San Diego's Technology

By Brock J. Rosenthal

Introduction

In the early days of oceanography scientists largely made their own equipment. While this tradition continues today, along the way specialized manufacturing companies sprang up to fill this niche. Many of these companies were started by scientists or engineers who had left ocean research labs. Over time new markets for these products were developed for offshore oil and gas, defense, environmental monitoring, hydrographic surveying and other applications. Today, there is a thriving worldwide trade for underwater products in what is often called the marine technology industry.

San Diego is one of the leading, if not the leading center of marine technology. It can trace its roots to Scripps Institution of Oceanography, dating back to 1903. Scripps has influenced local industry in many ways: from transferring technology, supplying people knowledgeable in ocean engineering and instrumentation, to purchasing products and services. Another large factor in the San Diego marine technology scene is the presence of several Navy facilities, especially the research lab in Pt Loma (see pages 32-59, this issue).

Many key marine technologies have been invented, developed, and/or evolved in San Diego. This article will highlight the role industry has had in this process.

Sampling Devices

The study of the oceans started as a descriptive science describing and cataloging biological and geological specimens. Many clever mechanical collecting devices were devised to remotely retrieve samples. Initially, by necessity, all were built by the scientists who used them.

One of the earliest companies in the U.S. to make sampling equipment for marine scientists was Kahl Scientific Company, sometimes known as Kahlsico. Started in New York City, by Joseph Kahl in 1935, Kahl Scientific began making metrological equipment; they soon catered to requests from customers for field equipment such as water and seafloor samplers.

In the aftermath of World War II, Kahl participated in Operation Paperclip – an Office of Strategic Services (OSS) program that recruited scientists from Nazi Germany. Kahl took on several experts in scientific glassblowing, who knew how to make reversing thermometers that, at the time, no one in the U.S. could make. These instruments locked in a temperature reading when flipped upside down and were used by oceanographers to record temperatures at various depths.

The Kahl family moved to El Cajon, in San Diego County, in 1948. Their product line of instruments steadily grew in number year by year, until eventually they had over 1500 devices. Most of their instruments were mechanical and many were designed in collaboration with scientists at various institutions, including Scripps. Their massive catalog was a testament to man's ingenuity. Joseph's son, Gerald Kahl, took over the reins in the late 1980s from Joseph, who passed away in 2003. Gerald semi-retired a few years ago and closed up the office, but kept some items available via the company's website. In 2011, Gerald died and Kahl Scientific came to a close.

Another early entry in the local scene was Ocean Instruments, started by "Moon" Hedricks in 1947 as a welding shop. Moon was a mechanic at Scripps and built gadgets for scientists there. Eventually he built up a line of marine biological and geological sampling equipment such as plankton nets and box corers.

Marine Industry

Brock Rosenthal is President of Ocean Innovations, a supplier of oceanographic instruments and underwater equipment. He has worked in the maritime technology field for nearly thirty years. Rosenthal has twice served as chairman of the San Diego section of the Marine Technology Society and as a vice president of its national board. For the past twelve years, he has been editor of the Southern California Marine Technology eNews.

His son John (aka "Half Moon") took over in 1977 and ran the company, until he retired a few years ago and sold the business to his chief machinist, Tim Marrs, who continues to operate the company today out of the original Quonset hut building. Ocean Instruments also makes a fish egg sampler under license from Scripps, which is used to study the distribution of fish eggs from a moving ship.

Sediment coring is important for bringing geological samples of the seafloor back to the lab for analysis. Vibracoring is a method for obtaining long, well-preserved cores in water-saturated sediments from wetlands, harbors and lakes, to the deep ocean. Equipment for vibrocoring was pioneered by André Rossfelder, an Algerian émigré who came to Scripps to study underwater geology. In the mid-1960s, he started his own company, Rossfelder Corporation. In addition to selling equipment, his company provided vibracoring services all over the world. Although Rossfelder passed away in 2011, his San Diego-based company is carrying on.

Underwater Acoustics

During World War II, the anti-submarine warfare program to counter German subs necessitated the rapid development of underwater acoustic research. A focal point for this was the University of California's Division of War Research, which had its headquarters next to the Navy Lab in Pt Loma. During the course of the war, UCDWR employed up to 575 people. When UCDWR closed after the war, Navy contracts for research in basic science were transferred to the newly formed Marine Physical Laboratory (MPL), which became part of Scripps Institution in 1948. One of the key researchers at MPL was Dr. Victor Anderson. Some of the pioneering developments he worked on included multi-element hydrophone arrays, multi-beam sonars, beam steering, and multiplexing power and data signals onto a single coax conductor.

In 1946, Anderson and two colleagues formed a company called InterOcean Systems, to work on Navy contracts for acoustic arrays. Other products that followed were devices that when commanded they could release anchors from the seafloor, a remotely operated subsea crawling vehicle, and a music analyzer! Later, InterOcean developed integrated monitoring systems for the nascent offshore petroleum industry that used some of the first acoustic and radio telemetry. In 1969, Mike Pearlman was hired as the business manager; he eventually bought the company. Today, InterOcean has a diverse product line of current meters, tide gauges, acoustic releases, winches, instrumented moored buoys, and oil spill detection systems.

Buoy Technology

Scripps has long been an innovator in buoy technologies (see "It Takes a Network to Build an Ocean Observing System," pages 18-31, this issue) from deep ocean moored buoys to ones that drift lockstep with near surface currents.

Drifting buoys are useful for studying ocean circulation as well as the dispersion of surface particles such as fish larvae and other plankton, and buoyant pollutants such as oil.

One popular design was developed by the late Peter Niiler, of Scripps, and subsequently licensed to one of his engineers, Andy Sybrandy, who founded the company Pacific Gyre in 1999 to build them on a commercial basis.

Another group at Scripps developed buoys (known as floats) that map subsurface currents by drifting at a specific depth and occasionally rising to the surface to report their position via satellite. Sensors have been added to some to measure other parameters such as salinity and temperature. An international program called Argos maintains a constellation of over 3000 floats across the world's oceans. Scripps has licensed the design of their Argo floats to several manufacturers, including MRV Systems in San Diego. MRV is headed by Jim Dufour, who recently left Scripps after a long career as an engineer working on the development of Argo floats, underwater gliders, and related systems.

Licensing of buoy designs has also come to San Diego from other directions. In 2005, a unit of SAIC in San Diego, licensed the design of the tsunami warning buoys developed by NOAA's PMEL lab in Seattle. SAIC commercialized the design and markets them to foreign countries. Data from one of the SAIC buoys was used to forecast the inundation of the March 11, 2011, Japan tsunami.

As an alternative to sending ships out to sea to collect data, moored buoys have long been used by Scripps as data collection platforms. The Navy also uses buoys to collect environmental data and to relay underwater acoustic communications up to satellites where they can be beamed anywhere. An expert in the field was Henri Berteaux, who literally wrote the book on the subject. After a long career at WHOI, Berteaux moved his consulting company to San Diego, which he operated until his death in 2007.

Connectors and Cable

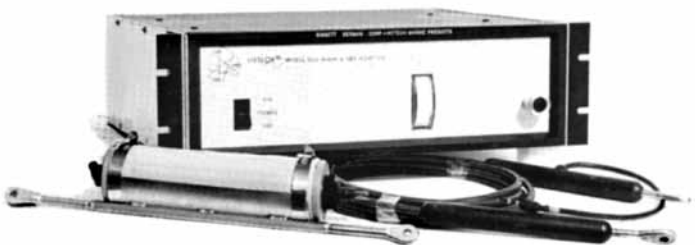
The link from underwater electronics to the surface, or to each other, is underwater cable and connectors. Underwater connectors are ubiquitous in marine technology and are another area that San Diego has long been a leader.

In 1963, Art Nelson started a company in Encinitas called Electro-Oceanic that made underwater connectors. Its product was the first wet-mateable connector based on interference fit, rubber-molded parts that is now a common design. E-O was the first of many underwater connector companies in the San Diego region and it was the second underwater connector company in the U.S. After just a few years in San Diego County, E-O moved to Los Angeles and was sold to Crouse Hinds, who in turn was subsequently acquired by Cooper Industries. Along the way at least two other underwater connector companies were started by people who had left Electro-Oceanic.

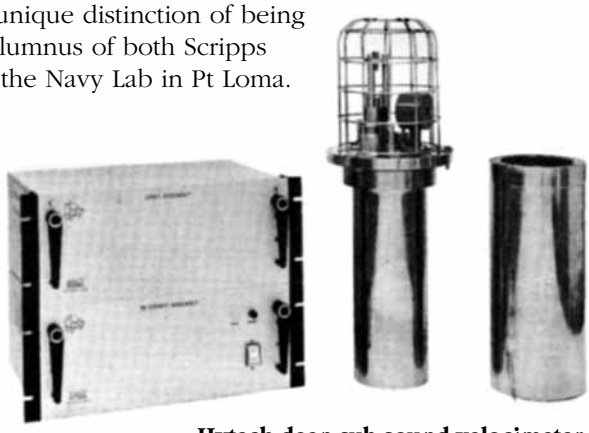
In 1964, Willard Brantner founded Brantner & Associates in El Cajon as a marketing representative for Texas-based Marsh & Marine, the only other underwater connector manufacturers in existence at the time. A few years later he started molding his own underwater connectors for the Navy. He later expanded his customer base to research institutions, including Scripps, and the offshore oil industry. Today, Brantner is one of the largest manufacturers of underwater connectors in the world and has production facilities in California, Texas, Mexico, and the UK.

San Diego is also home to Impulse Enterprises, which got its start in 1978 as a machine shop. A few years later, Impulse started making underwater connectors as well as distributing some made by another manufacturer. Over the years they expanded these initial product lines into several other types of underwater connectors. At the end of 2006, Teledyne Technologies acquired the company and renamed it Teledyne Impulse.

Another connector company with ties to San Diego was Challenger Marine. The company was started in Florida in the early 1980s by Dr. Jim Cairns, who has the unique distinction of being an alumnus of both Scripps and the Navy Lab in Pt Loma.



Hytech wave tide monitor



Hytech deep sub sound velocimeter

Challenger made some of the first connectors that could be mated by an ROV. The basic design consisted of a fluid-filled pressure-compensated chamber, which housed receptacle sockets. Male contacts penetrated the chamber through sealed openings; connections were made within the dielectric fluid, and removed from the hostile outside environment. The advantages of such connectors are that they may be mated and unmated repeatedly underwater, at any pressure.

In 1985, the company was sold to a division of Lockheed Martin in San Diego, which continued the development of the product line and expanded it to include fiber optic connectors. In 1997, Lockheed entered into a licensing agreement with Brantner & Associates to manufacture and market the connectors with technical support from Lockheed Martin. Cairns went on to found another connector company in Florida, Ocean Design Inc. (ODI), which ultimately was sold to Teledyne.

Connectors can't be used without cables, and specially designed cables are required for use in the harsh underwater environment. In 1973, ITT's Cable-Hydrospace Division built a massive manufacturing plant, totaling 317,000 square feet, in south San Diego. The plant specialized in building submarine telephone cables that were often hundreds of miles long. Cable-laying ships could dock right at the factory and be loaded from an overhead conveyor direct from the production facilities. After years of operation, ITT shuttered the plant when the telecom industry collapsed. The unique 4-story, 1,100-foot long building was demolished in 1997.

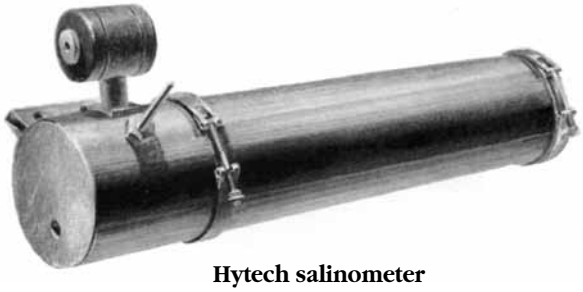
North San Diego County became home to another underwater cable manufacturer when Lewis "Pinky" Falk moved his company, Falmat, to San Marcos in 1988. The company started in Los Angles as a wire and cable distributor in the mid-1960s. Upon relocating to San Diego, Falmat discovered that local marine technology companies were in need of specialized cables and it began making some simple designs. Today, the company is run by the next generation of Falks and has expanded into three buildings. Its capabilities extend the entire spectrum of cable types used above and below the water.

CTDs (Conductivity/Temperature/Depth)

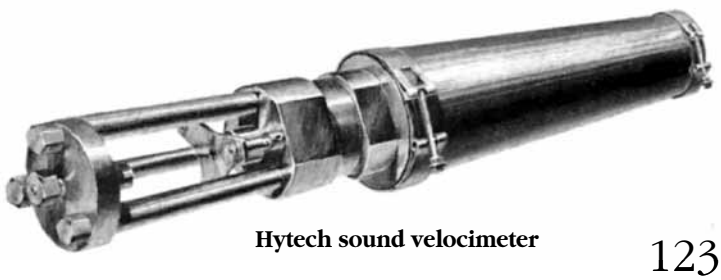
CTDs measure how the electrical conductivity and temperature of the water column changes relative to depth. Conductivity and temperature information is valuable because the speed of sound in seawater can be derived from these variables. This is used to correct devices that use sound underwater. CTD data 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

The first commercially made CTDs can be traced back to a company called Hytech, which was formed in San Diego (ca. 1960) by Don Cretzler. Initially, it made a bathythermographs, current meters, and a wave and tide monitor. These were amongst the first electronic ocean instruments. In 1962, an engineer named Neil Brown joined the company to develop a laboratory instrument to measure salinity. Soon after, he designed the electronic components that were the key to making in-situ computations of salinity enabling the first CTD to be built. The following year the Navy contracted with Hytech and Santa Monica based Bissett-Berman, who was one of the few companies at the time with computer technology. Together they made the first automated ocean data collection system that was used to collect large volumes of data to evaluate the underwater acoustic environment. As a result of this collaboration, Bissett-Berman acquired Hytech. In 1964, the Navy awarded them a contract to develop the first oceanographic sensors capable of continuous operation for up to one year in-situ. This was followed by other Navy contracts for specialized sensor systems. In 1969, the San Diego division moved into a 33,000 square foot purpose-built building in Kearny Mesa. In 1970, Bissett-Berman was purchased by the British company Plessey Ltd. and the San Diego Division was renamed Plessey Environmental Systems. Ten years later, Grundy bought the parent company of Plessey Environmental and a short time later phased out the oceanographic equipment.

Photos Courtesy of Hytech/Bissett-Berman



Hytech salinometer



Hytech sound velocimeter

Ocean Sensors' APV (Autonomous Profiling Vehicle) off the coast of Cuba, 1992.
Courtesy Kim McCoy

Neil Brown left Hytech in 1969 and moved to the East Coast where he eventually started his own company making CTDs. Neil Brown Instruments was later acquired by EG&G. He continued to develop improved CTDs for a company called Falmouth Scientific. In 2009, this product line was acquired by Teledyne RDI – Neil Brown's CTDs had come full circle and returned home to San Diego.

Not to be outdone, RDI's cross town rival, Sontek, came up with their own CTD, the CastAway, an innovative handheld deployable instrument with integrated GPS and LCD display.

Ocean Sensors, Inc. (OSI), formed by Kim McCoy and Scripps' graduate Michael Head, grew out of the pioneering efforts to create a lightweight internally recording conductivity-temperature-depth (CTD) instrument. The advent of the low power microprocessor and digital memory storage in the early 1980s enabled OSI to commercialize one of the first autonomous solid-state data loggers in the world.

In 1993, OSI integrated Global Positioning System (GPS) into its products. In the same year, OSI commercially introduced the Autonomous Profiling Vehicle (APV), which repeatedly profiled to 1000 meters depth. The APV transmitted to land via satellite radio and, when submerged, it used acoustic communications to other subsurface platforms.

Head left OSI in 1990 and started his own company, Precision Measurement Engineering. PME's initial product was a CTD designed to make very fine-scale measurements of ocean and lake waters. They have since added other sensors and systems for water quality monitoring.

A novel method for deploying CTDs from a moving ship was developed by Scripps and licensed to the Oceanscience Group – a company started in 1988 by SIO graduate Ron George. Oceanscience also makes surface buoy mounts, seafloor frames, and remotely-controlled boats, all for acoustic Doppler current profilers (ADCPs).

Current Meters

San Diego has also been a leader in developing instruments to measure the speed and direction of water currents.

In 1966, Plessey Environmental Systems introduced an electromagnetic current meter that recorded data on magnetic tape. After twelve years, production was taken over by Grundy Inc., also of San Diego.

InterOcean Systems introduced its S4 current meter, which senses current using two pairs of titanium electrodes mounted on a 10" diameter sphere that houses electronics and batteries. One of the key InterOcean engineers who worked on the development of the S4 was Ken Lawson; he left to start his own business, Sea-Bird, which was devoted to the development of CTD products.

Another approach to determining flow rates is to transmit an acoustic pulse in the water and measure the signal that is reflected back from particles in the water. The Doppler frequency shift can be used to compute the velocity of the particles and thus the water in which they are suspended. San Diego based Ametek Straza used Doppler techniques to measure ships' speed. Two engineers from Ametek, Fran Rowe and Kent Deines, collaborated with Russ Davis and others at Scripps, to develop a sonar that could obtain vertical profiles of water currents. Ametek was not interested in pursuing this, so Rowe and Deines left and started their own company, RDI, to commercialize Acoustic Doppler Current Profilers (ADCPs). They were very successful and ADCP's are now a standard oceanographic tool (see Russ Davis' article, pages 18-31, this issue).

Several former RDI employees formed companies using Doppler technology, including San Diego-based Sontek and LinkQuest. Sontek was formed by Ramon Cabrera and Atle Lohrmann in 1992. Their first product was the Acoustic Doppler Velocimeter (ADV) for making high precision single point measurements in laboratories. The product line has since grown into a diverse mix of instruments for all types of environments. In 1996, Lohrmann went back to his home country of Norway and started Nortek. In 2001, Cabrera sold the company to YSI, a large manufacturer of environmental monitoring equipment. The company remains in San Diego and after a sabbatical of several years, Cabrera returned to head up Sontek's new product development efforts.

LinkQuest was founded by former RDI engineer Dr. Xiolong Yu and Ning Xiao in 1998. In addition to ADCPs, LinkQuest has become a leading manufacturer of acoustic modems, which are used to transmit data wirelessly through the water. LinkQuest also makes acoustic tracking and positioning systems based on their broadband spread spectrum technology.

In 2005, RDI was acquired by Teledyne where it has continued to grow by acquisition and product development. Founders Rowe and Deine left subsequently, with each starting new endeavors. Deines developed products for the medical industry using laser Doppler technology. Rowe joined his sons in 2009, at Rowe Technologies, to develop new underwater Doppler sonar products.

Saturation Systems' Helinaut gas reclaim diving helmet.
Photo by the Author

Saturation Systems' deck recompression chamber.
Courtesy Don Rodocker

Diving Technology

San Diego was home to the first free diving club, the Bottom Scratchers, which started in 1933 and whose members invented much of the equipment they used. In 1949, when SCUBA diving gear first became available in the U.S., some of the first sets made their way into the hands of Scripps scientists. They developed the first non-military training program in the nation which served as a model for training agencies that came along later. Some of Scripps diving scientists started a consulting company with their diving colleagues at the Navy Electronics Lab called Geological Diving Consultants. Another group of divers at Scripps formed Scientific Diving Consultants, Inc. These prototypical companies developed equipment and techniques that would later be copied and commercialized.

One problem faced by divers was how to stay warm. Hugh Bradner, a physcist at UC Berkeley (and subsequently Scripps) was asked to think about this by some Navy divers.

Bradner came up with the idea that suits do not need to be watertight if thermal insulation is obtained by air entrapped in the material of the suit. His insight deemed that the diver does not have to be dry to stay warm. After trying several materials, Willard Bascom, an engineer at Scripps, suggested Bradner use a new material called neoprene and hence was borne the wetsuit.

Bradner set up two companies with others to make and market wetsuits to Navy divers: Engineering Development Company (EDCO) in Berkeley, and Beaver International of La Jolla. However, the Navy did not adopt their wetsuits out of concerns that the gas bubbles in the neoprene would make it easier for divers to be detected by sonar. Another disappointment was the U.S. Patent Office's rejection of their application because the design was viewed as too similar to a flight suit. Bradner decided to leave commercialization of the wetsuit to others and pursue his academic interests.

Drysuits are diving thermal protection designed to prevent water from entering the suit, as opposed to wetsuits that allow a thin layer of water in. One of the early manufacturers of drysuits was started in San Diego, in 1963, by Dick Long. His Diving Unlimited International has become a world leader in drysuits. Long also perfected the hot water suit in the early 1970s, which was used by commercial oil field divers who would sometimes make saturation dives for weeks at a time. Today, Long pursues his passion for converting retired ships into reefs and has turned the reins of DUI over to his daughter, Susan.

Jeremiah Sullivan is another local innovator in diving technology. His company, Neptunic, developed a flexible suit of armor for divers to wear while working around sharks.

Drew Michel (with controller), of Taylor Diving, accepts three Hydro Products RCV 225 from Chuck Strickland. These were some of the first ROVs used in the Gulf of Mexico (ca. 1976).

Courtesy Drew Michel

Saturation diving is a technique that allows divers to work at great depth for long periods of time without suffering from the bends. The U.S. Navy pioneered this technology. Their manned SeaLab underwater saturation habitat was operated for forty-five days without problems, northwest of the SIO Pier on a ledge in Scripps Canyon, at a depth of 205 feet in 1965.

In the early 1970s, former U.S. Navy saturation divers Don Rodocker and Chris DeLucchi started a company in San Diego to make saturation diving systems for the offshore oil industry. Appropriately called Saturation Systems, Inc., the company's founders proved their technology by making the first saturation dives on the fabled wreck of the *Andrea Doria*, a luxurious Italian ocean liner that sank off New England in 1956. The company's systems included a portable, submersible recompression chamber and a control van, as well as specialized diving helmets known as Sat Hats.

Rodocker was also the creator of the "Gas Mizer" deep diving gas reclaim system. This is a helium-oxygen diver gas recovery system that takes expired gas from the diver's helmet and passes it back up a return line, ganged to the diver's umbilical. The gas is then cleansed of its carbon dioxide, small particulates and excess moisture. Oxygen is then added and the gas is pumped back down to the diver. With this equipment expensive helium gas is conserved.

Divers working in saturation can have problems communicating with personnel on the surface due to the affect of helium on the human voice – the affect makes them sound like they are imitating Donald Duck. A local company, Helle Engineering, solved this by supplying electronic devices known as helium unscramblers. The company was started by Jim Helle, a former engineer at Scripps. Helle was Scripps' liaison with Jacques Cousteau's team when the famous French diver brought his diving saucer to SIO for a series of local dives in late 1964/ early 1965. For this effort, Helle developed underwater navigation equipment using acoustic pingers. Soon, others were asking him to build the equipment. Helle toyed with the idea of starting a company to sell them and consulted with the director of Scripps. He was cautioned that no one who had left Scripps had ever successfully started a company. Helle ignored the advice and followed his instincts. His pingers became a big success in the new industry of offshore oil and gas. Helle pioneered the development of other underwater electronic devices for communication and relocation. Helle eventually relocated to Scotland and the company was acquired by Nautronix in 1995.

Another local company making helium unscramblers and diver communication devices is Amron International, which was started by Norma Ockwig, a former employee of Saturation Systems. Amron started in 1978, operating out of Norma's home selling commercial diving equipment. Today, it is a full-line distributor and manufacturer of commercial diving, tactical, and hyperbaric equipment run by Norma's daughter out of a 40,000 sq ft building.

The tradition of diver communication device development in San Diego is being carried on today by Hydrolinx, which was formed in 2011 by former Amron engineer Todd Sadik, who saw a need for improved technology. By using digital signal processing, Hydrolinx reduces background and inhalation noise thereby making diver's speech clearer.

Underwater Cameras

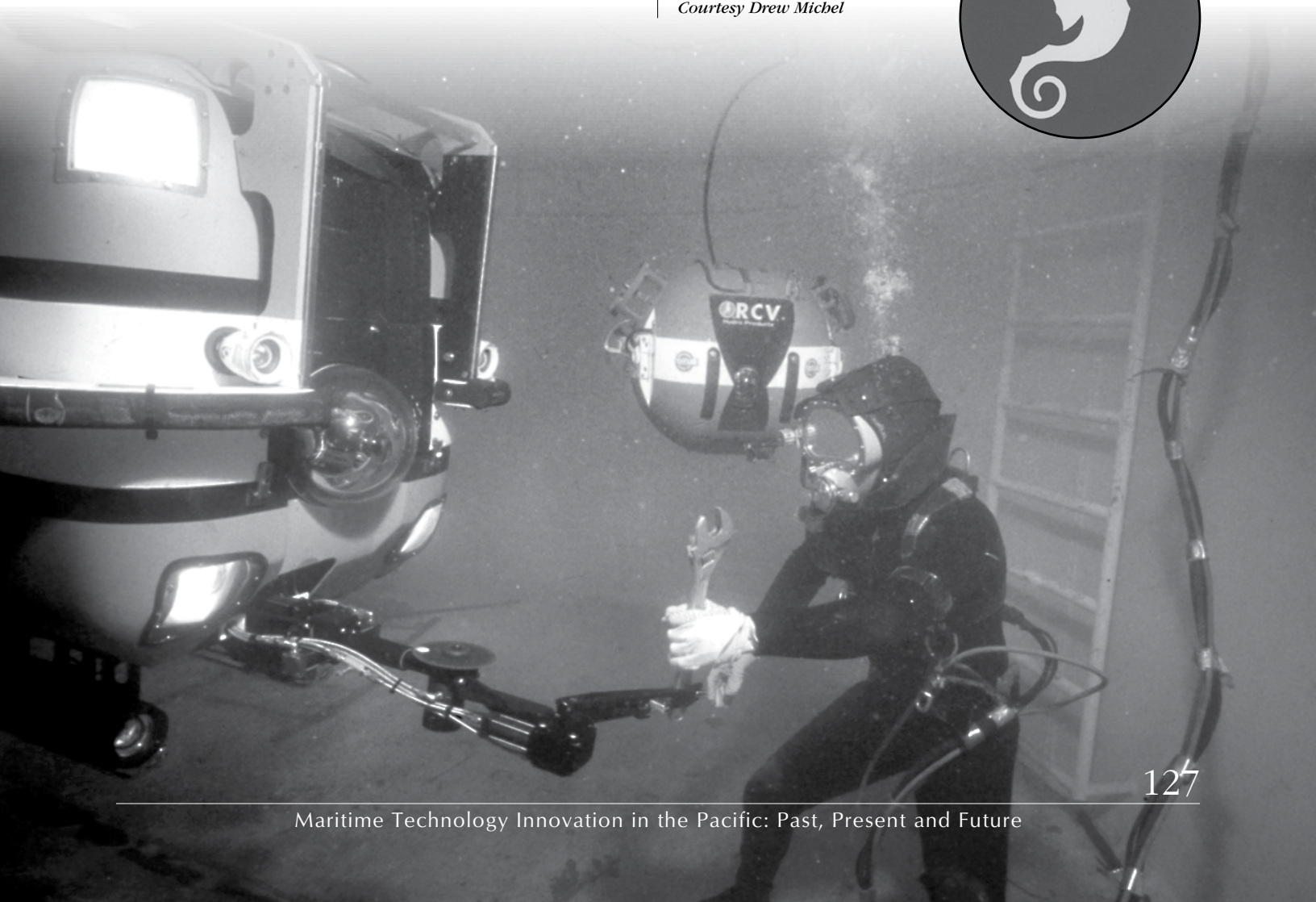
San Diego has been home to several of the world's foremost underwater photographers starting with Ron Church in the 1960's, to Chuck Nicklin who was an underwater cameraman on several Hollywood pictures including "The Deep," "The Abyss," and several James Bond movies; his son Flip Nicklin, a National Geographic photographer; Marty Snyderman and the current top cinemagraphic duo of Howard and Michelle Hall.

San Diego is also where underwater video cameras were first developed as a commercial product. The distinction for doing this goes to Oceanographic Engineering Corporation in 1959. After initially making pressure housings for Scripps scientists, OEC started making underwater television cameras. After some tumultuous early years, OEC expanded its product range to have a broader base of revenue. It introduced a wide variety of new products such as photographic cameras, current meters, wave recorders, wave samplers, sediment samplers, and devices to measure light transmission underwater. In recognition of having underwater instrumentation for almost all applications the company was renamed Hydro Products. Eventually Hydro Products grew into one of the largest marine tech companies the industry has ever seen.

One of the managers of Hydro Products, Joe Granville, became unhappy with how things were going and left in 1963 to start Sub Sea Systems in Escondido. Sub Sea found a new market for underwater TV cameras in the nascent offshore oil industry, as at that time Hydro Products was focused on the scientific and military markets.

Hydro Products went on to develop a great number of underwater products including a 35mm film camera. When Chuck Strickland, the engineering manager who became president of Hydro Products, decided to leave and form his own company, he was given the rights to their 35mm film camera. This was PhotoSea's first product, which was followed by a 70mm camera, stereo cameras, various lights and eventually video cameras. PhotoSea rose to become an industry leader. In 1991, Strickland decided to retire and sold PhotoSea to a Texas company called Hydro Vision International, who had also bought the Hydro Products camera line in 1984.

Hydro Products RCV 225 ROVs assist a diver.
Courtesy Drew Michel



In the 1980s, one of the biggest competitors for the American underwater camera manufacturers was a British company called Osprey. It had a large market in its backyard – the offshore oil contractors working in the North Sea. In 1984, Osprey opened a small office in Houston, Texas, to service some of the same customers. In the late 1980s, a dizzying binge of acquisitions occurred. Osprey purchased Sub Sea Systems of Escondido and moved the operation to San Marcos, at the same time closing their Houston facility. Osprey Ltd and its U.S. subsidiary was then purchased by the Norwegian company Simrad in 1993. What had then become Simrad Osprey acquired Hydro Vision, who had previously purchased PhotoSea and the Hydro Products camera lines, and integrated those operations into the San Marcos facility. Shortly thereafter Norwegian government majority-owned Kongsberg purchased all the Simrad operations and then, in 2001, closed down the San Marcos operation, laying off all but a couple of employees. This was the end of the line for some of the pioneering San Diego companies.

Brock Rosenthal holds a Hydro Products TC-125 camera and a DSPL Nano SeaCam.
Photo by Jake Rosenthal

Remote Ocean Systems, or ROS, was started by former Navy Lab engineers Bob Acks and Bruce Fugitt in 1978, with the intent of developing and manufacturing ROVs. Their first product, Telesub, was a 2000 ft. rated vehicle that had evolved from the ROVs designed by the entrepreneurial engineers when they were employed by the Navy. When sales for the vehicle were not forthcoming, they leased it for underwater surveys and inspections. ROS also did product development for SubSea Systems, who for a time owned a part interest in ROS. Eventually, they started offering the cameras, lights and pan & tilts they developed for Telesub to other ROV manufacturers. This developed into their main business and Telesub was sold off. ROS later branched out into sales of underwater inspection systems to nuclear power plants with significant sales in nuclear fuel pool lighting. In 1992, Fugitt left ROS to start his own company in Colorado. ROS has continued on with their product line of underwater video cameras, underwater lights, rugged pan and tilt units, and video inspection systems; manufactured primarily for the oceanographic, nuclear and defense industries.

DeepSea Power & Light (DSPL) was founded in 1983 by Scripps graduate student Mark Olsson, with Brock Rosenthal, Bill Hagey, and Ray Merewether. Their first product was a lead-acid battery that could be used at any depth. It was a commercialized version of a battery Olsson used for his deep ocean photography research at SIO. This was followed by small underwater lights that could go to great depths. The first use of their SeaLite was on Jason Junior, the small ROV Bob Ballard used to explore the *Titanic* in 1986. This was followed by making underwater versions of large studio-type lights called HMIs that were used to light up the famous wreck for nearly every film that followed its discovery.

Eventually DSPL got into the video camera business, making the first commercially available underwater cameras that used solid state imaging chips. Prior to this cameras used video tubes that were larger and more fragile. In the mid-1990s, DSPL diversified by making video cameras designed for inspecting inside sewer pipes. This business was eventually spun out to a separate company called SeekTech, which has now grown to be several times larger then DSPL. Another diversification for DSPL was to develop a line of lighting and cameras that are installed on the hulls of recreational boats. DSPL is managed by John Chew, whose pedigree harks back to PhotoSea and Hydro Products.

Hagey went on to found Pisces Design, in 1987, initially making devices to encode data on video. Today, Pisces makes animal-borne video cameras that are also data recorders. By correlating video images with sensor data, scientists use them to study the physiology and behavior of large marine animals, including seals, turtles, sharks and whales.

Insite Pacific was started by Tom Olkowski in 1994, to produce high-end underwater video cameras. Olkowski is an alumnus of Hydro Products, Sub Sea Systems, Photosea, and ROS. Insite's initial product was a low light camera that was the first to use software to control the settings. It has since gone on to make digital stills cameras and high definition video cameras.

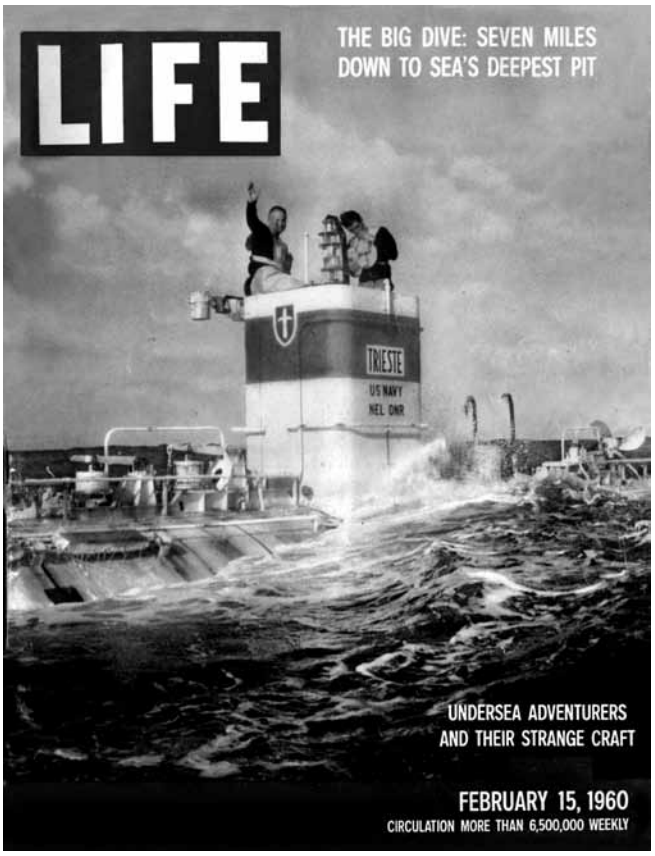
Sidus Solutions is another local San Diego underwater video camera manufacturer. It was started by Leonard Pool in 2000. His previous experience included stints at ROS and Nautronix, as well as owning a marine electronics store. In addition to cameras and lighting, Sidus also makes underwater positioning equipment and integrated systems that

combine all of their capabilities. In 2010, Sidus merged with Topside Offshore Technology, a Dutch company that makes crane load indicator systems, weighing systems, CCTV and control systems for on- and offshore applications.

Today, carrying on the tradition of underwater camera innovations in San Diego, is a company called Bellamare, started by Charles Cousin in 2006. In conjunction with the University of Miami, Bellamare has designed a plankton imaging system that is operated from a towed vehicle. Using this system scientists can study geo-referenced images of plankton in their natural environment, as opposed to looking at ones compressed into the end of a net that were captured while the net was being towed.

Manned Submersibles

In 1958, the Navy bought a deep diving machine called a bathyscaphe from its Swiss inventor August Piccard, and brought it to San Diego. Scripps graduate, Andreas Rechnitzer, was hired to be the program manager for a series of deep research dives that would culminate in a visit to the deepest spot in the world – the Mariana Trench. The exact location of the deepest dive was determined with the help of SIO oceanographers. On January 23, 1960, Jacques Piccard, son of the inventor, and Navy Lt. Don Walsh made a dive to the record depth of 35,800 feet. No one had attempted a return in fifty-two years, until filmmaker James Cameron ("Titanic", "Avatar," "The Abyss") recorded the deepest solo dive in *DeepSea Challenger*, on March 26, 2012.



(Above) Don Walsh and Jacques Piccard emerge from the bathyscaphe *Trieste*, after their record-setting dive in 1960.
Courtesy the Author's collection/LIFE Magazine

Other deep diving subs kept in San Diego by the Navy's Deep Submergence unit were the *Sea Cliff* and *Turtle*. The same group also operated the *Mystic* and *Avalon,* which were designed to rescue the crew of a stricken submarine if ever needed. Technical support for these specialized vessels was provided by a division of Lockheed based in San Diego.

In an interesting mix of academia, navy and commercialism, a group of Scripps trained geologists (H. W. Menard, Robert Dill, Dave Moore, Bob Dietz and Ed Hamilton), some of whom worked for the Navy Electronics Lab, formed a company in 1953 called Geological Diving Consultants, later called General Oceanographics, and then Nekton, Inc. This group mapped much of the geology to 150 feet off California, from the Mexican border to Oregon, and in several other parts of the world, by scuba diving. Later, under the Nekton banner, they built submersibles that they sold and also used for their consulting work.

NATIONAL GEOGRAPHIC Daily News

James Cameron Completes Record-Breaking Mariana Trench Dive

Solo sub dive is deepest ever.

The explorer-filmmaker emerges from his sub after returning from Challenger Deep.
Photograph by Mark Thiessen, National Geographic

See http://news.nationalgeographic.com

Dynamic Positioning

Dynamic Positioning, or DP, is a method used to maintain a ship in a fixed position relative to the seafloor. It was invented by one-time Scripps engineer, Willard Bascom, for a project (Project Mohole) conceived by Scripps scientists to drill a hole through the earth's crust to the mantle. It was determined the crust is much thinner in the oceans, so drilling methods had to be invented that could be done from a ship. Foremost among these methods was how to keep the ship parked directly above the hole it was drilling without drifting off too far. Bascom came up with the idea of putting a large outboard motor on each of the four corners of the drilling barge that could be manually controlled by a central joystick. Over the years, this has evolved to a GPS-guided, computer-controlled system that maintains a vessel's position using its own propellers and thrusters installed in the bow. Today's multi-billion dollar offshore oil & gas industry would not be possible without dynamic positioning.

Deploying a taut-line buoy for Project Mohole.
Courtesy National Academy of Science

At the forefront of making DP systems has been Nautronix, a company that was co-founded by Randy Jones, a former sales manager at Hydro Products, who bought some of the ship-keeping systems from Hydro Products' parent company, Honeywell Marine Systems. In 1993, the defense conglomerate L-3 acquired Nautronix. Today, the former manager of the Simrad Osprey office, Tony Gardiner, runs this business now known as L-3 Dynamic Positioning & Control Systems.

ROVs

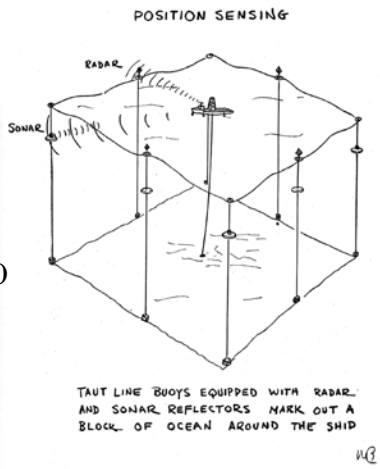
ROVs are underwater robotic vehicles that are controlled from the surface via a cable. While the very first ROV was not built in San Diego, nearly all the ones that followed in the early years had ties to the area, starting with a series of vehicles the Navy built in the early 1960's (see "SSC Pacific," pages 46-59, this issue). Scripps also got in the act with its Remote Underwater Manipulator (RUM), which essentially was an underwater tractor with a large mechanical arm. San Diego is considered the birthplace of the ROV industry, as it was here that they were first commercialized. For a time San Diego was the hub of the ROV industry with two major manufacturers, numerous component and accessory suppliers in the area, an annual conference dedicated to the new technology and home base for a magazine devoted to the subject.

Hydro Products produced the first commercial ROVs. They were contracted by the Navy to build the ANTHRO (Anthropomorphic) ROV that was a test bed for many new concepts such as a head-coupled display to control the vehicle and using hydrophones to provide acoustic feedback for the operator (see pg 120). In the midst of this program an emergency requirement arose. The Navy was sending the manned sub *Trieste* II to examine the wreckage of the submarine *Scorpion* that had mysteriously sunk. They did not want the sub to become entangled in the wreckage so they tasked Hydro Products with developing a new ROV called El Tortuga. The crash program was only seventy-one days from start to delivery. By necessity the vehicle was simple and consisted of a video camera and lights encased in a barrel-shaped block of foam. For propulsion, El Tortuga used bird bath pumps rather then propellers. The vehicle flew out of a cage mounted to the *Trieste* and was connected by a cable covered in small blocks of foam to make it neutrally buoyant.

The Navy then funded Hydro to develop the Advanced Maneuverable Undersea Vehicle System. AMUVS, as it was called, was more advanced then its

predecessors. Commercial versions were sold under the name RCV-125 for Remote Controlled Vehicle. The first one was delivered to a Norwegian contractor to the offshore industry in 1975. With the benefit of operational experience, a series of improvements were made and a new model was released called the RCV-225. Hundreds of 225's were sold worldwide and a new industry was born. Hydro Products flourished and, by 1981, had grown to 550 employees.

Hydro Products went through a series of owners. First was the Hawaiian maritime construction firm, Dillingham. Then, in 1974, Tetra Tech bought Hydro Products from Dillingham. In 1982, Hydro Products' partner in the Navy's Mine Neutralization System (MNS) program, Honeywell, bought the company from Tetra Tech. Its interest was in military systems and soon after it divested all the commercial products. Production on the MNS vehicle continued on for over twenty-five years from the first contract in 1978.



Willard Bascom (upper right) leans against a motor from his Dynamic Positioning System.

(Right) Diagram by Bascom of his positioning system for Project Mohole.
Courtesy of the National Academy of Sciences

Hydro Products was an innovator and driving force in many underwater products. It pioneered markets for these products in the offshore oil & gas industry, the nuclear power industry, science, and defense. Former employees of Hydro Products went on to start and lead other companies. The impact of Hydro Products on the marine technology industry was significant.

In the 1970s, the Ametek division of Straza, in El Cajon, started manufacturing large, work-class ROVs. Their first vehicle, called Deep Drone, was delivered to the U.S. Navy in 1975, to support deep ocean salvage projects. This was followed by SCARAB, which stood for "submersible craft assisting recovery and burial". It was built for AT&T and was the first ROV built for underwater cable burial and repair. Next was the very successful line of vehicles called Scorpios. They were used in the offshore oil & gas market as well as by the military for rescue and salvage operations. The division was spun off in 1988 to become a publicly traded company, Ketema Inc., in an effort to distance itself from charges of price fixing in government contracts. Ketema later divested itself of it marine tech business. In 1990, Ametek pled guilty to charges of defense contracting fraud in connection with the 1986 bids for sonar systems used on two classes of Navy nuclear submarines.

After the demise of Hydro Products and Ametek, San Diego had no commercial ROVs being built in the area. In the early 1980s, a young and enterprising engineer named Andrew Bazley started a company called Hydroscan to make ROV manipulators that used seawater as a hydraulic fluid. The product was not a big success, but his assistant, Tyler Schilling, went on to start a company in Northern California that has become one of the largest ROV manufacturers. In Bazley's next venture, Bentex, he designed the highly successful Sprint ROV that was manufactured in Norway by Bennex. He applied what he had learned from this effort and started a company, in 1985, specializing in the manufacture of ROV thrusters. Tecnadyne has since branched out into producing other ROV components such as hydraulic valve packs, pressure compensators, actuators, pan & tilts, and controllers.

Commercial ROV manufacturing returned to San Diego in 2000, when Don Rodocker, and son Jesse, founded SeaBotix. The company builds mini ROV systems. These small, highly portable vehicles have made ROV technology accessible to a new group of users due to their low cost and ease of operation. SeaBotix has developed several unique ROVs including one that is intended to rescue people in the water and another for hull inspection that has wheels and a low pressure generator enabling it to stick to the hull as it crawls along it. In 2011, the company was sold to Bolt Technologies, which has kept the company in San Diego, operating as an independent business unit.

AUVs

Autonomous Underwater Vehicles, or AUVs, are robotic submarines that are not cabled to the surface. They rely on pre-programmed routes, onboard navigation systems, and logic circuits to react to information detected by its sensors. In the last few years, AUVs have come into their own and have become popular for military, hydrographic, and scientific missions.

The first company to commercially manufacture AUVs was Advanced Remote Technologies. ART was formed in 1984, in San Diego, by Ron Walrod, the former ROV engineering manager at Hydro Products. Initially the company worked on subsystems and

SeaBotix's highly capable vLBV300 MiniROV.
Courtesy SeaBotix

work packages for ROVs. In 1986, ART was awarded a contract from Martin Marietta to design and build an AUV called MUST on a one year fixed price contract. To mitigate risk they built an in-house test vehicle called the XP-21. MUST was delivered on time and within budget, and ART was able to use the XP-21 for years to develop new payload packages. An important offshoot of the MUST project was the development of an acoustic data link in a joint project with the Navy Lab on Pt Loma, which had its own AUV program. These were the first commercially available acoustic modems and they were integrated into several other AUVs.

ART also developed an underwater laser line scan imaging system that was capable of making long range images underwater. A competing laser line scan system was built in San Diego by Westinghouse Underwater Laser Systems. Both worked by sweeping a narrow beam of laser light onto the seafloor and assembling the reflected light line-by-line to create an image. This technique eliminated the glare from back-scattered light, allowing views of up to ten times farther underwater then with conventional cameras.

In 1989, ART was sold to General Dynamics, which in turn sold it to Raytheon in 1993. In 1995, after sales contracts did not materialize, Raytheon shut down the company and transferred its laser imaging technology to a division on the East Coast, where it is still considered to be state of the art for long range undersea imaging.

Sonars

In addition to building ROVs, Ametek Straza built a sophisticated type of sonar using continuous transmission frequency-modulated (CTFM) technology. Unlike typical sonars that send out a ping and listen for its reflected return signal, CTFM sonars sweep through a band of frequencies, and thereby providing better range and resolution.

SunWest Technologies was founded in 1990 by former Ametek engineer, Jim Christensen, to continue the manufacture of CTFM sonars after Ametek's demise. He was subsequently joined by another ex-Ameteker, Richard Hess, who is now president of SunWest.

Remote Sensing

Remote sensing is the acquisition of information about an object or phenomenon, without making physical contact with the object. In the marine context, the term generally refers to the use of aerial sensor technologies used to measure properties of water at, or near, the surface of the ocean. Two San Diego companies have been pioneers in this arena.

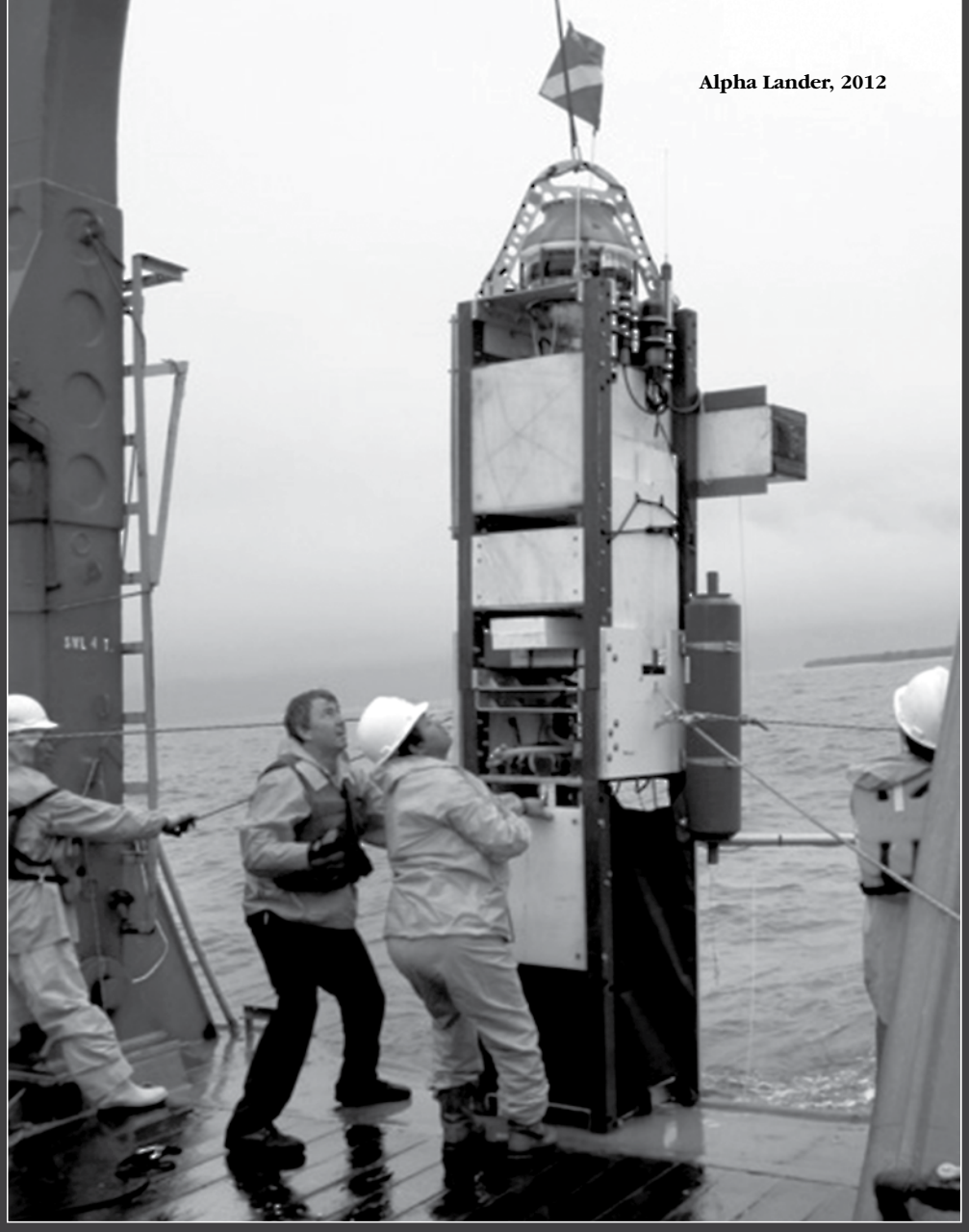
Ocean Imaging, started by Scripps graduate Jan Svejkovsky in 1984, specializes in satellite-derived ocean temperature analyses for fishing fleets and the derivation of ocean current and ice drift trajectories for the offshore oil industry. Its remote aerial imaging technology is also used for oceanic and coastal environmental studies. Most recently, it provided daily aerial oil thickness distribution and trajectory mapping for the entire Deepwater Horizon oil spill response community, during summer 2010.

Poway-based SeaSpace Corporation was founded by Scripps Institution of Oceanography scientist Robert Bernstein, who wanted to research changing water temperatures, but found that getting access to information collected by satellites was too expensive. He started SeaSpace to take information collected by government satellites and make it more readily available to users. Eventually, the internet made it far easier and cheaper to access satellite information, so the company shifted its business to the design and manufacture of satellite ground stations and processing software for remote sensing applications. In 2007, the company was acquired by Hyong Ossi, who previously was a sales rep for SeaSpace.

Optical Oceanography

Optical oceanography is the sub-discipline of oceanography concerned with the propagation and interaction of optical radiation. Ocean optic instruments are principally used to study photosynthesis and to calibrate remote sensing data.

One of the first companies to offer commercial products in this area is San Diego's Biospherical Instruments. Started by Charles ("Rocky") Booth in 1977, after he worked at Scripps, Biospherical makes a wide variety of ultra violet, visible, and IR region radiometers (single and multiple wavelength, and spectrographic) for use in oceanographic and atmospheric research. Its products are used for terrestrial and oceanographic global change studies, water quality assessment systems for municipal reservoirs, and other types of environmental monitoring.



Alpha Lander, 2012

For James Cameron's Deep Challenge Project, Scripps development engineer, Kevin Hardy, drew on decades of experience with free vehicles and seafloor landers, plus an extensive network of local and international contacts, to create the towering, multipurpose "Alpha Landers." The Alpha Landers function as both HD stereo video and still camera platform and ultimate remote science station. Scripps scientists and their academic colleagues will also obtain seawater, sediment cores and deep-sea animals to enable the detailed study of life forms adapted to the radically different environment of the deep sea. Similar research programs have discovered and isolated sources of novel natural products with important biomedical value.

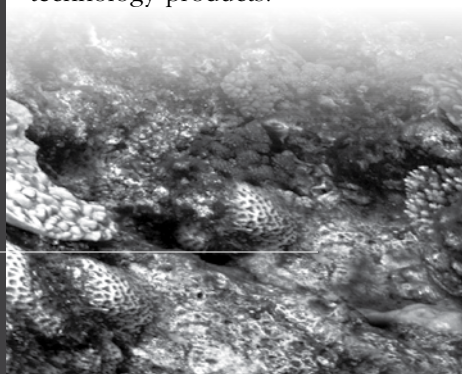
James Cameron's Alpha Landers are classified as "free vehicles," meaning they operate independent of surface support ships. They are known as "landers" because they descend from the sea surface to land upright on the seafloor at the bottom of the ocean trench. The surface ship then moves off, and, after the lander touches down, Cameron, inside his *Deepsea Challenger* submarine, is launched from the mother ship, the *Mermaid Sapphire*. Later, after Cameron's submarine is recovered, the Alpha Lander is recalled to the surface using a coded acoustic signal from the lander support ship.

San Diego companies that provided equipment on board Cameron's Alpha Landers include: **Ocean Innovations, Teledyne Impulse, Brantner SeaCon, Built Machine, Harrington Plastics, REI, Marshalls Industrial, and Southern California Plating.** Significant fabrication was done by the experienced crew of the Scripps machine shop.

Courtesy Kevin Hardy, Development Engineer, Scripps Institution of Oceanography

Conclusion

San Diego has a rich history in the field of maritime technology. Many key underwater technologies and devices have been invented or developed in San Diego, perhaps more than in any other region of the world. The genesis of these accomplishments can be traced to the influence that Scripps Institution of Oceanography and the Navy have had on the area. Scripps has developed many tools for their scientists to make new measurements. Along the way many of their staff have seeded local marine technology companies. The Navy Lab on Pt Loma has undertaken many technology development programs that ultimately led to commercial products and it has been a key customer to many of the region's maritime technology companies. Some of the pioneering marine technology companies in San Diego are gone, but many of those involved have moved on to other companies throughout the industry. Their legacy is the large number of companies in the San Diego region today making marine technology products.



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