SCIENTIFIC ENGINEERING

Geophysical Surveys

While seismic surveys are often used by the oil and gas industries to find reserves, scientists can use the same techniques to look for air bubbles, which can signify the presence of hydrothermal vents. Geophysics surveys are complex operations that require skilled specialists to operate the equipment.

Seismic surveys work by having a sound source generate energy, commonly in the form of airwaves, which travel towards the seabed and through different layers. Eventually this energy is reflected back up towards a listening device where the waves are recorded over a predetermined time period using hydrophones. Seismic surveys performed by the NOC are 2-D and consist of the following.

- A research vessel
- An array of air guns (sound source)
- A towed streamer (listening device) ending in a tail buoy.

The 3000m acoustic streamer that the NOC uses is a 'Solid Sentinel Active Section', which has a polyurethane outer skin surrounding a foam-filled inner with data wires and strain members to take the tension running through the middle. Each section is 150m in length, containing eight hydrophones in 12.5m compartments, with two communication coils per section. Sections are connected end to end with a maximum of five sections before requiring a module to boost and transmit the data. 2-D surveys commonly run 12km streamers and 3-D commonly eight times 6km.

Digicourse birds are connected to a communication coil every 300m to help maintain streamer depth and transmit compass data down the streamer to the acquisition system. This data can be used in processing to define the streamer shape, drift angle and streamer depth all to help locate the position of the reflection on the sea floor.

The tail buoy is used as an identifying mark for the end of the streamer- helps other vessels avoid the underwater obstruction, as well as for positional data.

How seismic surveys work

Before a survey can even begin the operators must perform a marine mammal observation. If the observation period passes, the test work can begin.

Positioning of the vessel, the source, the streamer and the tail buoy is extremely important. The greater the accuracy of the equipment the greater the accuracy of the data. Vessels use differential GPS (DGPS), which uses base stations with a known position to calculate what the travel time of the GPS signal should be to what it actually is. It then sends this correction to the vessel to be applied to the GPS signal sent to it to ensure greater positional accuracy of the at-sea equipment.

The gun source(s) and tail buoy can also accommodate GPS modules to help improve the accuracy. Commonly these would be used as referential GPS (RGPS) where the range and bearing of the units are applied to the overall positioning geometry of the streamer.

The data that is produced is a time slice of the ocean floor at the point of reflection for a given time period. The point of reflection is called Common Mid Point (CMP), or layback value, and is calculated as the distance from the vessel reference point to the centre of source plus half the distance from the centre of source to the first receiver group on the streamer. This data is then processed to produce a time slice per CMP showing the ocean floor and the layers beneath.

Conducting a survey
To run a seismic survey there is a lot of hardware and software systems required to capture the real time data and to ensure its quality. There should be at least one person to oversee the sound source software and data, one person for the compass data and positional data of all the systems, one person for streamer data acquisition and one for quality control of the real time data including networking and data transfers.

One of the major problems with seismic is the synchronisation of all the systems operating at real time. One-way to overcome this is to route all the data and networking through a central system that monitors and controls all the IO for the streamer the guns and the vessel.

Allowing one central system, referred to as a Navigation system, to be in control of synchronisation ensures the triggering and time stamping for each shot is all done centrally and not by different GPS systems that may vary slightly in time and position causing undue errors and deviations.

As seismic software and hardware progresses so will the manner in which data is captured. There are new developments and alternatives to traditional seismic such as magnetic and gravity seismic surveys. The seismic industry is fast paced and ever changing and with over 70% of the ocean still unexplored there is a lot of opportunity for new discovery.

Oceanographic Sampling

A diverse range of methods and equipment are used for obtaining samples from the sea and seabed, depending on the material or measurement required.

The National Oceanography Centre has a vast array of sensor and mooring equipment used for sampling seawater to collect a range of oceanographic data across multiple parameters. Instruments for sampling a wide range of oceanographic parameters include profiling instruments and shallow towed instruments deployed from research vessels at sea, or moored applications and platforms, which can be left at sea for significant periods of time (up to 24 months).

Explore the range of sensors and mooring equipment used for sampling seawater.

Sensors on a CTD sampling frame

The CTD (conductivity, temperature, depth) sampling frame is used on 90% of all research cruises and provides real-time, accurate and precise data from the water column. The stainless steel frame is able to take measurements up to 6000m in depth and usually has a rosette of water bottles that can collect up to 24 samples at depths chosen by the operator. These water samples can then be used in the laboratory to undertake a wide range of physical, chemical and biological investigations.

Parameters that can be measured by instrumentation fitted to the frame

- Conductivity (used for calculating salinity)
- Temperature
- Pressure (to infer depth)
- Turbidity (particulate concentration in the water column)
- Fluorescence
- Photosynthetically active radiation
- Dissolved oxygen
- Current (using a lowered acoustic Doppler current profiler).

Water bottle sizes for 24 samples

- 10 litres
- 20 litres

We also support a titanium frame holding twenty-four 10-litre water bottles to take water samples for trace metal analysis.

SeaSoar
SeaSoar is one of the leading towed oceanic vehicles for the acquisition for oceanic data. The robust, high performance vehicle is proven to have collected reliable data over long distances. For example, on a recent cruise in the Southern Ocean, SeaSoar was in the water for 96 hours, covered 1607km and collected 1458 profiles.
SeaSoar resembles a very small aeroplane. It is towed behind a research vessel at speeds of between 9 and 12 knots and undulates up and down in the water column (up to 420m depth), controlled by hydraulics. Data is transmitted back to the research vessel in real time via the conductive tow cable.

Parameters measured by the instrumentation

- Conductivity (used for calculating salinity)
- Temperature
- Pressure (to infer depth)
- Dissolved oxygen
- Turbidity (particulate concentration in the water column)
- Irradiance
- Bioluminescence
- Fluorescence
- Plankton

Scanfish
Scanfish is a towed undulating vehicle that is like a large flying wing and uses small electrically driven flaps to change its own attitude and therefore angle of attack. Though it has a smaller payload than SeaSoar, it has a very high quality CTD. It will only dive to around 150m without a depressor weight, however is very controllable. The ship speed for undulation need only be around 6 knots allowing it to collect higher resolved spatial data compared to SeaSoar.

Parameters measured by the instrumentation

- Conductivity (used for calculating salinity)
- Temperature
- Pressure (to infer depth)
- Dissolved oxygen
- Bottom depth

Moving vessel profiler
The moving vessel profiler (MVP) allows near vertical profiles to be measured from a moving vessel, typically to 300m depth at a speed of 10 knots. The system is comprised of an electro mechanical winch system with a Kevlar conducting cable, the tow fish carrying the instrumentation and the control and data acquisition elements, which can display the data in real time.

The instrument package is mounted in a small torpedo shaped tow-fish and this is towed on a rope from the side or aft of the ship by a semi-automatic electro-hydraulic winch. To start a profile, the brake on the winch is released and the tow-fish starts falling through the water column under gravity. When a predetermined maximum depth is reached the brake is applied to the winch drum and the fish immediately starts returning towards the surface due to the cable drag forces returning the towed system to its natural equilibrium streaming point.

Since the MVP can profile at very slow ship speed (even stationary profiling) it can collect very high resolved spatial data compared to both Scanfish and SeaSoar. However, the continuous turning of the winch drum during operation means that the system requires regular maintenance.

Parameters measured by the instrumentation

- Conductivity (used for calculating salinity)
- Temperature
- Pressure (to infer depth)
- Chlorophyll concentration
- Light intensity

Vertical microstructure profiler

Vertical microstructure profilers (VMP) are used for making small-scale measurements in the water column. VMPs are long, slender devices with the instruments contained at the nose of the profiler. These profilers contain shear probes, which are very fragile airfoil section strain instruments that are incredibly sensitive.

Deployed from a stationary vessel, the turbulence profiler falls under its own weight at constant speed. Small shear currents that the profile descends through cause a deflation of the shear sensors. The shear measurement and internal accelerometers can provide information about small scale mixing processes in the water column.

When the maximum depth is reached (usually deliberately to the ocean floor as there are often interesting currents here), the profiler is recovered either with a winch on a slack line or by dropping ballast weights for an untethered profiler. Tethered profilers can be deployed to around 200–2000m, but untethered instruments can go to 6000m. An untethered instrument can be deployed concurrently while operating the CTD sampling frame.

Untethered profilers use a combination of recovery aids including acoustic navigation and pressure telemetry while submerged, and radio direction finding, satellite beacons, lights and flags to allow us to locate them on the surface.

Parameters measured by the instrumentation

- Conductivity (used for calculating salinity)
- Temperature
- Pressure (to infer depth)
- Current
- pH
- Turbulence/shear
- Florescence

Stand-alone pump system

Some trace measurements require so much water that the volume that the CTD water bottles can obtain is not enough. For such measurements, we use a device called a stand-alone pump system (SAPS).

This is a battery powered water pump that sucks water through various filters leaving the object of interest on the filter paper for analysis. These can be used for trace metals and also biological applications.

The SAPS is programmed with a delay time (to allow them to get to their target depth – sometimes hours) and a pump time. With the ship stationary, they are usually clamped to a hydrographic wire for deployment, however they can also be fitted on the CTD frame and onto moorings. They can be lowered to 6000m and can pump thousands of litres of water over a couple of hours.

A pressure and temperature sensor can be attached to the frame so that the exact depth of the SAPS is known. The temperature measurements can also be helpful in inferring different water masses that pass during pumping.

Parameters measured by the instrumentation

- Temperature
- Pressure (to infer depth)

Moorings

Moorings are fixed at a particular location in the ocean for up to 24 months at a time. The data gathered are transmitted back to shore via satellite link, enabling real time analysis of a wide range of oceanographic parameters as well as monitoring meteorological events. Great care and attention to detail are essential to ensure reliable and consistent operation.

Stationary platforms

Stationary platforms moored in the ocean are used to provide time series data for a select location.

Mooring arrays

Mooring arrays include many individual moorings, spaced out across an area of ocean, which can be used to assess how oceanographic parameters change across a specific region of the ocean. These are used for projects such as the RAPID project.

Seafloor Sampling

A diverse range of methods and equipment are used for obtaining samples from the sea and seabed, depending on the material or measurement required.

Explore descriptions of different types of sampling.

Coring

Corers are used for collecting sediment from the ocean floor; they work by pushing or grabbing sediment into containers. The National Marine Equipment Pool has eight different types of corer with both tubular and box varieties available.

Tubular corers

Gravity corer

Gravity coring is the simplest method of obtaining a sediment sample from the seabed. This corer consists of a weight with steel tube sections attached to it. The weight can vary between 100kg to 1000kg. Selection of the length of sample tube is determined according to the type of sediment being sampled and is generally between one and four metres. The end of the corer is fitted with a tapered cutter section and a catcher to retain the sample. Sample tubes are fitted with a clear polycarbonate liner with diameter of 63.5mm. To collect a core sample, the corer is lowered down to the seabed on the end of a wire, stopping a set distance above. It is then lowered at a set speed into the sediment to obtain the sample, before being raised to the surface; it is dismantled and the polycarbonate core liner encasing the sample is removed.

Kasten corer

A slight variation on the gravity corer is the Kasten corer. This uses a similar set up, but uses a sample tube manufactured from sheet metal of square cross section with sides approximately 150mm. No liner is used. A cutter section fitted to the end of the sample tube has two spring-loaded flaps that close when the corer is withdrawn from the sediment. The sample tube is designed to be split to gain access to the sample.

Piston corer

The piston corer is able to take longer samples than the gravity corer. Core samples of 90mm and 110mm diameter can be taken. The corer consists of a weight fitted with steel sample tubes. A PVC liner tube is fitted the full-length core barrel. A piston is fitted inside the PVC liner and is attached to a wire, which runs inside the corer barrel, through a hole in the centre of the weight and is attached to the main deployment wire. Up to five sections of 5.4 metre-long barrels can be fitted depending on the type of sediment being sampled. The corer is lowered on a wire to the seabed until a trigger weight, suspended from the corer weight via an arm, contacts the seabed. This operates a mechanism, which allows the corer to free-fall a distance pre-set by the length of trigger wire and sink into the sediment.

As the corer descends to the seabed, the main deployment wire becomes taught at the point the piston inside the barrel is level with the surface of the sediment. As the corer sinks further into the sediment, the piston should remain static at its optimum point at the sediment surface. The core tube then moves past the piston into the sediment creating a vacuum at the top of the tube which helps to overcome the friction generated between the sediment and the inside of the core liner. On recovery, the corer barrels are removed one at a time and the PVC liner containing the sample is cut into manageable lengths. Sample lengths up to 25 metres long are possible in theory, but in practice this is dependent on the sediment type and is very difficult to achieve.

Multi-corer
The multi-corer has been developed to take up to twelve undisturbed cores in clear plastic tubes 56mm diameter × 600mm long. The corer consists of a tubular frame with a sampling head attached to it by a hydraulic damper. The core tubes are attached to the head, which has a series of spring-loaded arms to swing under the tubes, sealing the bottom and also plugging the top to prevent the sample being disturbed during recovery.

A series of lead weights are attached to the head, which can be selected to regulate the depth of sample taken. The corer is lowered on a wire to the seabed until the frame makes contact and the deployment wire becomes slack. At this point the core tubes are driven into the sediment by gravity, at a controlled rate of descent governed by the hydraulic damper and weight of lead on the head.

Mega-corer
The mega-corer works on a similar principal to the multi-corer but is able to take sample cores of a wider diameter. It is able to take up to 12 undisturbed samples in clear plastic tubes 100mm diameter × 600mm long.

Box corers

SMBA box corer
The SMBA (Scottish Marine Biological Association) box corer is designed to take an undisturbed sediment sample of 600mm square, up to a maximum depth of around 450mm. The corer consists of a sample box mounted on gimbals, and a spade assembly. The box corer is lowered onto the seabed on a wire at a controlled rate until its frame rests on the bottom. The sample bucket is forced into the sediment by the weight of the corer. As the corer is slowly pulled out of the sediment, a mechanism allows the spade to swing below the sample box sealing in the sediment. Simultaneously, spring loaded flaps above the sample box are closed to prevent the sample being disturbed during recovery. The use of this equipment is very dependent on the type of sediment to be sampled and the current sea state.

NIOZ (Haja) corer
The NIOZ (Koninklijk Nederlands Instituut voor Onderzoek der Zee, the Royal Netherlands Institute for Sea Research) box corer works on a similar principle to the SMBA Box Corer. It is able to take undisturbed samples of 500mm diameter or 500mm square, up to 500mm depth. It differs in design to the SMBA corer in that it has two spades, which operate from either side of the sample box. This design results in a more balanced ‘pull-out’ of the corer, reducing the risk of disturbing the sediment during sampling.

Day Grab
The Day Grab is a small corer consisting of two quadrant-shaped jaws mounted on a frame. Removable lead weights are bolted to the frame to allow the weight of the corer to be adjusted to suit the sediment type. The Day Grab is lowered to the sea floor on a wire with its two jaws locked open. When the grab contacts the sea floor, a trigger mechanism unlocks the jaws. The action of pulling the wire to recover the grab causes the jaws to rotate towards each other and close to grab a sample of sediment.

Dredging

Dredging gathers loose rocks sitting on the ocean floor using a technique that has changed little in hundreds of years. It is still a useful way of mapping the broad-scale distribution of rock types on the sea floor.

Dredgers have a chain-link bag with large metal-jawed opening that scoops the contents into the bag. The dredging equipment is lowered to the seabed on a cable and dragged along the bottom for some distance before being brought to the surface.

Performing a dredge

The rock dredge package is lowered to the sea floor using a steel wire cable. This means that there is no data transmission, such as video, to show what is happening below. Depending on the ocean depth, the amount of cable deployed to undertake the transit can be up to two and a half times the water depth.

When the rock dredge package and anchor weight chain reach the sea floor initially a reduction in the cable loading, of approximately one tonne, will be observed on the winch monitoring system. The cable loading will then be seen to increase as the dredge is dragged over the sea floor. The cable monitoring system will show ‘spike’ loadings as the rock dredge picks up samples or snags in the topography. This will continue until the transit line is completed and the rock dredge is recovered to the vessel.

During the dredging transit line, the speed of the research vessel controlling the dredge is kept between 0.5 to 1.5 knots. The speed of the vessel is adjusted as necessary depending on the loadings experienced on the winch monitoring system of the vessel. This means it takes many hours to perform a dredge and many more before the crew and scientists find out if it has been successful.

How the dredge works

The rock dredging equipment comprises of a mild steel frame with an opening approximately 1m wide by 0.5m high, and 0.25m breadth. Attached to the back of the frame, and secured by wire and shackles, is a steel net approximately 1.5m long. Secured to the net, by chain and shackles, is a 0.3m diameter by 0.8m long pipe ‘bucket’ used as a weight. The Dredge is deployed connected to the vessel’s main trawl warp (steel cable), nominally 14,700 metres in length, by an anchor chain and weak link.

The anchor chain acts as weight to keep the rock dredge on the sea floor during the dredge line transit. The rough terrain causes the frame to bounce around, so the anchor at the front and ‘bucket’ weight at the back keep it grounded. The weak links are a system safety device used to separate the main warp from a trapped rock dredge package.

A strangle wire, wrapped through the chain mail and also connected via a weak link to the main warp enables the dredge to be recovered in the event of snagging. The strangle wire works by closing the ‘neck’ of the rock dredge net and pulling the dredge net over the steel frame. This tumbling action hopefully frees the rock dredge from its trapped position without spilling the contents.

During transit lines (dredging) where the sea floor topography is known, or expected to be, extremely broken or rough a sacrificial pennant wire is attached. It runs, approximately 500 metres, between the rock dredge package and the vessels main trawling warp to prevent damage to the vessels trawling warp. An acoustic pinger can be secured to the trawling warp/pennant wire 100–300 metres from the rock dredge package. The acoustic pinger can help to indicate that the rock dredge package is on the sea floor by the separation distance of the pinger and the sea floor being less than the length of cable between the pinger and dredge net.

Dredges have been carried out on a number of research expeditions undertaken by the NOC, enabling us to discover more about the sea floor in a range of oceanic locations. Our dredging equipment is available for use via the National Marine Equipment Pool.

Trawling

Trawling usually happens in mid-water or at the bottom of the sea, and is used for sampling mega-fauna including fish, sea urchins and sea cucumbers. Trawls have a cone shaped net attached to a metal frame, and are towed on a wire behind a ship. Once a trawl has reached the correct depth its net is opened and samples are taken.

Performing a trawl

Before trawling begins it important to know if the terrain is suitable as extruding topographic features such as underwater mountains, cables and other obstacles need to be avoided. If the area is not well mapped a survey of the area will be performed first using echo sounders on board the ship or by deploying a Towed Ocean Bottom Instrument (TOBI). Once the trawl is in progress, the crew cannot visually see what is happening, as there are no cameras; instead they will use acoustic transmissions to give depth and angle information.

Trawling is a slow process. As the wire is let out it billows, so many extra metres of wire is needed to get to the right depth. For example, in 5,000m of water depth around 13,000m of wire will be required. Consequently, the trawl will be many kilometres behind the ship and many kilometres down, making both guiding and steering difficult.

The NOC mainly use two different kinds of trawl for scientific research, which are detailed below.

Agassiz trawl

- Used with a clump weight can be fished almost vertically, which is ideal for confined spaces such as canyons
- Small, basic trawl that is easy to use
- Wire out to depth ratio 2:1
- Time at the bottom is up to one hour before the net is full.

Otter Trawl Semi-Balloon 14

- A commercial shrimp trawl, used scientifically to carry out a bottom trawl
- Highly specialised and requires both scientists and technicians to operate
- Wire out to depth ratio 3:1 with 14-metre ground line
- Originally used on the Challenger research vessel, allowing sample comparisons to be made with previous years.

Container Laboratories

Portable containerised laboratories provide additional laboratory facilities on board research ships when scientists require additional space.

The containers are standard 20-foot ISO steel shipping containers fitted out to a high standard with 220V 13A socket ring mains, air conditioning, sink with fresh and sea water (non-toxic) supplies and fridge-freezer.

The National Marine Equipment Pool currently has four types of containerised laboratory.

Radionuclide

These container laboratories must be used for any work using radioactive isotopes. They have easily cleanable surfaces and spill containing benches to allow for easy cleaning to ensure effective decontamination after a cruise. A fume cupboard is installed to provide a safe working environment when using hazardous chemicals. Benches are modular and can be removed if required to allow installation of special equipment such as a Flow Cytometer. A small laminar flow cabinet can be installed if requested to provide a “clean air” working area. At the end of the Cruise a set decontamination procedure has to be undertaken by the user.

Clean chemistry

These laboratories are supplied when a Scientist needs a very clean environment to work in such as when carrying out trace element analysis. They are built to a similar specification to the radionuclide container with highly cleanable surfaces and any exposed metal surfaces kept to a minimum. A laminar flow cabinet is fitted to provide a “clean air” working environment for experiments. Ultra pure water purification systems (Millipore) can be installed if required. Bottle racks for mounting full CTD (conductivity, temperature, depth) water bottles in the container can also be supplied.

Constant temperature

This container laboratory is used when a Scientist requires a fixed temperature to carry out their work in. It is similar to a clean chemistry laboratory but with a very high specification air conditioning plant designed to maintain a lab temperature of between 2 and 30°C to within ±1°C of the set point. This lab is fitted with a recirculating type fume cupboard for working with hazardous chemicals. Ultra pure water purification systems and bottle racks for mounting CTD water bottles in the container can also be installed.

General purpose

These containers are more basic than the other containers and are used to give additional general lab space on board. They can be supplied with fridge-freezer, water purification systems or CTD bottle racks if required.