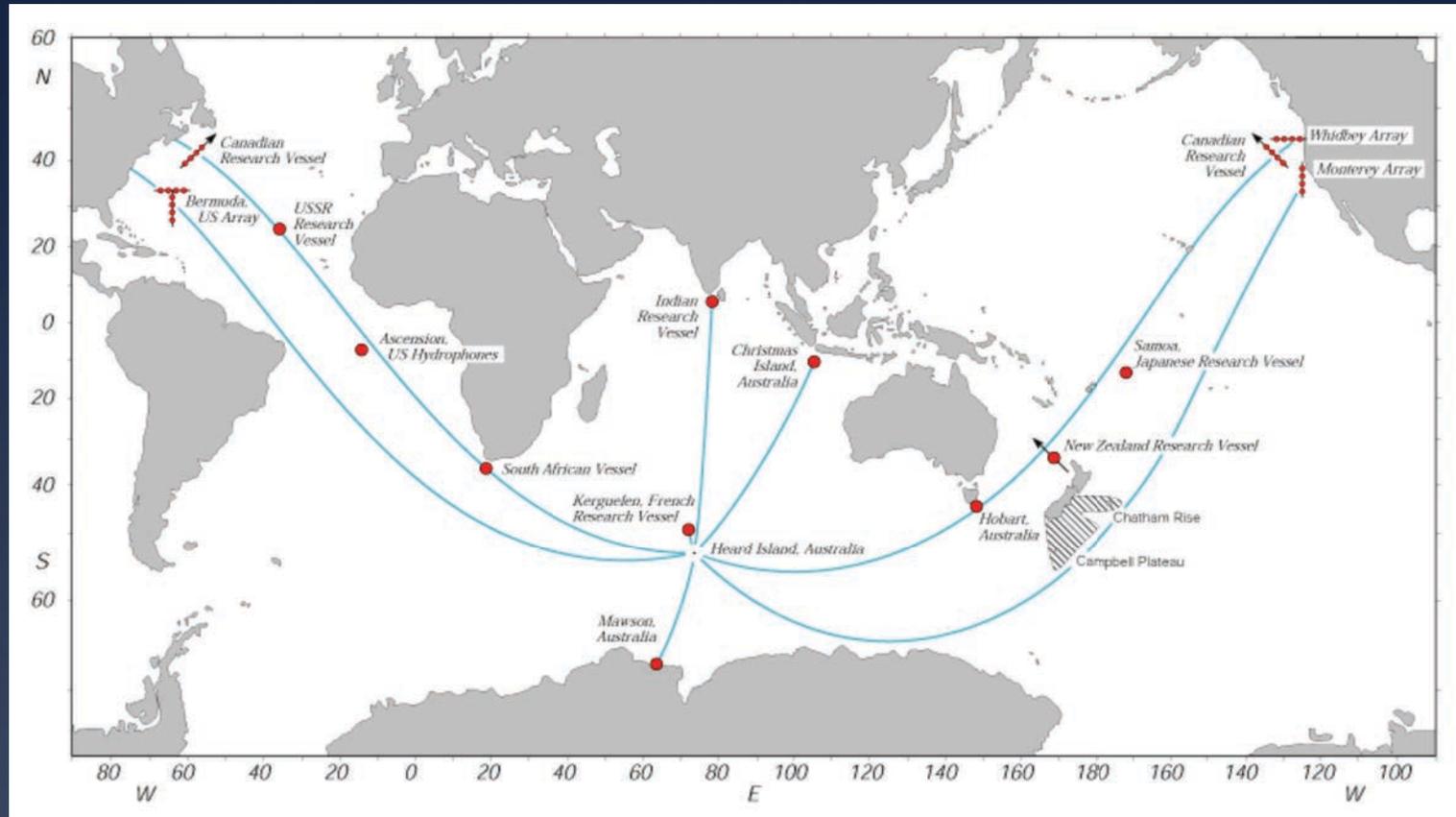


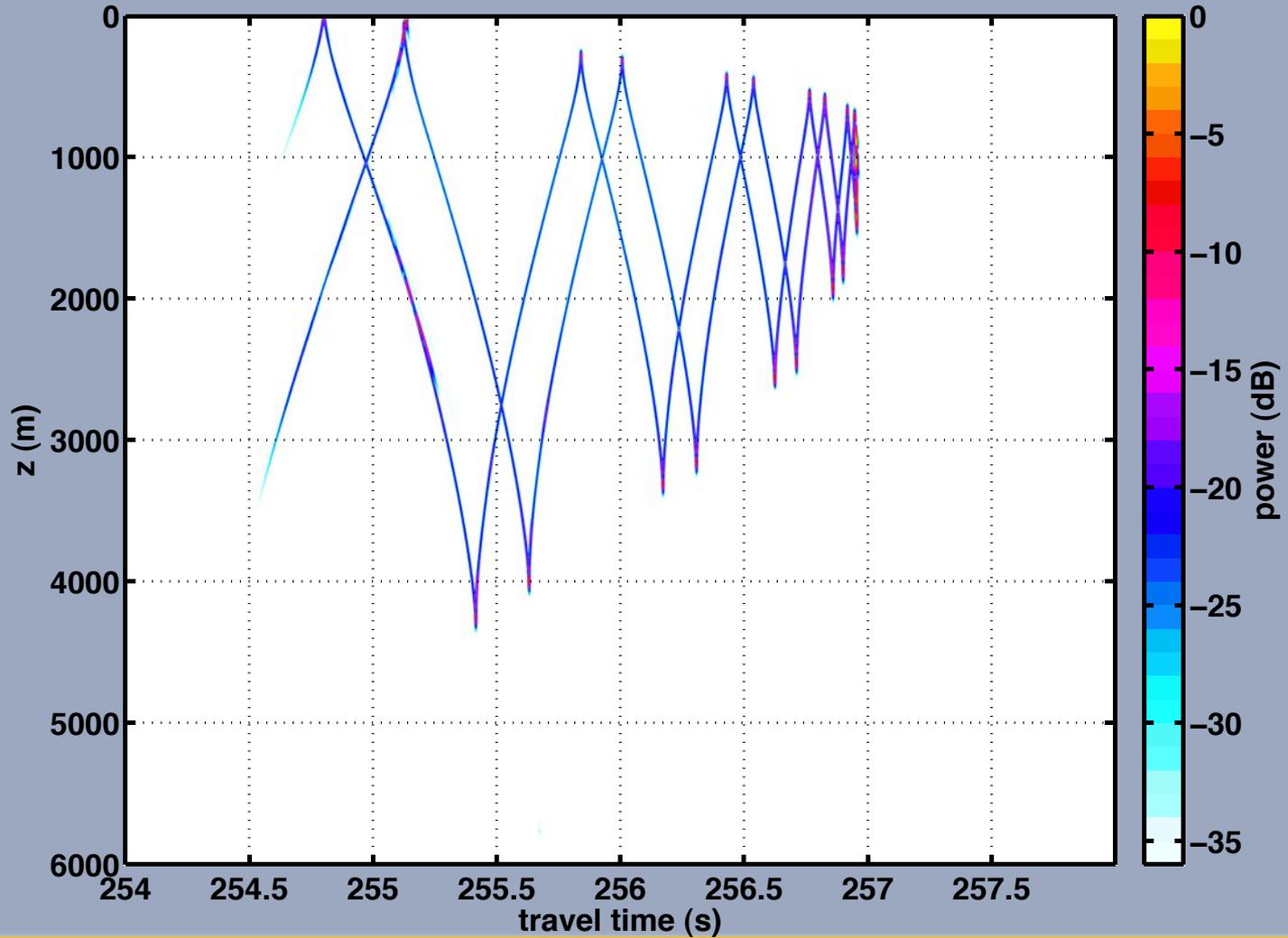
Figure 3. Multibeam bathymetry showing the “Ewing Bank Wreck” (Image courtesy C & C Technologies, Inc.).

Ocean acoustics





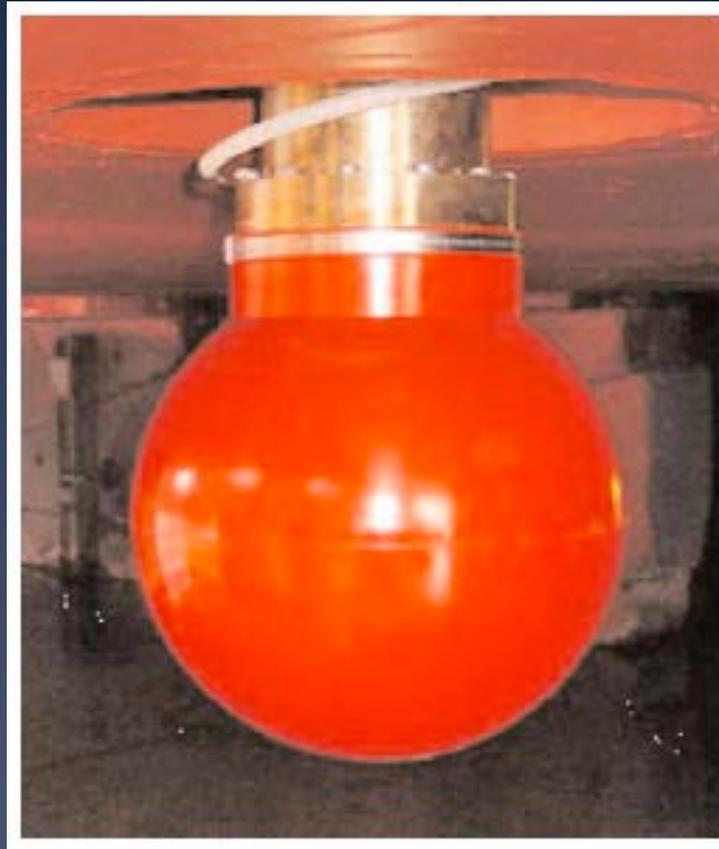
Philippine Sea T1 → T2



Short baseline acoustic navigation

- * Short baseline acoustic navigation
- * A transducer array of order 0.5 m diameter is mounted on the hull of a vessel
- * It emits an acoustic signal that is received and retransmitted by a vehicle mounted transponder
- * The range to the transponder is determined by the acoustic travel time and the angles are determined by the array phase response

Hull mounted array



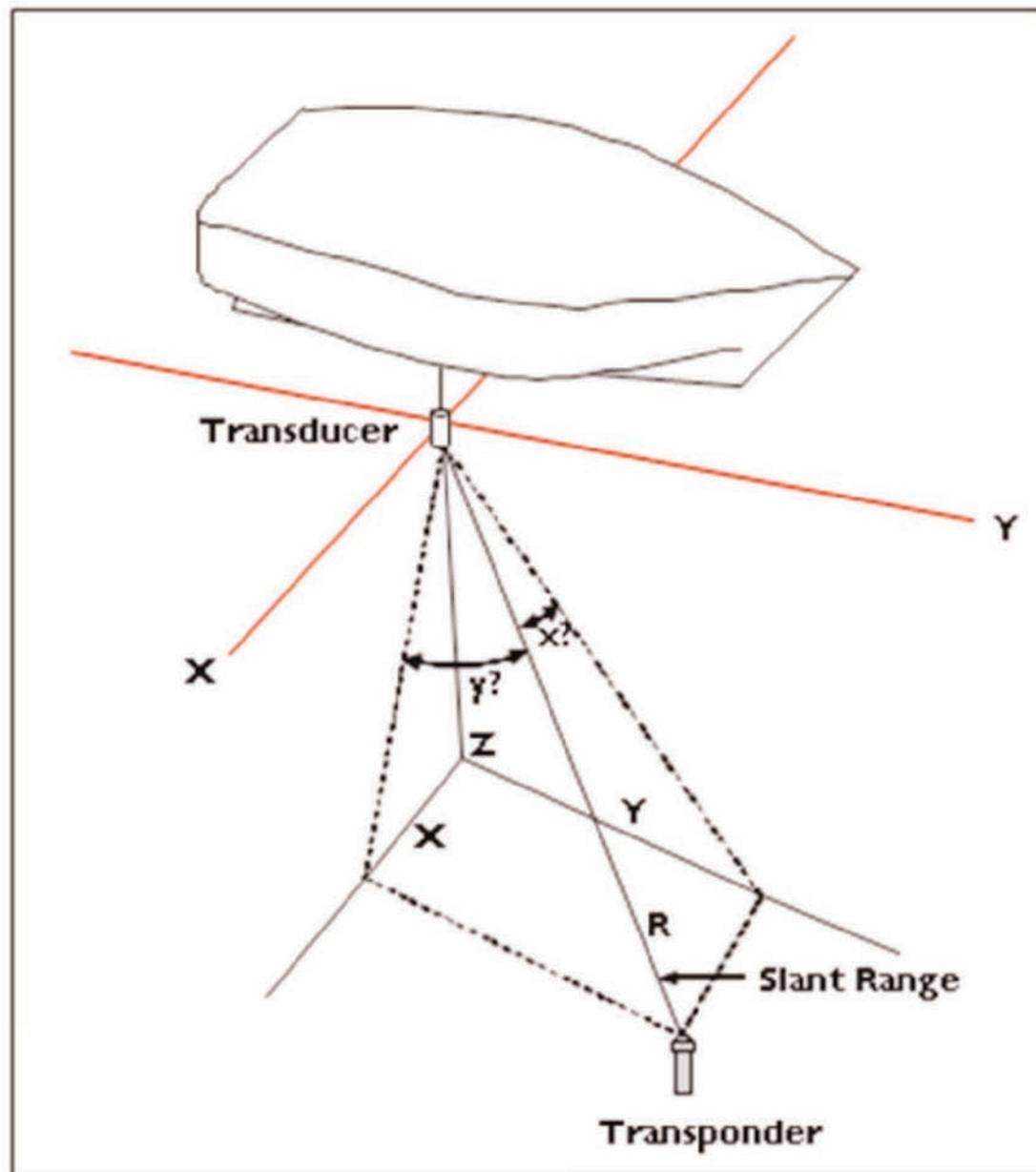
Source: Kongsberg

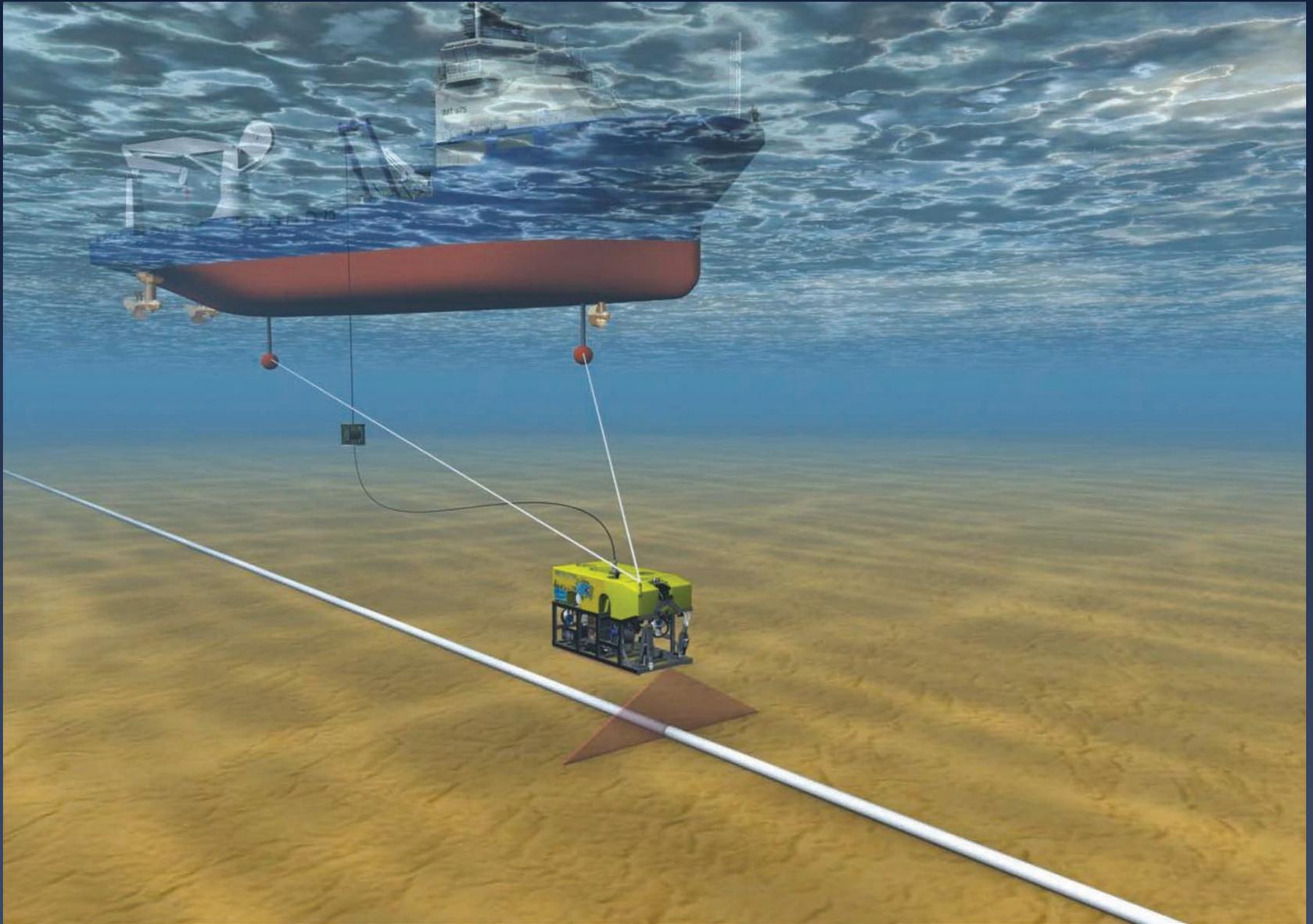
diameter = 40 cm

Multiple GPS receivers and attitude sensors on the vessel provide reference frame information.

Transducer array determines angles of signal arrivals w.r.t. the vessel.

Large effort needed to survey transducer location w.r.t. to GPS receivers on vessel





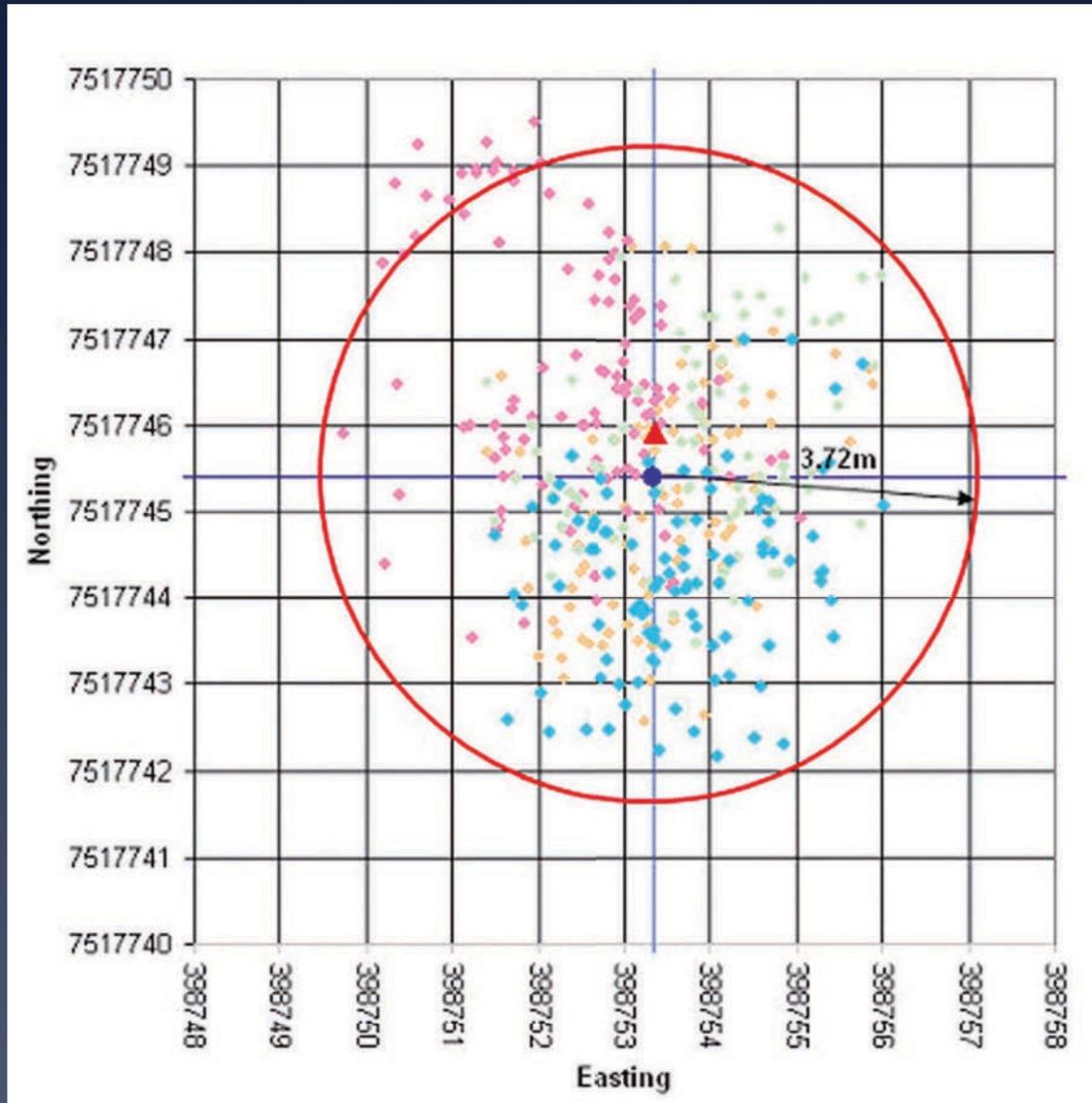
Results of multiple position determinations with USBL system in 1200 m water depth

Rule of thumb for USBL navigation: precision is typically 0.2% of water depth

(source: IMCA)

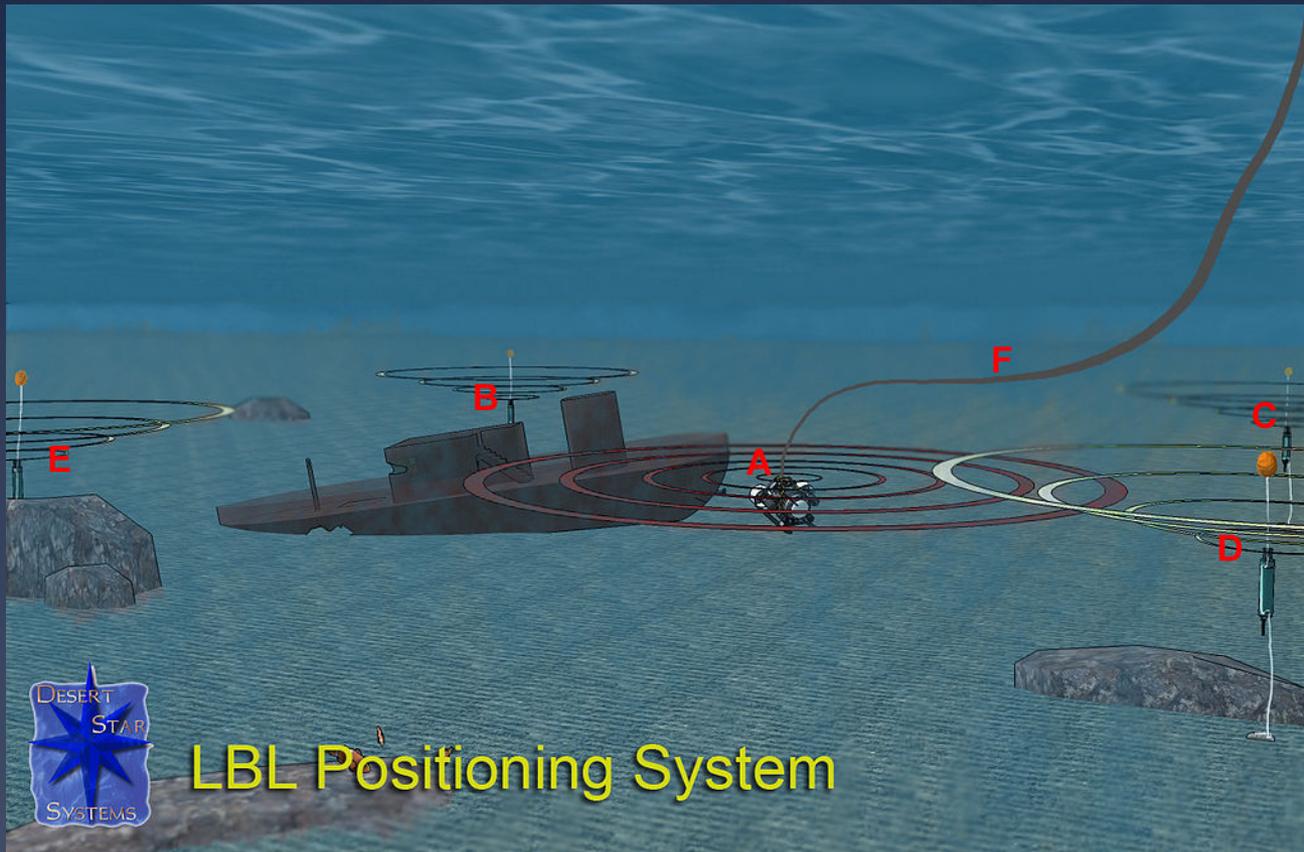
New technologies:

- spread spectrum
- coded signals
- pressure/depth info
- sound speed profile



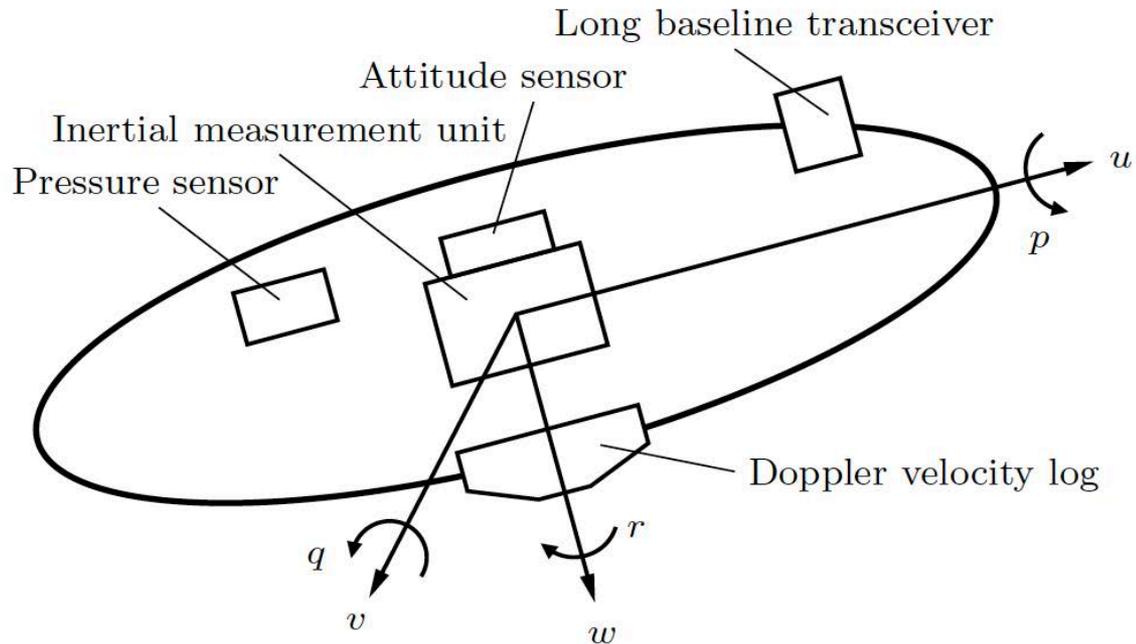
Long baseline acoustic navigation

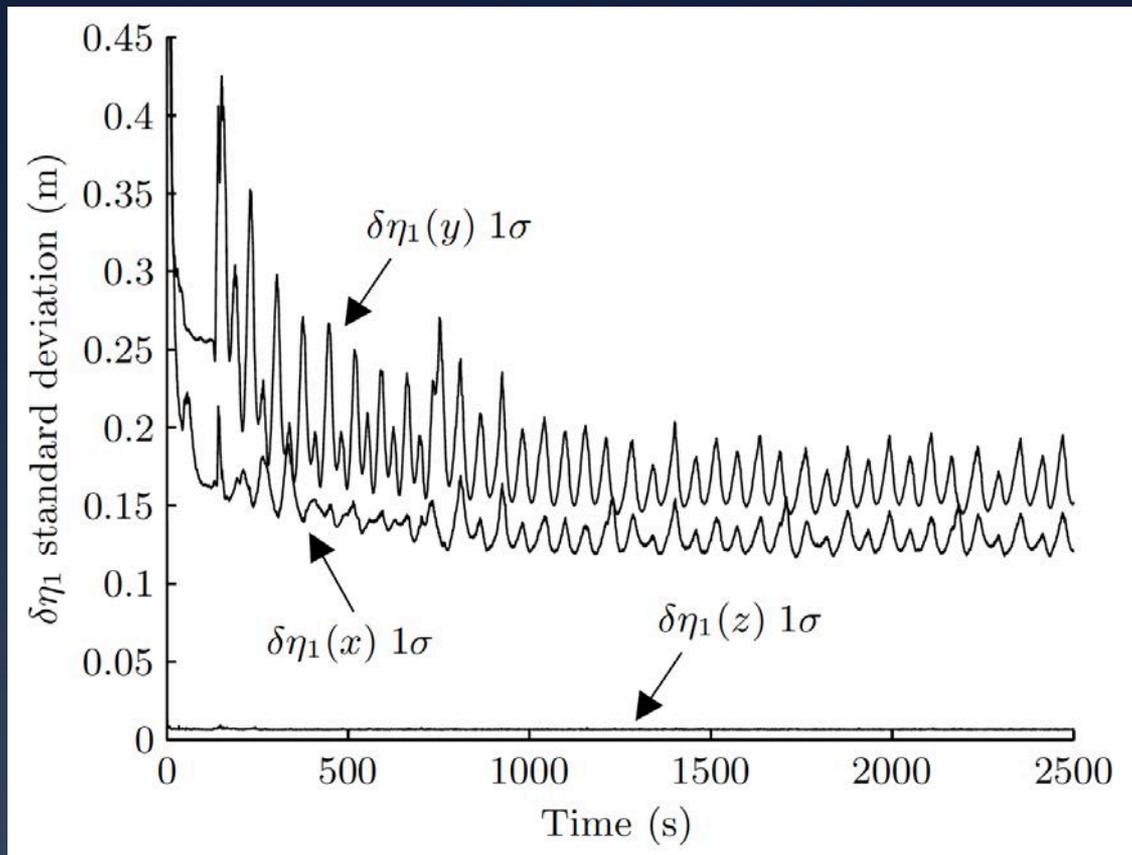
- * Acoustic transponder array deployed on seafloor over several km area
- * Vehicle emits a signal which is returned by all the transponders in the net
- * Times of individual replies recorded
- * Position determined by trilateration



- * More effective in deep water (distance to ship irrelevant)
- * Can be deployed and remain in place for many years
- * Can cover large region

Merged inertial and acoustic navigation for AUV positioning





If the DVL continuously tracks the seafloor,
the real-time navigation deviation is 0.05% of the total distance traveled.

Research is ongoing to use maps of Earth's gravity field to help correct
drift in inertial navigation

Geodesy for crustal deformation

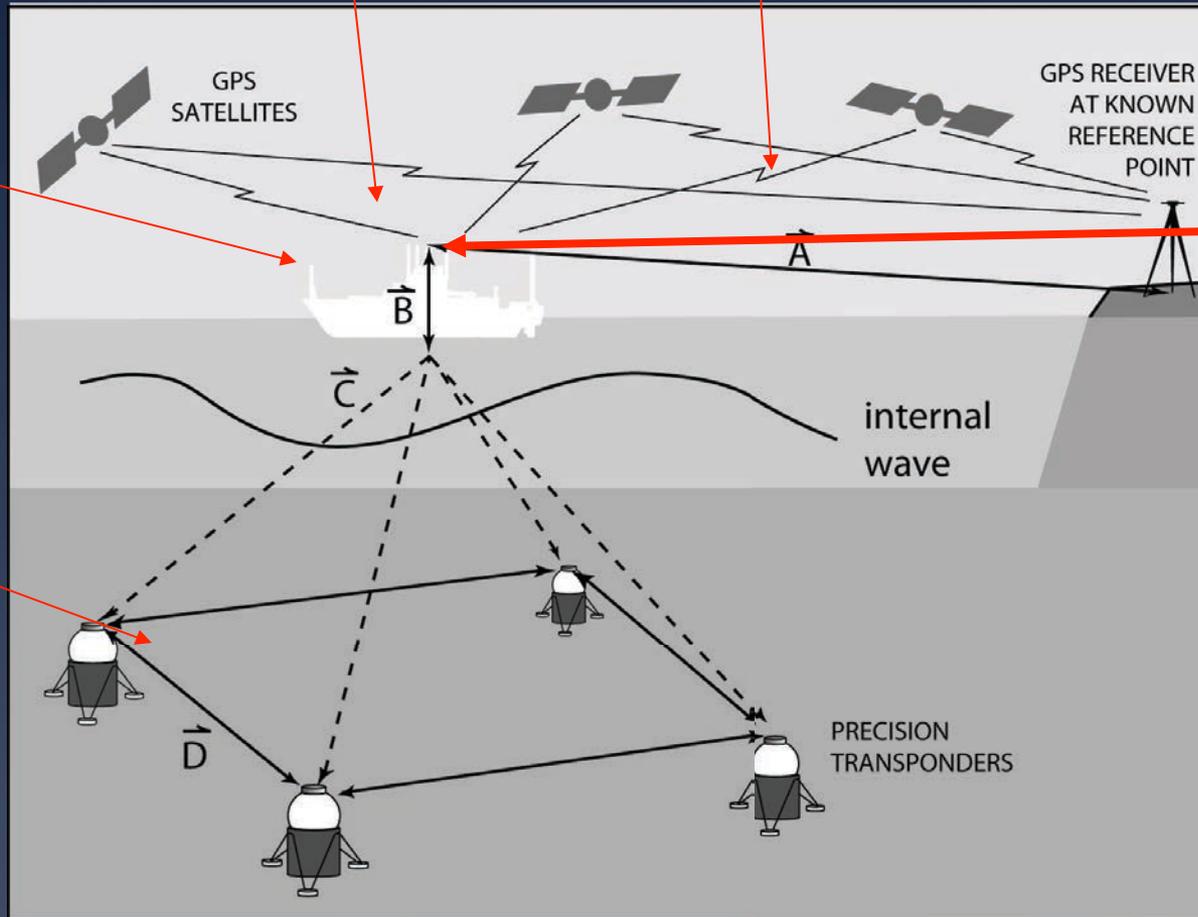
- * For geophysical studies of tectonics, higher precision positioning is needed
 - 1 cm in both height and lateral position

GPS-Acoustic positioning

Optical survey of phase center offsets

Precise kinematic GPS positioning

Shipboard hydrophone is common spatial point observed both by GPS from shore and acoustic triangulation from seafloor transponders



Acoustic range ship to PXP

Initial global position of seafloor array.

$$H(\text{GPS}) = A + B$$

$$H(\text{PXP}) = C + (D + \Delta)$$

Shipboard configuration

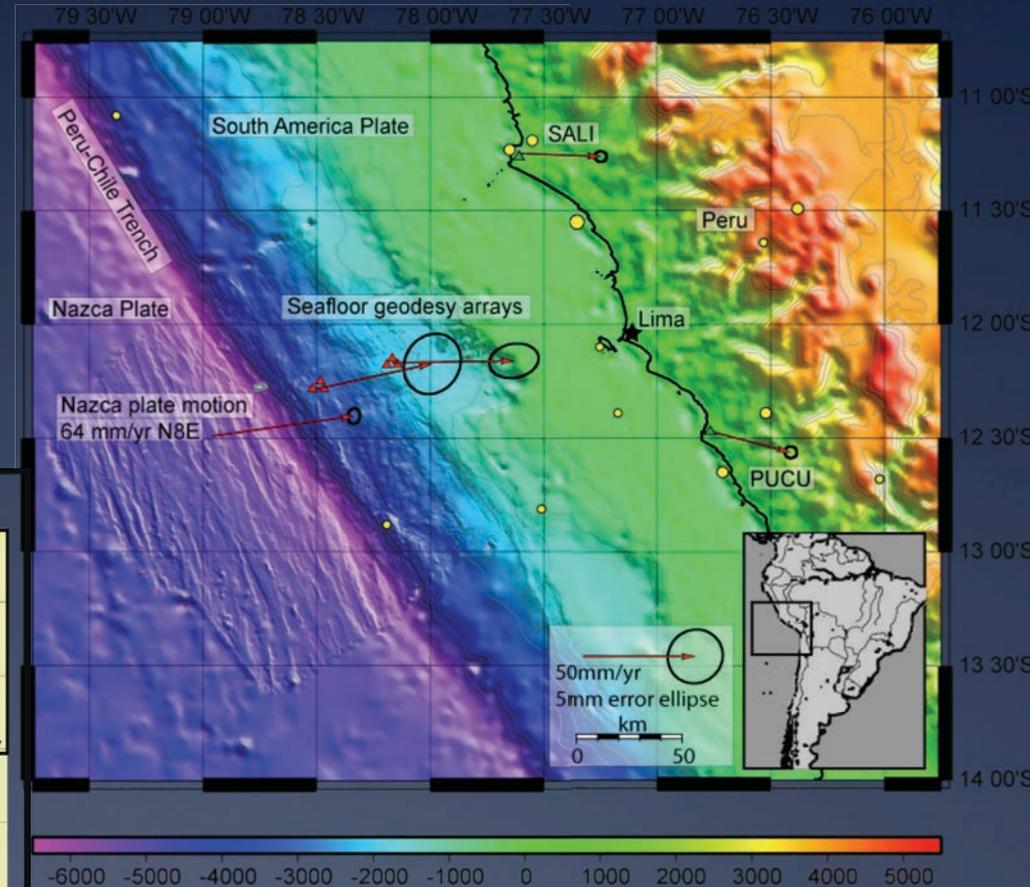
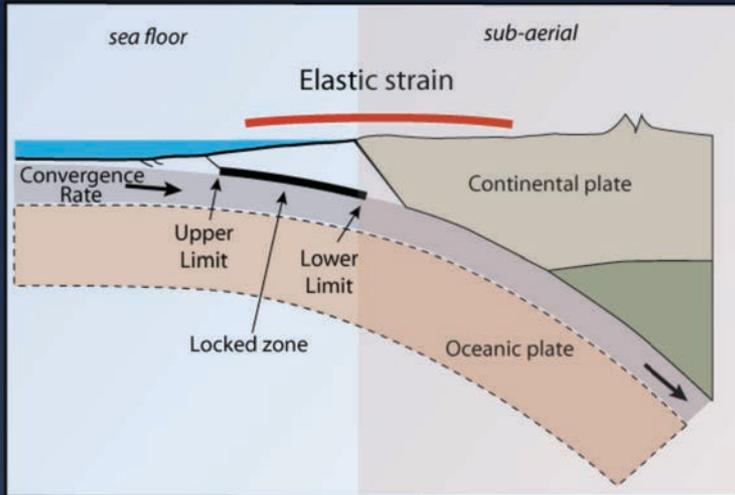


Hydrophone inside instrument well

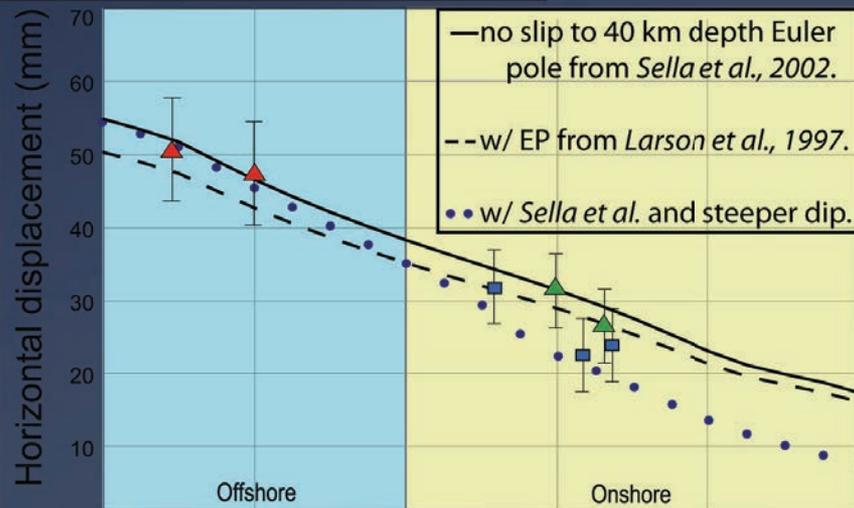
A red arrow points from this caption to the instrument well area on the ship's deck.



Contraction at the Nazca – South America plate



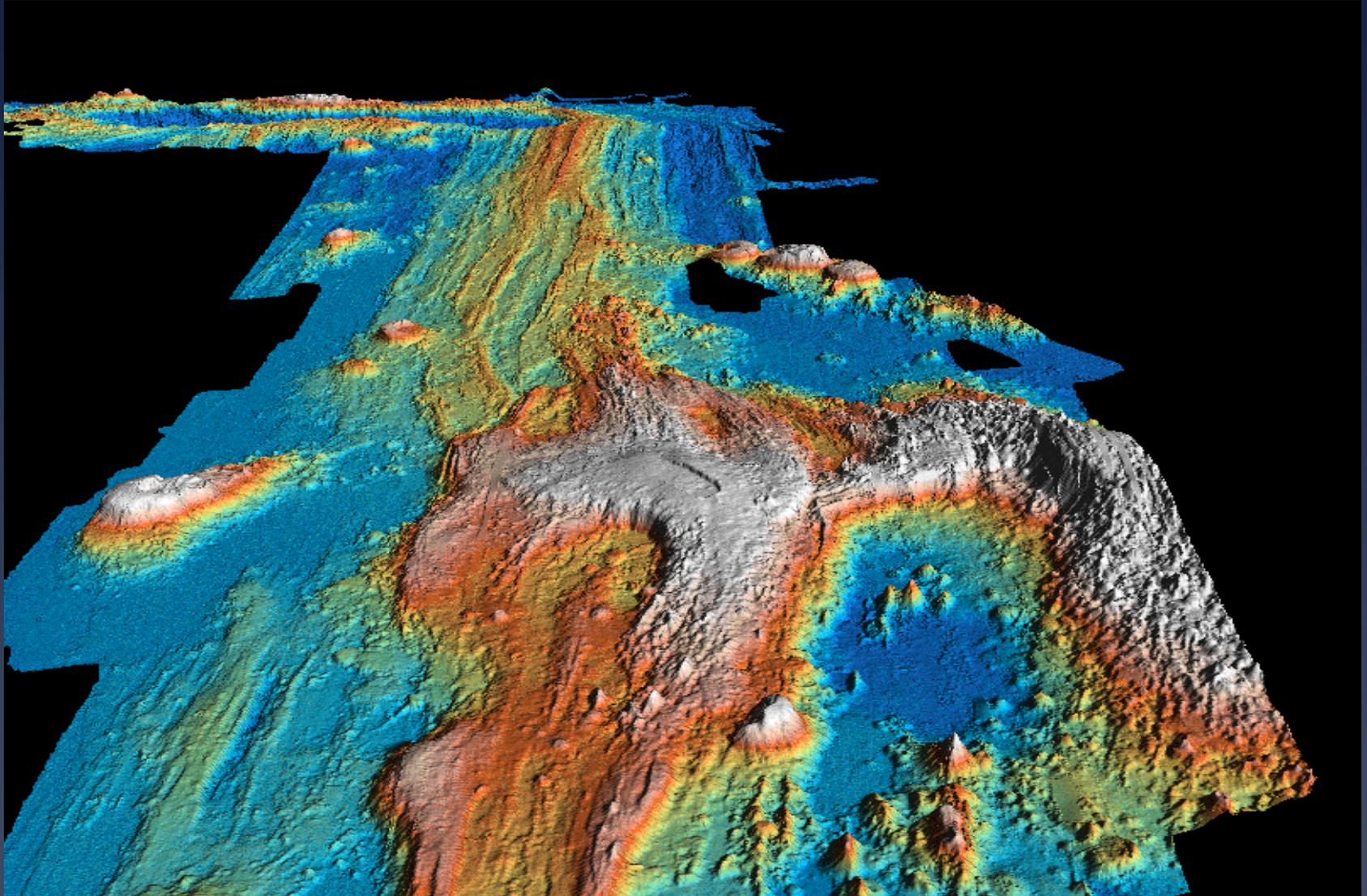
Modeling Surface Deformation



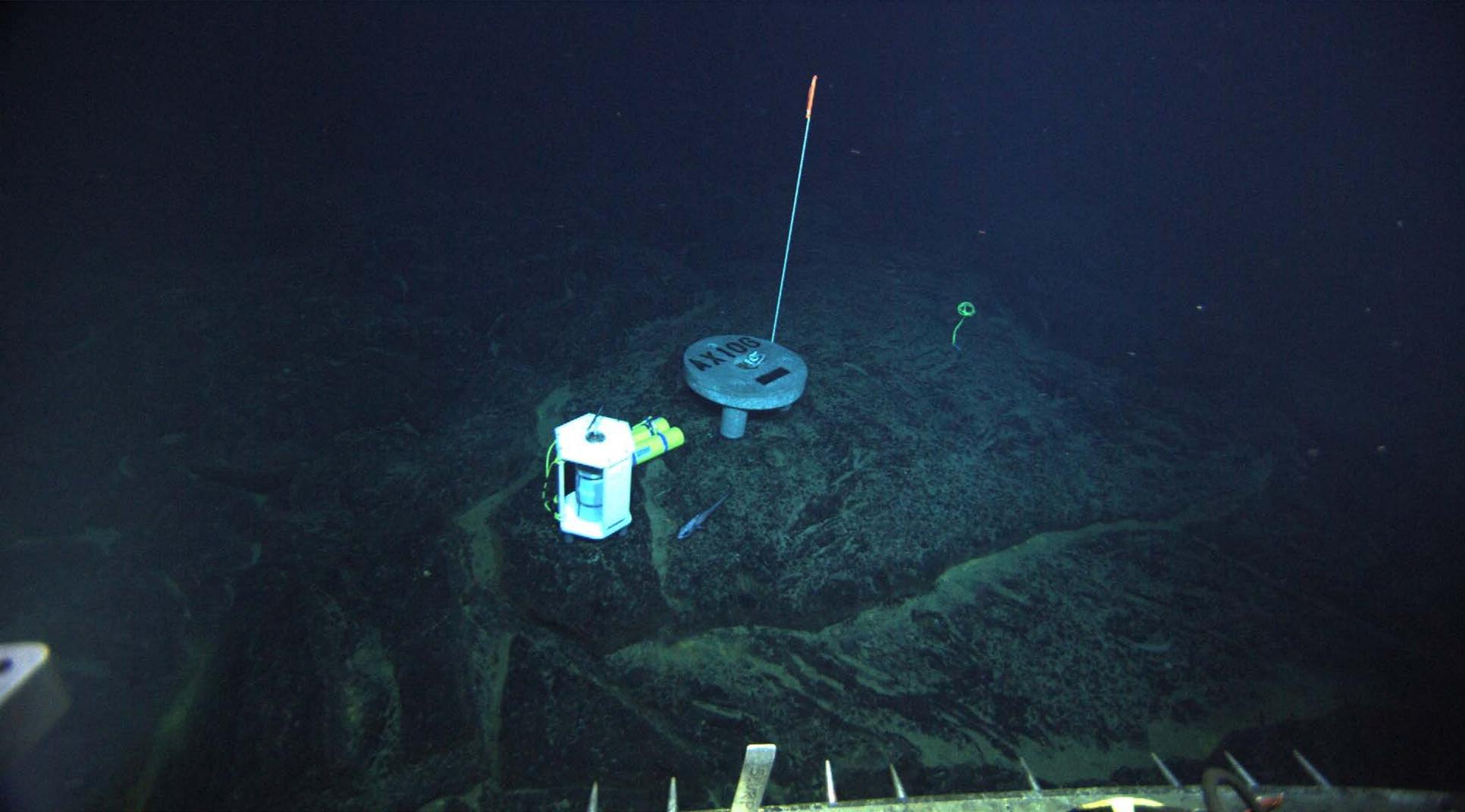
Height measurements with ambient seawater pressure

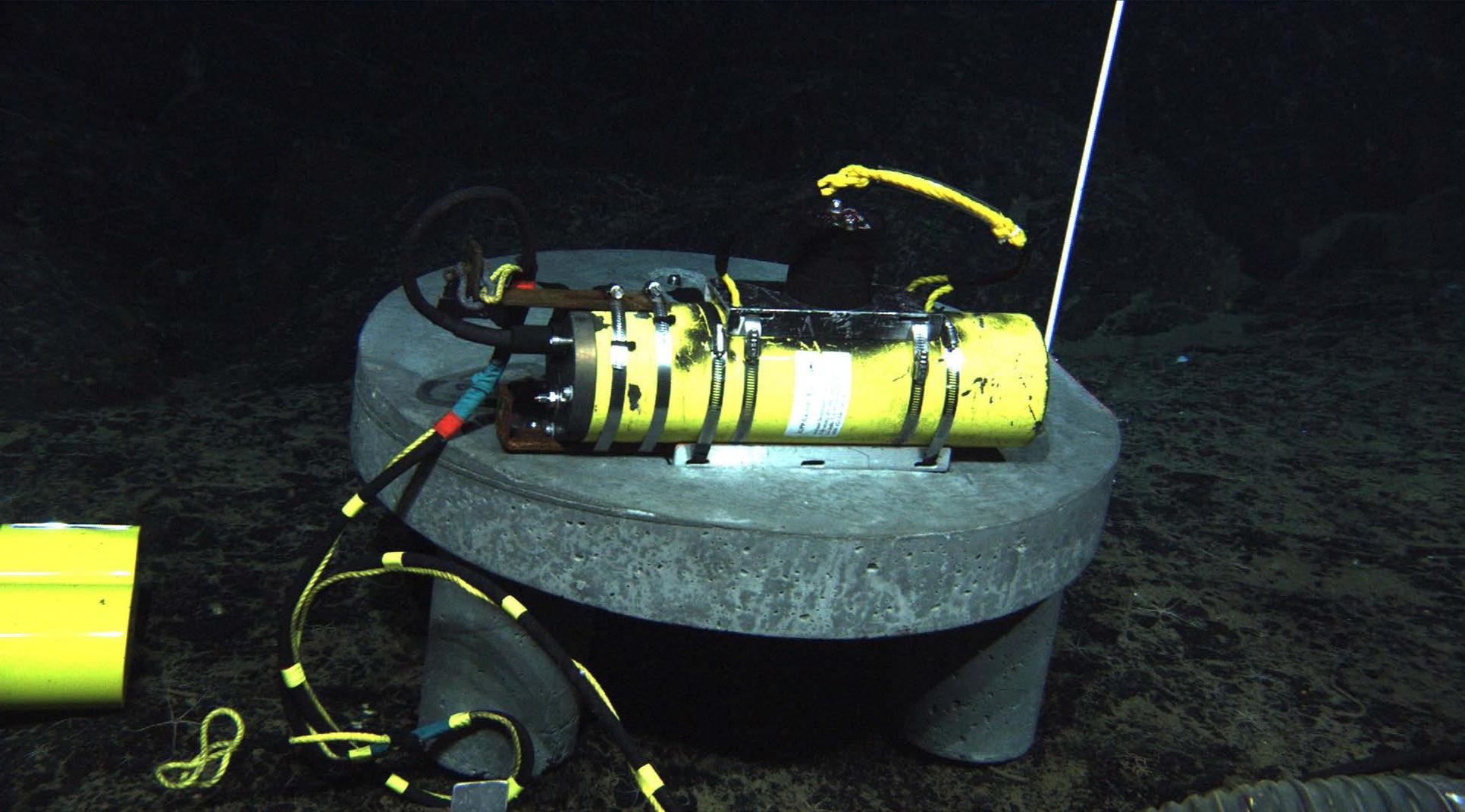
The uniformity of seawater density and the high precision available with quartz pressure gauges allows relative height measurements to 10 ppm, or 1 cm in 1 km

Axial Volcano

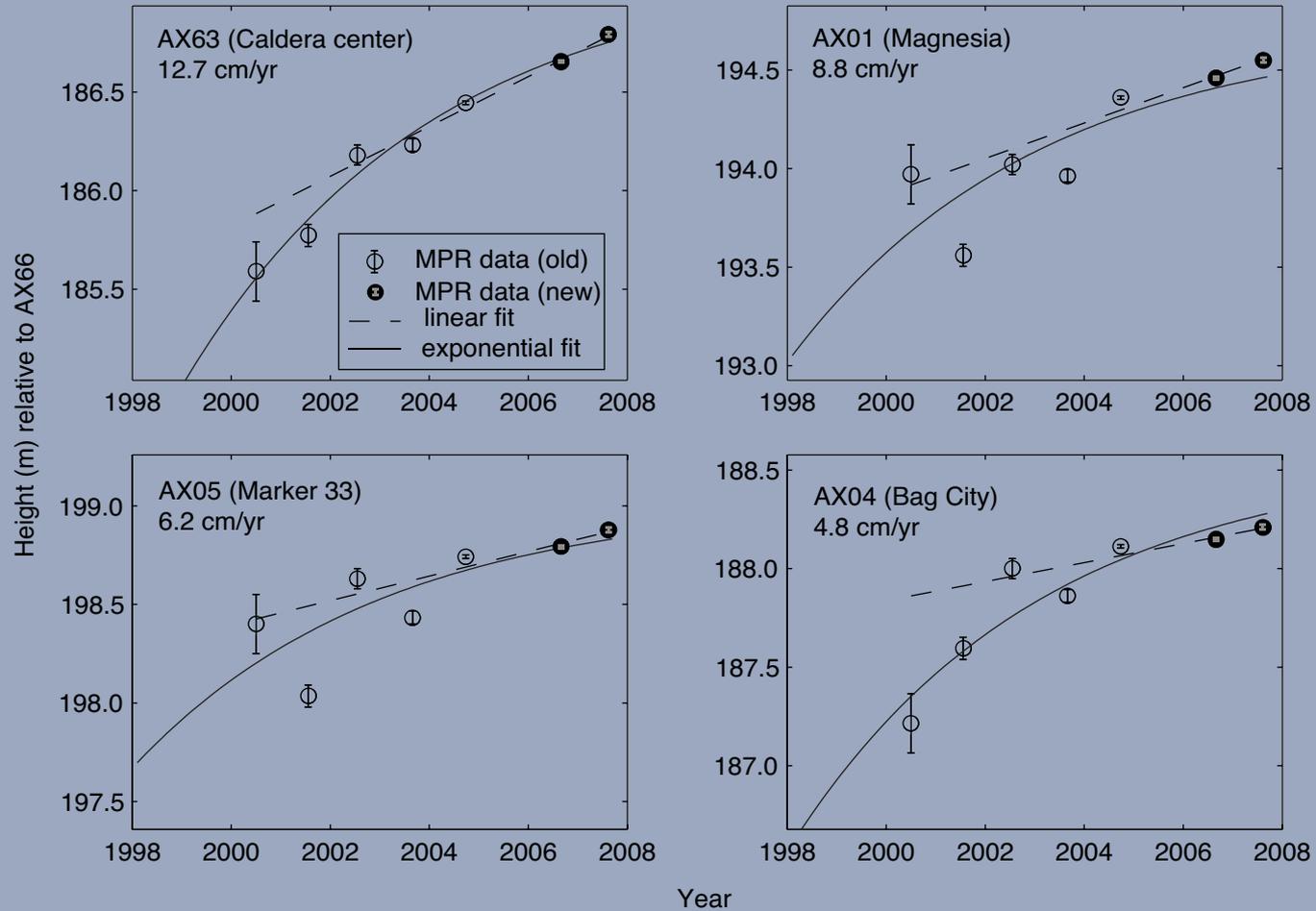


Oblique view of the seafloor around Axial Volcano (white area near the center). In this computer generated image blue areas are deep and white are shallow.

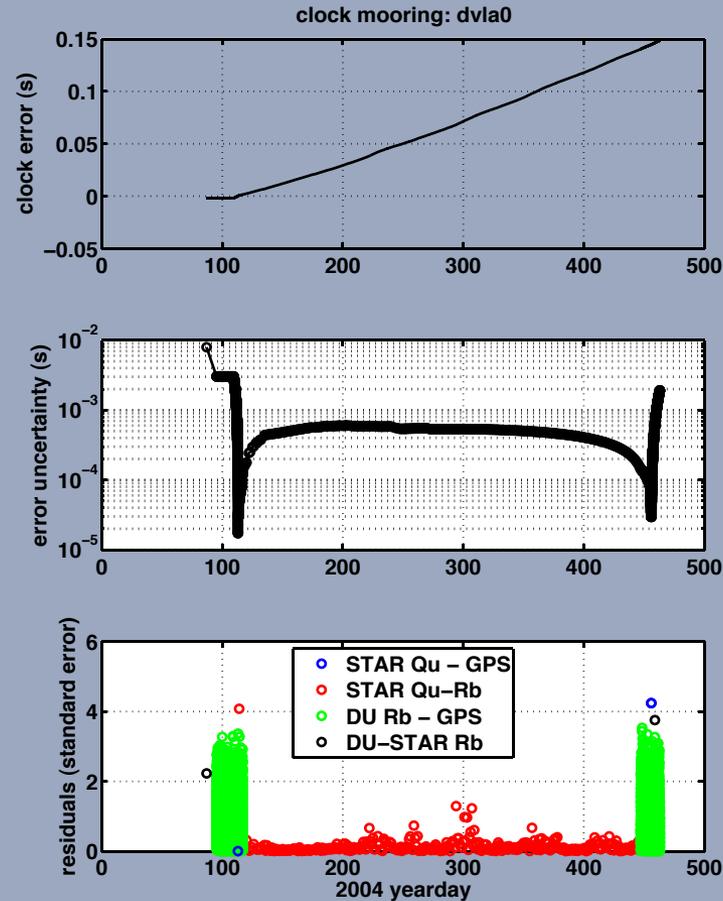




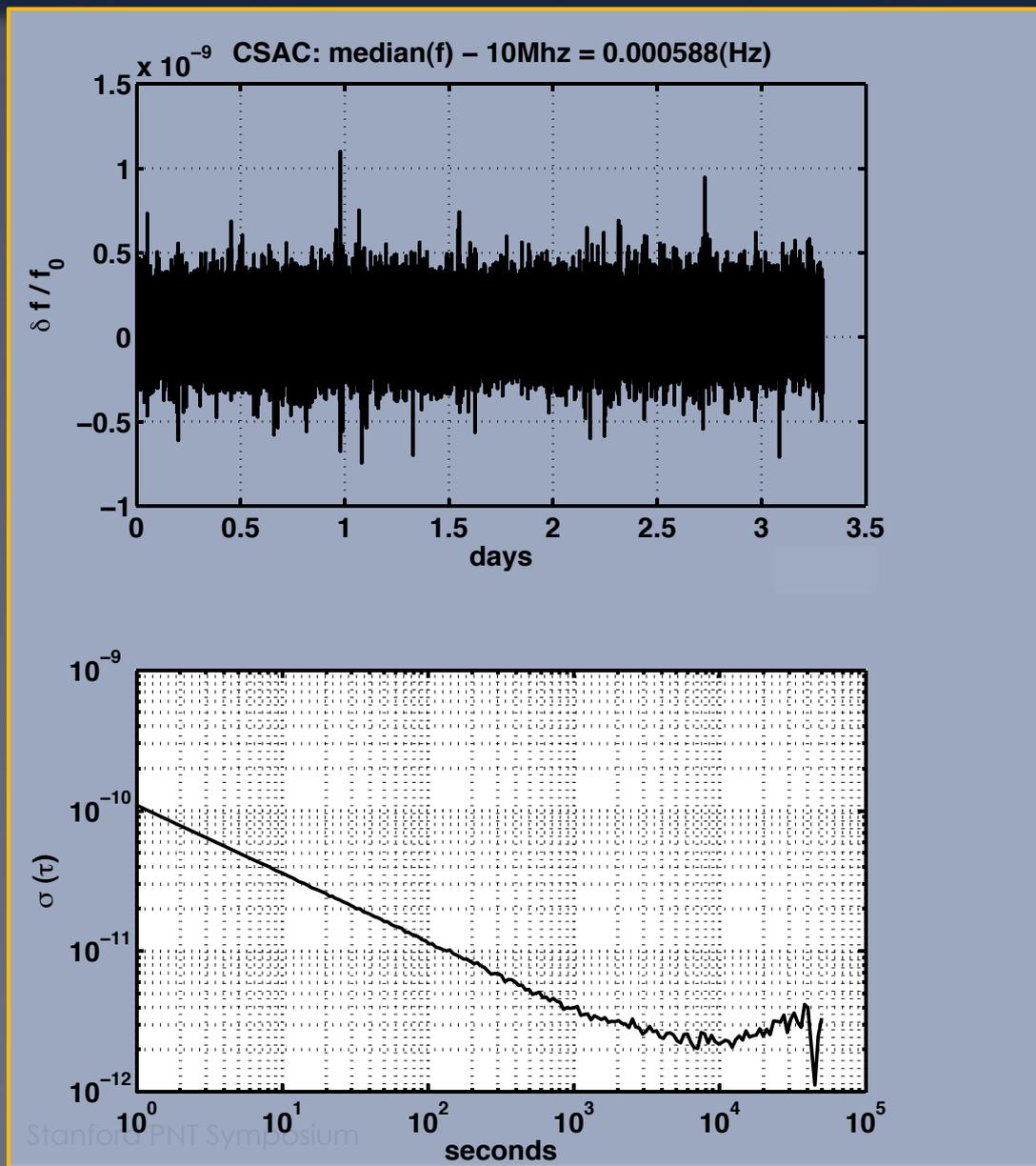
Height change vs time



Time measurement in acoustics and seismology



Chip scale atomic clocks



Questions?

Summary:

Routine position precision from acoustic navigation:

around 1 m

Geodetic quality of seafloor positioning:

around 1 cm

Global "Acoustic GPS" is under discussion