Glossary of Marine Technology Terms

This glossary was originally developed by MTS member Brock Rosenthal as the "Dummy's Guide to Marine Technology." We will continue to build on Brock's work by adding terms when appropriate. If there is a term that you would like to see added to the Glossary, please e-mail us at mtsprograms@erols.com.

A

AUVs, or Autonomous Underwater Vehicles, are underwater robotic vehicles that do not have a tether to the surface. They are pre-programmed to operate over a particular course or to respond to sensor data or perhaps acoustic commands. Applications include surveying, scientific data collection and mine-hunting.

B

Batteries: All types of batteries used topside (out of water) can also be used undersea. There are a few factors unique to using batteries underwater. One is that some batteries can produce gases that are potentially explosive. In the open air this is usually not a problem because the small volume of off-gases is quickly diluted. However, in sealed pressure housing, gas build-up can cause problems ranging from water leaks to explosive failure. Pressure relief valves can safely vent gas to eliminate these problems.

Some batteries and other subsea electronics use pressure-balanced, oil-filled packaging. In this method, all air spaces and voids in a housing are filled with oil or hydraulic fluid. A flexible membrane on the housing transmits ambient water pressure through the housing. Because the pressure inside the housing is the same as the outside water pressure, it is said to be equalized. Since there is no pressure gradient, a heavy pressure-proof housing is not required.

Seawater batteries utilize seawater as an electrolyte. Most use electrodes of magnesium for anodes, and oxygen dissolved in the sea water as oxidant. Advantages of seawater batteries are that they have a very long shelf life while dry, can be used to very deep depths, have high energy densities, and have long duty cycles. Disadvantages are that the cell voltages are low, necessitating DC/DC converters and that the output power can be influenced by factors such as the water circulation, quantity of dissolved oxygen, temperature and salinity.

Bottom Samplers are sediment sampling devices. There are many different types of bottom samplers. A box corer can be dropped into the mud to bring back a block of near-surface sediment. A piston corer can return a cylinder of sediment up to 100 feet (33 meters) long that may encompass several million years of sedimentary history. For researchers especially interested in the seawater-seafloor interface, a gravity corer can return cores up to 20 feet (6 meters) long with little core-top disturbance. Vibracorers use a motor that produces a high-frequency oscillatory vibration to help propel a long core barrel into unconsolidated sediments.

Buoys: There are two main classes of buoys: drifting and moored.

As the name implies, **drifting buoys** are not anchored to the seafloor. They are typically used to study currents and circulation patterns. A drogue (a cylindrical or funnel-shaped device) is sometimes added to have the surface buoy follow a subsurface current.

Subsurface drifting buoys, or **floats**, usually have variable buoyancy engines to descend to a predetermined depth where they follow this current and possibly collect environmental data. The buoyancy engine is programmed to occasionally bring the float to the surface where it can telemeter its data back to shore. (A telemeter is an electrical apparatus for measuring a quantity—such as pressure, speed, or temperature—and transmitting the result especially by radio to a distant station.) Trajectories of individual floats show how the water moves horizontally, and trajectories of groups of floats show how the water is mixed by eddies. This information is important for understanding how water tracers and pollutants are transported by the ocean. The Advanced Research and Global Observation Satellite (ARGOS) program is a large multinational effort to put thousands of floats in the world's oceans.

Moored buoys are used for many purposes. Some of the most common uses are:

- **Aids to Navigation** (ATON)—used to mark hazards to mariners, harbor entrances and other navigable channels.

- **Data Collection Platforms**—Moored buoys make excellent platforms for collecting data at one location anywhere in the ocean on time scales ranging from weeks to years. Sensors and instruments can be mounted anywhere from the seafloor on up to masts installed on the top of the mooring float

- **Marker Buoys**—used to relocate objects on the seafloor

- **Ship Moorings**—typically used to moor large commercial or military ships when dock space is not available or near-shore waters are too shallow. Also used for offshore loading and unloading of tanker ships.

Other special types of buoys are:

Subsurface buoys: used when surface measurements are not required. They also eliminate vandalism, which can be a big problem with surface buoys.

Self-deployed buoys have the anchor, line and sensors packaged in a compact assembly. Air deployed buoys are dropped from a plane.

Moored buoys come in a wide variety of shapes and sizes. Hull forms include disk, sphere, cone, boat hull and spar. The typical moored buoy consists of:

- Tower for mounting antennas, sensors and solar panels
- Float, usually has a well containing batteries
- Bridle for attaching the mooring line
- Mooring line to connect the bridle to the anchor
- Anchor

Moored buoys are important to the marine technologist because they make excellent platforms for collecting data anywhere in the ocean on time scales ranging from weeks to years. Sensors and instruments can be mounted anywhere from the seafloor on up to masts installed on the top of the mooring float. Anchors are connected to holding lines with acoustic couplings that are released to recall the instruments. Flotation holds the instruments and their tether line upright in the water column and brings them to the surface on release.

C

Cables can be electrical, fiber optic, or a combination of the two. Underwater electrical cables date back to the advent of the telegraph the mid 1840s. Hemp, tar and jute were used around conductors. The advent of plastics and other synthetic materials brought about a variety of new cable designs. The components of a typical underwater electrical cable are:

- **Conductors**—the metallic component of cables through which electrical power or electrical signals are transmitted.

- **Insulation**—material applied around a conductor to provide electrical isolation.
- **Strength member—**bears tensile load, ensuring that it does not transfer to the conductors. Internal strength members are made from various polymers. External strength members, referred to as armoring, are usually made from steel wire.
- **Jacket—**outer polymer layer protecting the parts inside.

There are two basic types of fiber used: SingleMode (SM) and MultiMode (MM). SingleMode fiber is generally used where the distances to be covered are greater. There are generally five elements that make up the construction of a fiber-optic strand: the optic core, optic cladding, a buffer material, a strength material and the outer jacket. Underwater optic cables have a heavy outer jacket and/or armoring. Many designs protect the fibers by running through a flexible steel tube that is filled with a gel compound that cushions the fiber and impedes or blocks water penetration.

The optic core is the light-carrying element at the center of the optical fiber. It is commonly made from a combination of silica and germania. Surrounding the core is the optic cladding made of pure silica . It is this combination that makes the principle of total internal reflection possible. The difference in materials used in the making of the core and the cladding creates an extremely reflective surface at the point in which they interface. Light pulses entering the fiber core reflect off the core/cladding interface and thus remain within the core as they move down the line.

Cameras are used underwater for all sorts of inspections and documentation. Most types of cameras that can be found topside can be housed and used underwater. They are used by divers, on subsea vehicles and as stand-alone devices. Film cameras are rarely used any more because of the limited amount of images that can be stored before the camera must be brought to the surface so the film can be changed. Thus, for still images, digital cameras are usually preferred. Video camera types include color, black and white, and low light. For low light, imaged-intensified CCD cameras are used, as are tube-type cameras known as SITs (silicone intensified targets). Dome port optics are used in some cameras to correct the distortions caused by looking through a flat window underwater.

Features to consider when selecting an underwater camera include, fixed vs. zoom lens, field of view, depth capability, resolution and sensitivity.

Chemical Sensors are commonly used to detect hydrocarbons, nutrients (nitrate, nitrite, ammonia, urea, phosphate, silicate, and iron) as well as pH and dissolved oxygen in and on water. A variety of sensing techniques are employed including optical methods.

Compasses: Magnetic compasses consist of a small, lightweight magnet balanced on a nearly frictionless pivot point. Magnetic compasses have several problems when used on moving platforms like ships. They must be level, they correct rather slowly when the platform turns, they are influenced by ferrous metals and they indicates magnetic north rather than true north . For these reasons, most ships and airplanes use gyroscopic compasses.

A **spinning mass gyrocompass** has a spinning body with three axes of angular freedom constituting a gyroscope. They can take up to several hours to spin up and stabilize.

A **flux gate compass** consists of a field sensor, usually an inductor, mounted to a gimbaled platform that is intended to sense the horizontal component of the earth's magnetic field.

Fiber Optic Gyrocompasses (FOGs) and **Ring Laser Gyros (RLGs)** work by shining light through two coils of optical fiber. The input light beam is split into two beams that travel the same path but in opposite directions: one clockwise and the other counter-clockwise. The beams are recombined and sent to the output detector. In the absence of rotation, the path lengths will be the same and the output will be the total constructive interferences of the two beams. If the apparatus rotates, there will be a difference in the path lengths traveled by the two beams, resulting in a net phase difference and destructive interference. The net signal will vary in amplitude, depending on the phase shift; therefore, the resulting amplitude is a measurement of the phase shift, and consequently, the rotation rate. Because there are no moving parts, there is no friction, and hence no drift.

Flux gates are small, light weight and relatively inexpensive. Spinning mass gyros can be more accurate but are large and heavy by comparison. FOGS are intermediate in size and offer the highest accuracy, along with the highest price tag. For more information, see http://www.autonav.com/html/anav4009.htm

Connectors are used to join a cable to a device such as an underwater vehicle, instrument or battery; or to join two cables together. They can be used for electrical conductors or optical fibers, or both. There are many types of underwater connectors, some can be mated when wet, others must be dry. Some of the common types are:

- **Cable Glands**—actually not a connector at all but a rubber grommet in a housing that seals around a cable. They are inexpensive and easy to install but are not reliable for long-term immersions or in dynamic situations where the cable will be subject to flexing.

- **Rubber Molded**—neoprene rubber connectors molded to cables or onto metal bulkhead posts use compression seals or o-rings seals molded in female sockets. There are several common styles. Some have a vent hole for purging water when wet mated. Advantages are inexpensive and deep depth ratings; however, rubber can degrade with long-term exposure to sunlight and certain chemicals. It is not available in high-contact counts.

- **Epoxy**—glass filled epoxy construction bulkhead connectors with rubber molded mating cable connector. Inexpensive but not good for applications where epoxy part is subject to shock or impact.

- **Metal Shell**—some utilize rubber molded connectors bonded to an outer metal shell for increased robustness. Other types utilize an insert in shell. Wide variety of configurations available, including high contact counts.

- **Glass to Metal Seal**—hermetic sealing of pins to glass puck makes for a very reliable pressure proof seal but at higher cost.

- **Pressure-Balanced Oil-Filled (PBOF)** connectors, typically can be wet mated at any depth, because they are pressure equalized.

Connectors that mount to a pressure housing are known as **bulkhead connectors**. They typically have one or more o-rings for sealing. BCR-type bulkhead connectors thread into a tapped hole or are retained in a thru hole by a nut and washer. FCR types have a flange that attaches with mounting screws or bolts. In-line connectors are installed on the end of the cable. They are often known as CCRs and CCPs, where R stands for receptacle (female sockets) and P stands for plug (male pins). Dummy connectors are used to keep contacts clean when connectors are unmated.

Fiber optic connectors are available in both dry mate and wet mate styles, as are hybrid connectors, which have electrical and optical contacts.

Corrosion results when two dissimilar metals are in contact with each other and are immersed in a conductive solution (i.e., seawater). Corrosion can cause structural failure of materials or cause sealing surfaces to leak; thus, it is a very important engineering concern. The rate of corrosion is determined by several factors, including:

- Valence of the metals
- Salinity of the water
- Temperature
- Oxygen level

Several techniques are used to minimize or eliminate corrosion. These include:

- Replace one of the metals with a plastic material. For machined parts, Delrin (acetyl) is a good choice. For pipes, PVC is available in many sizes.

- Isolate the metals from each other. Plastic washers are often used with metallic hardware.

- Use sacrificial anodes. Zinc anodes are available in an assortment of sizes and shapes in most marine hardware stores.

- Passify the metal. Various processes are available for different metals that help protect it from corrosion. For aluminum it's anodize, for titanium it's Tiodize, for stainless steel it's passification.

- Paint—coating the entire surface of an object eliminates contact with seawater and hence prevents corrosion. However, any scratch or pin hole in the paint will put the metal in contact with water, so it is usually advisable to have the metal passified before painting.

- Most corrosion occurs as an oxidation of a metal, and thus freely available dissolved oxygen is required. Crevice corrosion is an anaerobic process that occurs in low-oxygen-level waters or in cracks and crevices where there is little exchange of water.

CTDs (conductivity temperature depth) measure how the electrical conductivity and temperature of the water column changes relative to depth. Conductivity and temperature information is valuable, because the speed of sound in seawater can be derived from these variables. This is used to correct devices that use sound underwater. CTD data can also be used to calculate water density. Oceanographers use CTDs to study the physical properties of water, which can help them understand currents, mixing, biological processes and other phenomena. For this reason they are one of the most common instruments used by marine scientists.

A CTD may be deployed by itself, attached to a submersible, or as part of a larger metal water sampling array known as a rosette, or carousel. Multiple water sampling bottles are often attached to the rosette to collect water at different depths of the cast.

Current Meters are devices that measure water velocity and direction. Measuring currents is a fundamental practice of physical oceanographers. By determining how ocean waters move, scientists can determine how organisms, nutrients and other biological and chemical constituents are transported throughout the ocean. There are several common types of current meters:

- **Mechanical current meters** are like underwater pin wheels. The rate at which the wheel spins is used to calculate the current flow. A drawback to mechanical meters is that they do not work well in weak currents.

- **Electromechanical current meters** are based on the principle that a voltage is produced when a conductor (the water) moves through a magnetic field. The magnetic field is produced by a coil and the voltage is picked up by electrodes on the surface of the instrument. By having two orthogonal pairs of electrodes, two axis flow velocities are obtained from a single probe. The sensor has no moving parts and the system is capable of measuring fast changing flows over a wide dynamic range.

- **Acoustic current meters**, sometimes called sing arounds, measure how long it takes for sound pulses to travel around a prescribed area. By comparing the phase shift of the signals, very precise measurements can be taken.

- **Acoustic Doppler Current Meters** measure the Doppler shift of sound bouncing off reflectors suspended in the water. They can be used to take a point measurement at a specific distance from the instrument, or to take a series of measurements known as a profile. Doppler current meters can be mounted in the hulls of ships, installed on buoys or mid-water mooring lines, or mounted on the seafloor looking up towards the surface.

- **High-Frequency Radar** is used to measure surface currents. HF Radar can map areas of tens to hundreds of square kilometers from shore-based antennae.

D

Data Loggers are used to acquire and store information from sensors. The entire spectrum of data storage devices used topside have and can be housed in pressure vessels. These include hard disk drives, flash memory, video tape, etc. When brought to the surface, the logged data can be transferred to a computer or the memory can be removed for archiving. Factors to consider when selecting a data logger include how many sensors will be measured, for how long at what sampling rate, how much power is available, how much space is available, etc.

Environmental sensors and transducers often measure things such as temperature, pressure, sound or light, as voltages or current levels. These analog signals must be converted to digital ones for use by computers. The conversion, known as A/D conversion, is done by electronic sampling of the analog signals.

This function is often performed by a data acquisition board in a data logger. The board may have several input channels to take in data from more then one sensor.

Data Multiplexing is the practice of sending multiple signals or streams of information on a carrier at the same time in the form of a single, complex signal and then recovering the separate signals at the receiving end.

In analog transmission, signals are commonly multiplexed using frequency-division multiplexing (FDM) in which the carrier bandwidth is divided into sub channels of different frequency widths, each carrying a signal at the same time in parallel.

In digital transmission, signals are several common multiplexing techniques. These include time-division multiplexing (TDM) in which the multiple signals are carried over the same channel in alternating time slots; frequency-shift keying (FSK) in which the frequency of the transmitted signal is varied and phase-shift keying (PSK) in which the phase of a transmitted signal is varied to convey information.

Electrical signals can also be converted to optical signals. A fiber optic transmitter consists of an interface circuit, a source drive circuit and an optical source. The interface circuit accepts the incoming electrical signal and processes it to make it compatible with the source drive circuit. The source drive circuit intensity modulates the optical source by varying the current through it. The optical signal is coupled into an optical fiber through the transmitter output interface. Multiple optical signals can be carried together as separate wavelengths of light in a multiplexed signal using dense wavelength division multiplexing (DWDM). Very high data rates can be achieved with DWDM.

Data Telemetry is the process of measuring data at the source and transmitting it automatically. There are many ways to telemeter data back to shore such as by cell phone, radio transmitter, microwave and satellite. There are several satellite services available (ARGOS, Inmarsat, Irridium, GOES, Orbcomm) that can receive data from most anywhere on the planet. Data can be transmitted from a variety of platforms, including moored buoys, drifting floats, and even marine animals.

Acoustic modems are used to telemeter data through the water column from a source to a receiver. They rely on coded pulses of sound. Acoustic modems are often used with seafloor sensors to telemeter data to a surface buoy or surface ship. From there the data can be relayed to shore using one of the previously mentioned methods of telemetry.

Dynamic Positioning is a method to keep a ship, platform or subsea vehicle stationary over a fixed spot on the seafloor. Such station keeping is desirable for many tasks including coring, drilling, lifting, sampling and diver support. DP systems use thrusters in the bow and stern to maintain position. A computer is used to direct power to each thruster when necessary based upon input from GPS, compass, motion sensors, wind sensors, current meters, acoustic navigation equipment and other systems. More information on this subject may be found at http://www.imca-int.com/divisions/marine/reference/intro.html

E

Echo Sounders are used to measure water depth by sending an acoustic pulse to the seafloor and measuring how long it takes to be reflected back to the surface. Single beam echo sounders have a single transducer to transmit and receive sound. Multi-beam echo sounders have many transmit/receive hydrophones and thus cover a much larger area on the seafloor. This greater coverage makes it much quicker to survey a given area. Interferometry-based swath bathymetry survey systems offer wide-area, high-data-density coverage and are particularly suited to surveys in shallow coastal regions

The term "interferometry" is generally used to describe swath-sounding sonar techniques that use the phase content of the sonar signal to measure the angle of a wave front returned from a sonar target. This technique may be contrasted with multibeam (and single beam) systems, which look for an amplitude peak on each beam in order to detect the sea-bed, or other targets, across the swath.

F

Flotation: In marine technology, flotation can be divided into materials intended for use on the surface and those for use underwater. For surface flotation, buoys are fabricated out of steel or other metals, molded plastic or plastic foams. Ionomer foam is a popular material because of its reduced weight and high durability.

Underwater, subsea flotation is often needed to achieve neutral buoyancy for subsea vehicles and platforms or to provide a positively buoyant upward force. Because of the compressive force of water pressure, subsea flotation is a more challenging problem then it is on the surface.

For shallower depths, foamed materials may be used. Foams compress as they descend into the depths and thus the amount of buoyancy they provide is not constant. Ultimately at some depth they will become so compressed that they will lose all of their buoyancy. For deeper depths, non-compressible materials that are less dense then water should be used.

The bathycaphe *Trieste* solved this problem by using a large volume of aircraft fuel, which is less then water and compresses very little. In 1963, under the supervision of Dr. Andreas Rechnizter, this submersible carried Don Walsh and Jacque Piccard to the deepest point in the world—The Challenger Deep.

In more recent years, non-compressible foams made from a matrix of small glass spheres embedded in epoxy have been used. Known as syntactic foam, this material can be cast into shapes and sanded or machined. Syntactic is available in various densities with different depth ratings. Hollow ceramic spheres are also available for deepsea flotation.

Subsea buoys are made from a variety of materials, ranging from PVC plastic pipes with end caps to titanium spheres. Glass spheres are popular for deep depths, because they are relatively inexpensive. Plastic "hard hats" are often used to protect the glass.

G

Geophysical Instruments are used by scientists and those seeking hard minerals and hydrocarbon deposits to study those parts of the earth hidden from direct view. Instruments used underwater include magnetometers (which are described in this glossary under their own listing), gravimeters, and seismometers.

Seismic devices are another class of underwater geophysical equipment used to generate shock waves so reflected signals can be used to detect structures under the sea floor. Dynamite was originally used to generate shock waves. Today mechanical devices such as air guns, bubble pulsers, boomers and sparkers are utilized. The reflected signals are detected by hydrophones that can either be placed on the seafloor or towed behind a ship. Streamer cables are arrays of hydrophones that are wired together and contained in oil-filled plastic hose.

In recent years three dimensional (3D) and three dimensional times series (4D) seismic survey techniques have been developed. The newest technique in this field is Continuous Source Electro-magnetic Measurements (CSEM). CSEM involves towing a source of low frequency electromagnetic signals to an array of seafloor receivers. The received data is used to determine the resistivity structure of the subsurface. This is of interest, because there is a significant contrast between resistive hydrocarbons reservoirs and conductive saline water saturated layers.

GPS (Global Positioning System): Users of a global positioning system can calculate their location anywhere on the earth. Two "public" GPS systems are The NAVSTAR system, owned by the United States and managed by the Department of Defense, and the GLONASS system, owned by the Russian Federation. Global Positioning Systems are space-based radio positioning systems that provide 24-hour, three-dimensional position, velocity and time information to suitably equipped users anywhere on the surface of the Earth. The GPS signals do not penetrate through water, so subsea vehicles must surface to get a GPS fix. The system works by a constellation of satellites that transmit timing information, satellite location information and satellite health information. The user requires a special radio receiver - a *GPS receiver* - to receive the transmissions from the satellites. The GPS receiver contains a specialized computer that makes calculations based on the satellite signals. The user gets 24-hour, three-dimensional position, velocity and time information and does not have to transmit anything to the satellite.

Standard GPS has accuracy on the order of 10 meters. Differential GPS uses a correction signal from a regional source and has typical accuracies of 2-3 meters. Real-Time Kinematic (RTK) GPS is a technique that uses a local base station that is surveyed in and that transmits a local correction signal to a roving receiver. RTK can yield positional accuracies of up to 10 centimeters.

H

Hydrophones: Underwater hydrophones detect acoustic signals in the ocean just as microphones collect sound in the air. Most hydrophones are based on a special property (piezoelecticity) of certain ceramics that produce a small electrical current when subjected to pressure changes. When submerged in water, a ceramic hydrophone produces small-voltage signals over a wide range of frequencies as it is exposed to underwater sounds propagating from any direction. By amplifying and recording the electrical signals produced by a hydrophone, sound in the sea can be measured with great precision. Although a single hydrophone records sound arriving from any direction, several hydrophones can be simultaneously deployed in an array, and the resulting signals can then be manipulated to "listen" in any direction with even greater sensitivity than a single hydrophone element. Whether within an array or as a single element, the hydrophone is the basic sensor of underwater acoustics. Things to consider when selecting a hydrophone include receiving response, beam width, and depth rating.

I

Inertial Navigation Systems

When you spin a gyroscope, its axle wants to keep pointing in the same direction. If you mount the gyroscope in a set of gimbals so that it can continue pointing in the same direction, it will. This is the basis of the gyrocompass. If you mount two gyroscopes with their axles at right angles to one another on a platform, and place the platform inside a set of gimbals, the platform will remain completely rigid as the gimbals rotate in any way they please. This is this basis of inertial navigation systems (INS). In an INS, sensors on the gimbals' axles detect when the platform rotates. The INS uses those signals to understand the vehicle's rotations relative to the platform. If you add to the platform a set of three sensitive accelerometers, you can tell exactly where the vehicle is heading and how its motion is changing in all three directions. With this information, a ship's autopilot or an AUV's guidance system can keep the vehicle on its intended course.

L

Lighting is used underwater to provide illumination for divers, for submersible pilots and passengers, and for cameras. Three general classes of lights exist: incandescent, arc, and LEDs.

Incandescent lights work by heating a filament to the point where it radiates light. Quartz halogen lights are the most commonly used incandescent. The name derives from the quartz glass bulb used that is filled with a halogen gas which is used to redeposit evaporated filament materials back on the filament. Incandescent lights are inexpensive but bulbs are fragile and have relatively short life times.

Arc lights, or gas discharge lights, utilize electrodes to heat a mixture of gases until a luminous plasma is produced. Depending on the gas mixture, different qualities of light can be produced. Examples are HID, HMI, and Xenon. Since gas discharge lights have no filament to break, they are more robust then incandescents and usually have longer burn life. Additionally, they are much more efficient at converting electrical power into light, an important consideration if utilizing battery power. Power limiting electronics called ballasts are required. These can be housed with the light fixture or remoted to a separate electronics bottle. In addition to the drawback of having a ballast, some arc lights require several minutes to warm up to full power and need to cool down before re-starting.

LEDs are small, low-cost, solid-state devices. They have very long life times and have no filaments to break nor do they require a ballast. They are available in a variety of color outputs including white. Because of their small size, they can be easily incorporated directly into a camera housing.

M

Magnetometers are used to measure anomalies in the earth's magnetic field. These can be due to local geologic features or man-made objects in the area (i.e., ship wrecks). Underwater magnetometers are typically towed behind a ship.

Proton magnetometers operate on the principal that the protons in all atoms are spinning on an axis aligned with the magnetic field. Ordinarily, protons tend to line up with the earth's magnetic field. When subjected to an artificially-induced magnetic field, the protons will align themselves with the new field. When this new field is interrupted, the protons return to their original alignment with the earth's magnetic field. As they change their alignment, the spinning protons precess, or wobble, much as a spinning top does as it slows down. The frequency at which the protons precess is directly proportional to the strength of the earth’s magnetic field.

Overhauser magnetometers use electron-proton coupling to produce stronger precession signals than conventional proton precession magnetometers. Optically pumped magnetometers (Cesium, Potasium, and Rubidium) make even more precise measurements of magnetic fields by determining the frequency of radio waves required to change the transparency of a glass vapor cell containing gaseous metal that is exposed (or pumped) to polarized light of very specific wavelength.

Meterological Sensors (met sensors): Exchanges across the air-sea interface, including heat and fresh water, couple the ocean and atmosphere and are of major interest in studies of global climate. Met sensors on either research vessels or buoys include those used to measure sea surface temperature, air temperature, wind speed and direction, barometric pressure, solar and long-wave radiation, humidity and precipitation. From these measurements, accurate estimates of air-sea fluxes can be made.

Motion Sensors measure heave, pitch and roll – typically on surface vessels. Correcting for vessel motion is critical for multi-beam hydrographic surveys, for high-accuracy acoustic positioning systems and for other applications. Most are based on three orthogonal accelerometers of which there are several types having different accuracies at different costs. Older systems, some of which are still in use, are based on pendulums.

For less dynamic or static applications, tilt sensors can be used to measure the angle of inclination. These are commonly used on subsea vehicles or instruments resting on the seafloor. Electrolytic tilt sensors use a sealed glass vial partially filled with a conductive fluid. Several metal electrodes go through the glass into the fluid filled chamber. As the sensor tilts, the surface of the fluid remains level due to gravity. The fluid is electrically conductive, and the conductivity between the two electrodes is proportional to the length of electrode immersed in the fluid. Electrically, the sensor is similar to a potentiometer, with resistance changing in proportion to tilt angle. Single and dual axis sensors are available.

O

Optical Oceanographic Sensors measure the optical properties of water such as absorption, attenuation, scattering, fluorescence and volume scattering function. The instruments used to measure these parameters include:

Transmissometers are devices for measuring transmission or beam attenuation. They work by shining a narrow, collimated beam of light through the water. A receiver with a narrow field of view measures how much light arrives at the other end of a set distance. Light that is lost to absorption or is scattered will not be detected.

Nephelometers, or turbidity sensors, measure light scattering to determine the overall concentration of particles suspended in water.

Fluorometers provide an indication of the concentration of a given material by measuring the amount of fluorescence attributed to the material. For example, a fluorometer provides an excitation beam at a wavelength that is known to cause fluorescent emission from chlorophyll and measures light at a wavelength that matches the chlorophyll emission. As a result, the amount of chlorophyll-containing biomass can be estimated.

Spectrofluorometers are fluorometers that use multiple excitation wavelengths and multiple emission wavelengths to isolate and determine relative concentrations of different materials in the water.

Spectrophotomers measure the scattering of light. The volume scattering function (VSF) describes the directional dependence of this scattering. The VSF is an "inherent optical property" of water that is used by optical oceanographers to predict light propagation, image degradation, remote-sensed ocean color, biological environment, etc. in water.

P

Pan & Tilts are positioning devices used to remotely move cameras, lights, sonars and other devices. Pan refers to movement along the horizontal axis and tilt refers to movement in the vertical axis. A scanner is a one-axis positioner.

Physical Oceanographic Sensors are used to measure the basic physical properties of seawater. The most common are conductivity, temperature, and pressure (depth). Together these three sensors form a CTD, a common oceanographic instrument (described under its own listing in this glossary).

Conductivity is the measurement of the water's ability to conduct electric current. It is often used as a proxy for measuring salinity. The basic unit of conductance is Siemens (represented by an S), formally called the mho (omh spelled backwards). The principle by which instruments measure conductivity is simple. After an electrode consisting of two conductive plates is placed in the water, a sinewave voltage is applied across the plates and the current is measured. Electrodes are prone to corrosion, and the pumps that supply them with water can foul.

Electrodeless conductivity sensors use inductive coils. The inductive conductivity sensor consists of two high-grade toroids (coils) that are incorporated concentrically and adjacent to one another in a polymer or ceramic body. These coils form a current transformer. The sensor is designed so part of the liquid media forms a closed conductive current path passing through the toroids. The primary coil is activated with a sinusoidal alternating voltage, which induces an alternating voltage in the liquid loop (sample medium). In liquids that conduct electricity, this causes a current flow that is proportional to the conductivity of the sample medium. The liquid loop is also acting as the primary winding of the secondary coil, which functions as a current transformer. This current is rectified to the correct phase and amplified.

Temperature is typically measured by one of two types of devices:

Resistance temperature detectors (RTDs) are made of coils or films of metals (usually platinum). When heated, the resistance of the metal increases; when cooled, the resistance decreases. Passing current through an RTD generates a voltage across the RTD. By measuring this voltage, you determine its resistance, and thus its temperature. RTDs are popular because of their excellent stability, and because they exhibit the most linear signal with respect to temperature of any electronic temperature sensor. They are generally more expensive than alternatives, however, because of the careful construction and use of platinum.

RTDs are also characterized by a slow response time and low sensitivity.

Thermistors (thermally sensitive resistors) are similar to RTDs in that they are electrical resistors whose resistance changes with temperature. Thermistors are manufactured from metal oxide semiconductor material which is encapsulated in a glass or epoxy bead. Thermistors have a very high sensitivity, making them extremely responsive to changes in temperature. Thermistors are generally less expensive and less accurate then RTDs.

There are many ways to sense **pressure** (depth). Most pressure sensors require the transduction of pressure information into a physical displacement. Measurement of pressure requires techniques for producing the displacement and means for converting such displacement into a proportional electrical signal.

One common element used to convert pressure information into a physical displacement is the diaphragm. A diaphragm is like a spring, and therefore extends or contracts until a force is developed that balances the pressure difference force. The bellows is another device much like the diaphragm that converts a pressure differential into a physical displacement, except that here the displacement is much more a straight-line expansion. Other pressure sensor transducers consist of a ceramic disk that changes its capacitance linearly with applied pressure. This variation is measured by an electronic circuit and is converted to a voltage output, to give an accurate pressure measurement reading. Integrated circuit manufacturers have developed composite pressure sensors that are particularly easy to use. These devices commonly employ a semiconductor diaphragm onto which a semiconductor strain gauge and temperature-compensation sensor have been grown. Appropriate signal conditioning is included in integrated circuit form, providing a DC voltage or current linearly proportional to pressure over a specified range.

The most accurate measurements of pressure use a transducer made of a single quartz crystal whose frequency of oscillation varies with pressure-induced stress. Quartz crystals were chosen for the sensing elements because of their remarkable repeatability, low hysteresis and excellent stability. Accuracies of ±0.01% of full scale are readily achieved. When operating in deep water (i.e., >10,000 feet), a small difference in accuracy can equate to a large difference in depth measured.

Pressure Housings

Pressure housings are used to enclose electronics underwater. There are two primary types of housings.

Pressure compensated housings are fluid filled and are maintained at ambient pressure. A flexible diaphragm is typically used to transmit the external pressure to inside the housing. Benign substances such as mineral oil or silicone oil are used for the compensating fluid which must completely fill the inside of the housing leaving no air pockets. Components that are air or gas filled cannot be used, because they will implode under pressure.

One-atmosphere housings maintain constant pressure inside. Typically they are air filled, but sometimes dry nitrogen or other gases are used to prevent condensation. Cylindrical- and spherical-shaped housing designs are strongest. Rectangular and other shapes are usually only used in shallow water applications. Common materials selected for immersion in seawater are anodized aluminum, stainless steel, titanium and plastic.

Cylinders are the most common housing geometry. Flat or hemispherical end caps are typically retained with bolts or are threaded into the main tube. Glass spheres are also sometimes used for pressure housings. The clarity of the glass can be taken advantage of by optical sensors and controllers.

Things to consider when designing or selecting an underwater pressure housing include depth rating, safety margin and material selection.

R

Releases: A common task is to recover an object that is weighted down or anchored to the seafloor. To do this without divers or an ROV, a **release** is utilized. There are several types of releases.

Galvanic releases rely on seawater to corrode a wire or link. Generally these are inexpensive but the rate of corrosion can differ from place to place and thus the time to release is not controlled with great precision.

Burn wire releases utilize a timing device to activate an electrical current that will burn out a wire, which in turn causes the payload to be released.

Timed releases use some sort of mechanical device that is activated by a timer.

The drawback to all these methods is that the release time must be set before the device is deployed. Thus, there is no way to change the release time if inclement weather or other issues change one's schedule. **Acoustic releases** solve this problem, because they are activated when they receive an acoustic tone of a specific frequency. Typically this is done by someone in a boat who is in the vicinity of the object to be released. Acoustic releases are available with different frequencies that have different ranges. Other considerations in selecting a release are battery life, depth rating and strength rating. More sophisticated acoustic releases use a coded pulse to prevent being accidentally activated if a passing ship or some other source in the area happens to emit noise at the release frequency.

Remote Sensing is ocean data collected by sensors on satellites or aircraft. The term implies that the sensor is placed at some considerable distance from the sensed target, in contrast to close-in measurements made by "in situ" sensing. Commonly measured parameters are ocean color, sea surface temperature and sea surface altitude.

Ropes and Tension Members are used to carry loads on moorings, towed sleds and devices lowered over the sides of ships. Fiber ropes, wire ropes and chains are examples of flexible tension members. Synthetic fiber ropes are made from Nylon, Dacron, Polypropylene, Kevlar, Vectran and Spectra. Considerations in selecting a material are strength, weight/buoyancy, and stretch. Synthetic fiber ropes can be terminated by eye splicing or by socketing with epoxy.

Wire ropes are typically made from high-strength carbon steel but stainless steel and other alloys are sometimes used. They are much more cut-and-abrasion resistant then fiber ropes. They are terminated with eyes, swaged sockets, and zinc- or resin-poured sockets.

Chains made of steel can provide even higher levels of strength and cut/abrasion resistance. They are typically terminated with shackles but other fittings such as links, rings, and swivels are also used.

ROVs or Remotely Operated Vehicles are underwater robots used for a wide variety of tasks, ranging from simple inspection to maintenance and repair work. These tasks are performed on offshore oil rigs, ship hulls, docks, mooring buoys, dams, bridges and power plants, and in water tanks. ROVs are lowered on a cable either alone or in a protective cage and then operated on a slack tether that decouples it from the ship's surface motion. Video cameras serve as "eyes" for the operator who controls the vehicle via the cable. An ROV can explore, take photographs, collect samples, or handle instruments, operating around the clock for many consecutive days. Job-specific tool skids are sometimes mounted under larger vehicles.

A good write up on ROVs and their history may be found at the MTS ROV committee Web site http://www.rov.org/info.cfm.

S

Scour is the destructive effect that flowing water has on a submerged object. When a man-made object such as a bridge pier, pipeline, cable, etc. is submerged in flowing water, the local effect is to increase the current velocity around the object. This increased velocity has the tendency to remove or scour away the bottom material that supports the structure.

Seals: The type of seals discussed here are not marine mammals or navy commandos. Seals are a means for keeping water out of pressure housings. Types of seals used in the marine environment include gaskets, shaft seals, lip seals, stuffing tubes and gland seals. The o-ring is the most commonly-used type of seal underwater. It is a solid piece of elastomeric material shaped like a doughnut or torus. When pressed between mating surfaces, an o-ring blocks the passage of liquids or gases. The o-ring is the most widely used seal due to its simplicity, low cost, ease of installation, and small space requirements without supporting structures. An O-ring can be considered an incompressible viscous fluid with very high surface tension. This "fluid" is forced by mechanical or hydraulic pressure to flow into the sealing cavity, blocking the flow of the less-viscous fluid being sealed. Properly installed, the O-ring is squeezed about 10% to 15% of its original cross-sectional diameter. The compression absorbs the tolerance stack up between mating surfaces (or between shaft and gland in dynamic applications) and forces the elastomer into microscopic surface grooves on mating parts.

Successful use of o-rings depends upon proper groove dimensions and selection of the right elastomeric compound. Compounds are chosen for their resistance to chemicals and temperatures. Common materials utilized include Nitrile, neoprene, flurocarbon (Viton), silicone, fluorosilicone, and urethane.

Today's dynamic o-ring in a short rectangular groove was the result of experimental work in the early 1930s by Niels Christensen (see http://www.uh.edu/engines/epi555.htm). In the early 1940s, the o-ring became the standard seal for U.S. Air Force hydraulic systems. This established the basic sizes and design information. Today, billions of o-rings are sealing every conceivable apparatus all over the world, in the air, on land and sea, and in outer space.

Sediment Traps are used to collect samples of particles sinking through the water column. Scientists can learn the rate of sedimentation and about the organisms that populate the water column using sediment traps.

Slip Rings are electromechanical devices that allow the transmission of power and electrical signals from a stationary to a rotating structure. Also called a rotary electrical joint, collector or electric swivel, a slip ring can be used in any electromechanical system that requires un-restrained, intermittent or continuous rotation while transmitting power and/or data. They are commonly used on cable winches. For fiber optic conductors the Fiber Optic Rotary Joints (FORJs) are used in place of slip rings.

Sonar (**SO**und **NA**vigation and **R**anging) is used for many purposes. Passive sonars detect noise from marine objects, such as submarines, ships and marine animals. Active sonars emit a pulse of sound or "ping," into the water and then listen for an echo when the signal is reflected off an object. To measure the distance to an object, one measures the time from emission of a pulse to reception. Some common sonar devices are:

Side Scan Sonar—as the name implies, is a sonar that looks out sideways. It is used to map seafloor topography or to locate objects on the bottom or in the water column. It consists of a tow fish with a transducer running along each side. Acoustic pulses are transmitted orthogonal to the axis of the tow fish. The receiver measures the time it takes for the pulses to return and their strength. These are combined together to create a "shadow picture" that depicts the shape and texture of the seafloor and any objects laying on it. A good review of side scan sonars can be found at http://inventors.about.com/gi/dynamic/offsite.htm?site=http://www.instituteformarineacoustics.org/SonarPrimer/SideScanSonar.htm

Scanning Sonars—also known as forward-looking sonars and sector scanning sonars, are used for navigation on subsea vehicles. The transducer sweeps back and forth to paint a picture of what is in front of the vehicle.

Sonar altimeters are underwater echo sounders. They measure height off the seafloor from a subsea vehicle. Altimeters are also used to study sediment transport and to monitor scouring around bridge pilings.

Sub-Bottom Profilers use low-frequency sonar (2 to12kHz) to penetrate the seafloor. Sound pulses are reflected from the boundaries between sediment layers. This information can be used for geological studies and to find buried objects such as shipwrecks, mines and lost equipment.

In side scan sonar surveying, it is desirable to cover the seabed quicker and at higher resolutions. This causes great difficulty for conventional side scan technology. There are only two choices—using higher frequencies (to achieve narrower beams and thus higher resolutions) or using longer apertures to achieve the same effect. The downside to this approach is either shorter operational ranges with higher frequencies (compromising coverage rates) or problems associated with handling large tow fish. Similarly, as the imagery is tied to the sonar beam width, the resolution of conventional side scan degrades with range. Two techniques have been developed to get around these obstacles. Multi-beam side scan sonars use several transducers along each side of the tow fish. With beam steering and focusing techniques, several simultaneous adjacent parallel beams are generated per side. This allows for 100 % coverage at very high tow speeds with extraordinary resolution and image clarity. Another method, Synthetic

Aperture Sonar (SAS) synthesises a long aperture image by adding successive sonar returns, which are processed to compensate for the movement between returns and other factors. The results are much improved resolutions.

Submersibles: Manned submersibles are non-combatant craft capable of independent operation on and under the water's surface. Manned submersibles have their own propulsion power and a means for direct viewing for the occupants who are in a dry one-atmosphere cabin. Manned submersibles have a long history going back hundreds of years and now employ many of the technologies described in this glossary. Today they are primarily used forscientific research, exploration and tourism Major subsystems include the pressure hull, viewing ports, life support systems, exostructure, ballast/trim, propulsion, batteries and fairings/sail. Operational instrumentation typically includes lights, cameras, sonar, thru-water communications, and often a manipulator. Navigation equipment consists of a pressure sensor, tilt sensor, gyrocompass, doppler velocity log (DVL), underwater tracking system, altimeter and perhaps an inertial navigation system that would integrate the data from all the other sensors. In addition, mission-specific scientific equipment is often added.

The MTS Manned Submersibles Committee web site at http://www.mtsociety.org/pro_committees/mannedsubmersibles/default.html has a suggested reading list and links to many valuable resources. Also, the out-of-print classic "Manned Submersibles" by Frank Busby is available on-line at http://busby.psubs.org/html/page-001.html . A comprehensive compilation of American subs by Will Forman is *The History of American Deep Submersible Operations*.

Surface-Supplied Air Diving: Divers tethered to a surface-supplied-air-diving system can achieve dives up to 190 feet of seawater (FSW) in air diving and 300 FSW in mixed gas diving. Air is supplied via an air compressor or high-pressure air flasks. A surface-supplied-air diving system can permit a diver to stay down for a longer period of time than a SCUBA system would allow.

T

Tide Gauges are used to measure changes in sea level. This is important to know for many reasons, including the correction echo sounder data used in making hydrographic charts.

The first known tide measuring devices were used by the Egyptians 5,000 years ago, making tide gauges the first known marine technology. Wooden or reed sticks and later marble columns planted in the river bottom were sufficiently long enough to extend above the waterline where the fluctuating level of the Nile River could be measured against markings. The hydrological information collected is one the longest scientific time-series data sets ever collected. Today, tide staffs are still widely used.

Mechanical tide recording devices have been used for more then a century. These devices typically consist of a wire hung over a pulley wheel. At one end, there is a metal float and at the other end a counter weight. As the tide fluctuates, the wire turns the pulley that is geared to a pen that runs over a paper chart held in tension over a platen. The paper is moved from a supply spool to a take-up spool by a clock-driven mechanism. The recorder is placed in a shelter or in a security box on top of a stilling well. A stilling well consists of a pipe attached vertically to a pier or other structure. It has a sealed bottom with an inlet hole of about 1/50 of the diameter of the well. This "stills" wave action, allowing an accurate measurement to be taken.

Modern electronic tide gauges use pressure sensors and data loggers. For information on the different type of pressure sensors used, see the section on this subject in this glossary.

Long-term tide gauge records can be used to determine changes in mean sea level. However, with tide gauges alone, it is impossible to distinguish between any "true" sea level variations and vertical land movements at the tide gauge site. GPS monitoring can be used to decouple vertical land movements from changes in relative sea level, so that tide gauges can provide estimates of changes in "absolute sea level."

Towed Vehicles: Many types of underwater towed vehicles have been developed for oceanographic real-time surveys. They offer the capability of moving in wide area with stable attitude at speeds much faster then ROVs and AUVs. Towed vehicles are used for such tasks as monitoring the oceanographic environment, surveying the seabed and inspecting pipelines on the seabed. Some types can be steered and others can be winched in and out.

U

Underwater Acoustic Imaging is used to produce high-quality images in water where visibility is too poor to use optical methods. In underwater acoustic imaging, electrical energy (electricity) is sent to a crystal, which causes the crystal to vibrate. The sound of the vibration (mechanical energy) travels out into the water column until it hits an object and is reflected back to the crystal. After the energy returns to the crystal, a computer converts it to an image.

Underwater Positioning & Tracking Systems are used to identify the location of an object or vehicle underwater. Since radios do not transmit through water, GPS cannot be used unless an antenna is cabled to the surface. Several acoustic methods have been developed for the purpose of underwater navigation. These include:

Long Base Line (LBL) uses several transponders on the seafloor. The distance between each transponder is measured. A transducer on the vessel, ROV, AUV or tow fish, interrogates each transponder and the ranges to each are measured. From this information, the position of the subsea platform can be determined by triangulation.

Short Base Line (SBL) is similar to LBL except the array of transponders is spread along the underside of the vessel.

Ultra Short Base Line (USBL) uses only one transponder and one multi-element hydrophone on the surface. The measurement of the angle to the transducer is made across the face of the hydrophone (the ultra short base line). In addition to the angle, the range is determined by measuring the amount of time it takes for a pulse to travel from the hydrophone and to be returned by the transponder. So range and bearing to the target are determined.

LBL is the most accurate of the methods described and is more common in deeper water, because the accuracy of SBL and USBL degrade with range. The disadvantage of LBL is the time and expense required to deploy and survey in the seafloor transponders. USBL is the least expensive method and the easiest to use. SBL falls somewhere in between the two.

W

Water sampling devices range from a bucket dropped over the side of a ship to large water bottles sent thousands of meters toward the seafloor on a wire. Probably the most commonly used water sampler is known as a CTD/rosette: it is a framework designed to carry 12 to 36 sampling bottles (typically ranging from 1.2- to 30-liter capacity) and a conductivity/ temperature/depth sensor that sends information to the laboratory so that the water bottles can be closed selectively as the instrument ascends. Alternatively a single water bottle can be equipped with a spring-loaded release and lowered on a line. When the desired depth is reached, a messenger weight is slid down the line and trips the release allowing, the end caps to snap close on the bottle. The largest water bottles, called Gerard barrels, collect 250 liters. Particles in the water samples may be quantified with a transmissometer sent down the wire or attached to a CTD/rosette. Aboard the ship, a flow cytometer may be used to analyze particles in the form of single-celled organisms for optical properties indicative of their physiology and structure.

Wave Gauges are made in several ways. Electric wave staffs measure wave height by changes in resistance. More common is using a pressure sensor with a current meter in a technique called PUV. Wave height is measured as changes in pressure. With an array of three or more sensors, wave direction can be determined.

Another method uses Doppler current meters to form a virtual wave array. This is done by bottom mounting an upward-looking, multiple-beamed Doppler so it can measure the range to the surface as well as the orbital wave velocities in a series of bins extending away from the instrument. These manifold measurements allow one to differentiate among multiple sources of waves—something that a single point sensor cannot do.

Wave heights can also be measured from vessels or piers using microwave altimeters. An accelerometer is used to remove ship motion from the wave amplitude measurement.

Buoys can be used to measure waves if they have an elastic mooring line that allows them to travel with the waves. By using three orthogonal accelerometers, the buoy motion can be used to measure wave height and direction. Another technique uses the Doppler shift of GPS signals to determine buoy movement. By analyzing the signal from several GPS satellites, wave height and direction can be determined.

A good primer on wave theory and measurement may be found at http://cdip.ucsd.edu/?nav=documents&sub=index&xitem=waves#gauging

For info on wave measurement instruments used at the Scripps Institution of Oceanography, see http://cdip.ucsd.edu/?nav=documents&sub=index&xitem=gauge

Winches are devices used to pay out, pull in, and store cable. They consist of a movable drum around which a cable is wound so that rotation of the drum produces a drawing force at the end of the cable. Winches can be powered by diesel, hydraulic or electrical power. A reel is a hand-powered winch. Winches are selected by cable capacity, line speed, strength (line pull) and material (typically steel or aluminum). Options include remote controls, level winds, variable speed drives, brakes, clutches (for free spooling), cable counters and heave compensation. There are many special types of winches for specific applications, including those for ROV umbilicals, diver hoses, and CTDs. Slip rings are used with winches to transfer electrical power. Other related devices include:

- **Traction Winches** are used for tensioning the cable so there will be no spooling problems due to slack line.
- **Launch and Recovery Systems** (LARS) are used for ROVs, AUVs, and submersibles.
- **Linear cable engines** (LCE) can pull any size cable, chain or pipe and can pull the material to be deployed from a storage tank or even from an organized "pile" on the deck of a ship. They have the ability to grip nearly any surface and pass or "climb over" joints or other objects
- **Tether Management Systems** (TMS) are essentially under winches used with ROVs, particularly in deeper water. A heavy duty lifting cable connects the TMS to the surface allowing a lighter weight umbilical to be used with the ROV.

REFERENCES

National Science Foundation Ocean Sciences program information:
http://www.geo.nsf.gov/oce/whatis/tools.htm

NOAA Ocean Explorer observation tools site has pages on ADCPs, ocean acoustics, GIS, satellites, sonars, CTDs, drifting buoys and more:
http://oceanexplorer.noaa.gov/technology/tools/tools.html

National Academy of Science ocean acoustics tutorial
http://www.beyonddiscovery.org/content/view.article.asp?a=219

NOAA ocean acoustics tutorial
http://pmel.noaa.gov/vents/acoustics/tutorial/tutorial.html

Underwater acoustics and sonar primer:
http://inventors.about.com/gi/dynamic/offsite.htm?site=http://www.instituteformarineacoustics.org/SonarPrimer/SideScanSonar.htm

Dr. Bob Stewart of Texas A&M has several excellent web resources. One covers a wide range of ocean topics: http://oceanworld.tamu.edu/index.html

Another has an on-line introduction to physical oceanography textbook:
http://oceanworld.tamu.edu/resources/ocng_textbook/contents.html

And another has online general oceanographic textbook for high school and college students.
http://oceanworld.tamu.edu/home/oceanography_book.htm