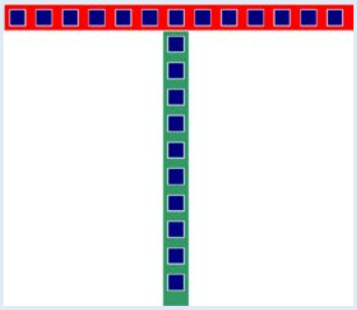
Introduction to Sonar and Multibeam Mapping

SOund NAvigation and Ranging (sonar) systems consist of a transmitter that sends pulses of sound energy through the water and a receiver that detects return signals (echoes) that are reflected back from the seafloor or other objects, including living organisms. In use, an acoustic signal or pulse of sound (often called a ping) is transmitted into the water by a sort of underwater speaker known as a transducer. The transducer may be mounted in a variety of ways including on the hull of a ship, on a pole, on underwater vehicles, or towed in a container called a towfish. If the seafloor or another object is in the path of the sound pulse, the sound bounces off the object and returns an echo to the sonar transducer. The time elapsed between the emission of the sound pulse and the reception of the echo is used to calculate the distance of the object. Some sonar systems also measure the strength of the echo, and this information can be used to make inferences about some of the reflecting object's characteristics. Hard objects, for example, produce stronger echoes than softer objects because softer objects absorb some of the sound energy instead of reflecting the energy. Modern ocean exploration vessels use several types of sonar.

Multibeam sonar is one of the most powerful tools available for modern deep-sea exploration. A multibeam system uses multiple transducers pointing at different angles on either side of a ship to create a swath of signals. The NOAA Ship *Okeanos Explorer* is equipped with a Kongsberg EM 302 multibeam system that uses separate transducers for transmitting and receiving acoustic signals. These transducers are mounted to the ship's hull in a T-shaped arrangement known as a Mills Cross configuration. In this arrangement, transmitting transducers are arranged so they are parallel to the ship's keel, and receiving transducers are arranged to be perpendicular to the keel. This system produces a swath of sound pulses in the 30 kHz frequency range, and can generate up to 864 soundings per ping. The maximum width of the swath is approximately eight kilometers. The EM 302 is designed to produce maps in depths ranging from 10 to 7,000

This ~4,200-meter (~13,800-foot) high seamount called "Kahalewai" was almost 1,000 meters taller than previously thought. Image courtesy of the NOAA OER, Mountains in the Deep: Exploring the Central Pacific Basin.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1705/dailyupdates/media/may3-2.html



Mills Cross configuration, separate transmit and receive arrays. Image courtesy of NOAA. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1503/logs/jun6/media/mills-cross.html*

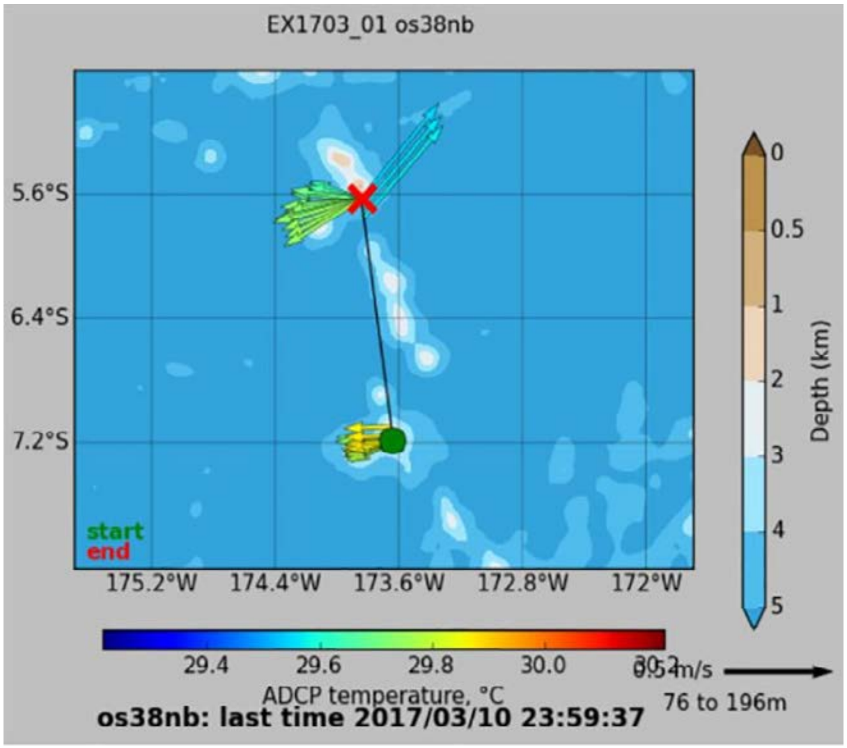
None of the sonars on the ship are standalone units, they all have transducers mounted on the hull of the ship and then a top-side unit located within the ship. The top-side unit does some signal processing on the acoustic returns. The top-side units are connected to computers that run data acquisition software. The image above is the top-side unit of the Knudsen Chirp, courtesy of Knudsen Engineering Limited. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1503/logs/jun6/media/knudsen-chirp.html*

Multibeam sonar bathymetry of Mona Canyon, off the northwest coast of Puerto Rico, showing large landslides that might be related to the 1918 magnitude-7.3 earthquake. Image courtesy of NOAA OER, Océano Profundo 2015: Exploring Puerto Rico's Seamounts, Trenches, and Troughs. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1502/logs/apr27/media/mona.html*

meters, but the system aboard the *Okeanos Explorer* has been able to detect the seafloor at depths exceeding 8,000 m.

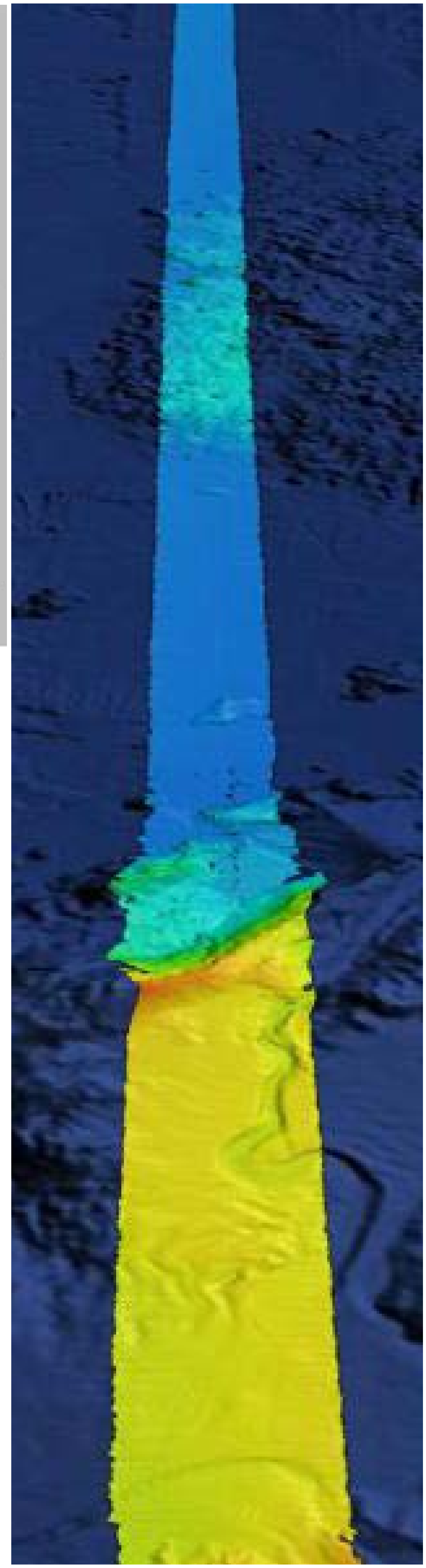
The Knudsen Chirp 3260 sub-bottom profiler sonar is used to collect shallow seismic reflection profiles, which provide details about sediment layers below the seafloor. When the acoustic signal (ping) reaches the seafloor, some of the acoustic energy will penetrate the seafloor surface. The ping will be reflected when it encounters a boundary between two layers of materials that have different densities, and the reflected energy can be used to provide information about the layers (technically, the sub-bottom profiler detects changes in acoustic impedance, but this can be generally thought of as changes in density). The Knudsen Chirp 3260 system operates at a frequency of 3.5 kHz, and can survey the seafloor at water depths up to 10,000 meters.

Split beam echosounders (such as the Simrad EK60 sonars on the hull of the *Okeanos Explorer*) are able to detect various-sized objects and are widely used for fishery research. The EK60 uses a single split beam transducer that emits pings at a single frequency. Transducers are available for frequencies ranging from 18 to 710 kHz. The acoustic properties at different frequencies vary among pelagic species, so the ability to compare return signals at different frequencies provides a way to identify species detected by the sonar system. At present, the *Okeanos Explorer* uses five EK60 echosounders operating at 18, 38, 70, 120, and 200 kHz to detect acoustic signals from objects that include fish, plankton, seeps, and hydrothermal vents. Because these echosounders can detect bubbles in the water column, ships of exploration have been able to discover hundreds of previously unknown methane seeps off the Atlantic and Pacific U.S. coasts (please see the *What's the Big Deal? http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_bigdeal.pdf* lesson for additional details).



Example of an ADCP vector plot. The red "X" is the location of the ship. The many arrows coming from the X show the magnitude and direction of currents at a variety of depths beneath the ship. Image courtesy of the NOAA OER, Discovering the Deep: Exploring Remote Pacific MPAs.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1703/logs/mar11/media/acdp.html

Acoustic Doppler Current Profilers (ADCP) are another type of sonar system that measure the speed and direction of ocean currents using the principle of "Doppler shift". If you have ever heard a train whistle you are probably familiar with the Doppler effect. As the train travels towards you, the whistle's pitch is higher. When it passes you and is moving away, the pitch is lower. The change in pitch is proportional to the speed of the train. The ADCP emits a series of high frequency sound pulses that scatter off of moving particles in the water. Depending on whether the particles are moving toward or away from the sound source, the pitch of the return signal is either higher or lower, and the frequency shift is proportional to the speed of the water. Two ADCPs are presently aboard NOAA Ship *Okeanos Explorer*. The Workhorse Mariner ADCP operates at 300 kHz, and is capable of collecting current profiles up to about 100 m below the sea surface. The Ocean Surveyor ADCP operates at 38 kHz and is capable of collecting current profiles up to 1000 to about 1300 m below the sea surface.



The NOAA Office of Ocean Exploration and Research pursues every opportunity to map, sample, explore, and survey at planned destinations as well as during transits; "Always Exploring" is a guiding principle. Mapping data is collected at all times when the ship is transiting and underway. This image shows the multibeam bathymetry data acquired during the ship's transit west from Oahu to the Johnston Atoll Unit. Image courtesy of the NOAA OER.
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1706/dailyupdates/media/july11.html

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