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Comparative Analysis Science and Technology: Ocean Floor Mapping and Exploration

Final

Introduction

Almost 71% of earth is covered with water. Oceanographers teach there is one large planetary ocean with five ocean basins, the Atlantic, Pacific, Indian, Arctic, and Southern oceans. Only 5% of the oceans have been explored and mapped in detail (Earle and Glover 26). For centuries, mankind has used the ocean for trade routes, military excursions, and extricating natural resources. Within the last 216 years, mapping the oceans has been necessary to find safe trade routes and support the fishing industry, detect foreign vessels and protect the homeland, and locate and mine veins of precious metals. During the Contemporary World period (1945 to present), the United States and Europe have produced more sophisticated technologies to accurately map the ocean topography at greater depths for commercial, military, and mineral extraction purposes than the science and technological advancements in ocean exploration during the Age of Imperialism (1800-1920) and the Modern World Wars (1914-1945) periods combined.

Ocean Floor Mapping Technologies for Commercial (Shipping and Fishing) Purposes

Mapping the ocean for commercial purposes refers to the use of understanding the ocean floor mainly for the shipping and fishing industries. As seen throughout history, the sea is the most important trading route: ships move more goods than any other mode of transportation.

During the Age of Imperialism (1800-1920), rather basic technologies were used to map the ocean floor. Sounding pole and hand lead lines were used to produce early maps of coastlines for reefs, hills and valleys for shipping companies. Lead lines were ropes that had depth markings and lead weights attached; they were lowered from the ship and read manually which made this process very time-consuming [See Figure 1] (“The History of Hydrographic Surveying”, http://www.nauticalcharts.noaa.gov/hsd/hydro_history.html). Starting in 1904, wire drag surveys were introduced. The wire drag consisted of a long wire with weights and buoys which was attached to two vessels and was dragged between two destinations. If the wire met an obstruction, it would become taut and form a “V”; this shape would reveal the depth and position of submerged rocks [See Figure 2] (“The History of Hydrographic Surveying”, http://www.nauticalcharts.noaa.gov/hsd/hydro_history.html). These technologies were developed to create safe and efficient shipping lanes.

Later, during the Modern World Wars period (1914-1945), Herbert Dorsey, an American scientist, invented the fathometer which is a wireless device that sends a high pitched sound through the water. This sound would travel at a known speed to the bottom and then had a recognizable echo. The Dorsey fathometer, named after its inventor, sped up the process of mapping areas and aided in generating new maps of the continental shelf area [See Figure 4] (“Age of Electronics (1923-1945)”, http://oceanexplorer.noaa.gov/history/electronic/electronic.html). In the 1930s, the bathythermograph (bathy=depth), a scientific instrument, allowed scientists to create a continuous sketch of ocean temperature, which allowed more precise depth measurements [See Figure 5] (“Tool of the Times”, https://www.whoi.edu/image-of-day/tool-of-the-times). A more modern version of this instrument is still used today.

More recently, in the Contemporary World period (1945-present) advanced technologies on the seafloor and in space are used to accurately build a map of the seafloor. Satellite-based altimeters measure variations in Earth's gravitational field to detect slight differences in the height and angle of the sea's surface. With this information, scientists can build topographical maps of the ocean floor, particularly volcanoes, mountains, and ridges (Giller, http://www.scientificamerican.com/gallery/new-map-shows-seafloor-details-where-malaysian-airliner-likely-crashed/). There are currently four satellites that possess high-resolution radar altimeters in space; these satellites are able to detect previously unknown seamounts between 1,000 and 2,000 meters tall littering the ocean floor [See Figures 6a and 6b] (Gramling, http://news.sciencemag.org/earth/2014/10/satellites-reveal-hidden-features-bottom-earths-seas). Anchored buoys that are fully equipped and moored thousands of miles from shore collect hourly information on wind speed, temperature, and currents to predict weather, wave and circulation patterns for fisherman, shippers, and oceanographers ("History of Oceanography", http://divediscover.whoi.edu/history-ocean/21st.html). By using satellite altimeters and anchored buoys to collect information on the ocean's topography and weather conditions, ships can travel more safely and be aware of hazards both under the water and above it.

Underwater vehicles were produced by oceanographers to collect data and create detailed maps of the seafloor. The autonomous underwater vehicle, also known as the "AUV", is an untethered torpedo-shaped robotic vehicle used to document the seafloor and collect data from the depths. Data is kept on the AUV and accessed once the vehicle docks on a ship or surfaces and connects to a satellite [See Figure 7] ("History of Oceanography", http://divediscover.whoi.edu/history-ocean/21st.html). Remotely operated vehicles, or ROVs, are another type of submersible vehicle. ROVs require a cable connecting them to a ship and have a rather limited range. One of the most famous ROVs is the *Alvin*, a submersible originally built in the 1960s and fully restored in the early 2000s. The *Alvin* helped researchers find the *RMS Titanic*, a World War II-era hydrogen bomb, and it discovered the first hydrothermal vents in 1977 (Messmore, “Alvin Test”, http://www.udel.edu/udaily/2014/mar/alvin-submersible-031314.html). With the discovery of the *RMS Titanic*, researchers were able to find safer trade routes and better equip ships for hazard-free voyages. Some of the newer AUVs can record the seafloor in incredible resolutions that are high enough to find ancient shipping containers amidst the sediment [See Figure 8] (Messmore, “Aegean Exploration”, http://www.udel.edu/udaily/2014/aug/aegean-expedition-081513). In the future, submersibles such as these are believed to be an important component of ocean exploration. Commercially, advancements like satellite-based altimeters, submersibles such as AUVs and ROVs benefit the shipping and fishing industries.

Throughout these time periods, mapping the oceans was necessary to find safe and fast trade routes. Similarly, from 1800 to date, a key component to ocean mapping is ships lowering lines and equipment to collect data; for more than 200 years, hydrographers have remotely operated the technology. In contrast, the focus of ocean mapping changed from the coastlines to the continental shelf to the deep ocean, from the location of rocks to identifying changes to mountains, ridges, and volcanoes. As time passed, the technologies progressed from being rather basic to quite advanced. More recent technologies measure gravity, are located in outer space, and build upon older devices, the buoy for example.

Ocean Floor Mapping Technologies for Military Purposes

For national security reasons, ocean floor mapping has also been heavily utilized by navies of coastal nations like the United States and France. In the Age of Imperialism (1800-

1920), several basic technologies were employed. During the North Pacific Exploring Expedition of 1853-1856, the United States claimed the depths of the oceans by using deep sea sounding tools like seine nets, dredges, and lead balls and shots. This expedition was led, manned, and financed by the U.S. Navy. Seine nets are large fishing nets that hang vertically with the bottom held down with weights and the top afloat with buoys. Naturalists on the North Pacific Exploring Expedition created naturalist's dredges, enormous dredges that could reach depths of between 30 to 50 fathoms (1 fathom=6 feet) (Rozwadowski 34). In the 1860s, U.S. Coast Survey ships dredged depths up to 850 fathoms in the Gulf Stream [See Figure 9] (Rozwadowski 35). Lastly in this expedition, Lieutenant John M. Brooke, a naval hydrographer, created and used a lead shot with a hole bored through the center, where a metal rod was inserted. The shot rested in a sling which opened when the sounding line holding it slackened. This device revolutionized oceanic sounding by enabling accurate deep-sea soundings to be available for the first time in history [See Figure 10] (Rozwadowski 84-85). Although these devices are rather primitive, they worked well and allowed for mapping coastlines to happen.

To detect submarines, sound navigation and ranging, or SONAR, was developed in 1905 and improved steadily throughout World War I. At this time, SONAR was a single beam of sound transmitted through the water ("Oceanographic Tools…", http://www.divediscover.whoi.edu/tools/sonar-singlebeam.html). Throughout the Modern World Wars (1914-1945), echo sounders were designed to transmit sounds farther and more exactly calculate depth. The Submarine Signal Company produced the first oscillator devices capable of sending signals through the ocean. The U.S. Navy used these devices for underwater reconnaissance (Reidy, Kroll, and Conway 176). Single beam echo sounders, a more advanced method of SONAR, were developed in the 1930s and used one beam of sound to measure the depth to the sea floor directly below a ship [See Figure 3] (Embley, http://oceanexplorer.noaa.gov/explorations/02fire/background/seafloor_mapping/seafloor.html). Echo sounders and SONAR were an incredible development in helping the military protect U.S. shores and strategically position U.S. Naval vessels.

Throughout the Contemporary World period (1945 to present), ocean technology became much more sophisticated and precise. Following World War II, Swiss father and son team, Auguste and Jacques Piccard, worked with the United States Navy and invented the Trieste. This was the first underwater bathyscaphe, or "balloon", to descend to the deepest trench on Earth, Challenger Deep, in 1960 [See Figure 13] (Bodden 14). Next, researchers created light detection and ranging technology, or "Lidar", to measure elevation or depth by analyzing the reflection of pulses of light off of an object. Often Lidar systems are mounted in aircrafts and generate a seamless, contiguous picture between land and sea, aiding in detecting foreign vessels and missiles. Interestingly, these systems work particularly well gathering data in areas with rugged and difficult shorelines such as Alaska, the North Atlantic, and the Caribbean [See Figure 14] ("Lidar", http://www.nauticalcharts.noaa.gov/hsd/lidar.html). The bathyscaphe and Lidar provided the military with technologies to map the extremes of ocean topography.

Single beam echo sounders cover very small areas and thus are time consuming and labor intensive in both gathering data and analyzing it. Multibeam echo sounders use SONAR technology, but emit sound waves in the shape of a fan from directly beneath a ship's hull ("Multibeam Echo…", http://www.nauticalcharts.noaa.gov/hsd/multibeam.html). These systems are typically used by the military to obtain the sonic equivalent of an aerial photograph. Lastly, side scan SONAR systems give a crisscross scan of a larger area of the ocean floor. In this SONAR scan, side scan systems are towed deep underwater at high speeds. Side scan SONAR technologies provide the most detailed picture of the sea floor's composition [See Figure 11] (Embley, http://oceanexplorer.noaa.gov/explorations/02fire/background/seafloor_mapping/seafloor.html). Ocean mapping tools for military purposes help detect foreign vessels, missiles, and objects while also mapping the sea floor for ocean exploration.

Some similarities between the three time periods are the perpetual use of dredging, lead balls and shots, and echo sounding techniques. Across the time periods, they also use technology to detect the enemy underwater. Usually, civilian scientists partnered with the Navy to map the ocean. Over time, echo sounding techniques began as single beam SONAR, evolved to multibeam SONAR and then sidescan SONAR. In modern times, the bathyscaphe and Lidar are very different, unique devices that give the military the ability to map difficult to access areas.

Ocean Mapping Technologies for Mineral and Natural Resource Extraction Purposes

Technologies were also developed for mineral and natural resource extraction purposes as well as studying the oceans and marine life. Minerals to be extracted include sulphide deposits, manganese nodules, cobalt crusts, and resources such as natural gas, iron, and oil. Deposits rich in these minerals are located around hydrothermal vents and have been found to be rich in precious metals (Gelpke, http://worldoceanreview.com/en/wor-4-overview/how-the-sea-serves-us/the-bounty-of-the-sea/). In the Age of the Imperialism (1800-1920), some of the more elementary ways of extraction were utilized. Since the late 19th century, dragline dredges have been used to obtain material from the sea floor for gold and iron mining. Dredging technology is the standard for seafloor excavating and often consists of the rudimentary bucketline technique where several steel buckets connect in a closed loop. The buckets are lowered and dragged across the seafloor, then they are raised on a conveyor belt and their contents are processed [See

Figure 15] (Office of Technology Assessment 169-170). Later in the 19th century, German scientists were interested in mapping the ocean near the Mediterranean coast. They employed sounding devices with early SONAR that divers used in the 75 to 100 foot range to detect reefs and rocks (Lerner 359). By dredging and using sounding devices, scientists were able to discover areas rich in precious minerals.

With the coming of the Modern World Wars period (1914-1945), scientists and naturalists created devices that would allow humans to personally spend time underwater. In 1930, Americans Charles Beebe, a naturalist, and Otis Barton, an inventor, invented the bathysphere. This vehicle took Beebe and Barton 3,028 feet below the surface in 1934 and allowed them to observe marine life and the underwater terrain [See Figure 16] (Bodden 12). During World War II, Frenchman Jacques-Yves Cousteau tested one of the new sets of autonomous diving gear. The Aqua Lung had a precursor in 1925 that had a wonderful compressed-air device; however, this device ran on automobile gas and had a very limited time frame during which it could be used underwater. During the war, the Germans requisitioned all automobile gas. Jacques Cousteau, with the help of his colleague Emile Gagnan, modified the air regulator to run on cooking gas. In 1943, Cousteau finished his modifications and created the first Self-Contained Underwater Breathing Apparatus, commonly known as SCUBA. Later, in 1966, Cousteau set up a team of his best divers, engineers, and designers to streamline the SCUBA gear. These alterations and new equipment reduced fatigue and air consumption which allowed divers to move quicker and stay underwater for longer periods of time (“Aqua Lung”, http://www.cousteau.org/technology/). By using SCUBA, divers can personally experience shallow areas and examine the underwater landscape.

From 1945 to present day, in the Contemporary World, many highly sophisticated technologies have been developed. To save money, time, and receive real-time data, scientists want to establish permanent underwater observatories on the seafloor. These observatories obtain important measurements and data that is shared between scientists around the world. Seafloor observatories would be monitored via submerged fiber-optic cables or telegraphic cables and then satellites would transmit the data directly to scientists in real-time [See Figure 17] ("History of Oceanography", http://divediscover.whoi.edu/history-ocean/21st.html). For years, film director and now National Geographic Explorer, James Cameron and his team designed and tested a vertical submarine, the *Deepsea Challenger*, to descend into the Mariana Trench, also known as Challenger Deep. On March 27, 2012, after several test dives in several shallower trenches, James Cameron descended alone and successfully reached the seafloor at a depth of 35,756 feet [See Figures 18a and 18b] ("Sub Facts", http://www.deepseachallenge.com/the-sub/sub-facts/). This record-breaking dive brought mankind to the deepest point on Earth and reawakened the desire to explore the depths of the oceans.

In September 2015, President Obama called for more Coast Guard ice cutting ships and arctic nautical charting ships to, "gain a foothold", in the ecologically delicate and rapidly changing Arctic. As stated by Julie Hirschfeld Davis in September of 2015, "Mr. Obama will announce an initiative by the National Oceanic and Atmospheric Administration (NOAA) and Coast Guard to map and chart the newly open Bering, Chukchi, and Beaufort Seas." President Obama hopes these ships will make the Arctic region safer for mineral and natural resource exploration (Davis, http://www.nytimes.com/2015/09/02/us/politics/obama-to-call-for-more-icebreakers-in-arctic-as-us-seeks-foothold.html?_r=0). One of the most fascinating tools used to map the oceans is Fledermaus. Fledermaus is a 4D geographic information software program that creates a picture of the seabed make-up and is the premier 4D visualization tool for dense multibeam SONAR data (“Fledermaus”, http://www.qps.nl/display/fledermaus/main). This software is leading the world in computerized maps and visual devices for exploring the ocean and its resources. With the deployment of United States ice cutters and the implementation of Fledermaus software, deep-ocean mining and natural resource extraction will be safer and easier.

In December 2015, XPRIZE announced the launch of a $7 million Shell Ocean Discovery three-year global competition challenging teams to advance ocean technologies for rapid and unmanned ocean mapping. Teams are required to make a bathymetric map, which is a map of the seafloor. This challenge is hoped to accelerate technological innovations to explore the greatest unexplored frontier, the oceans (Desatnik, http://oceandiscovery.xprize.org/press-release/new-7-million-xprize-competition-seeks-usher-new-era-of-ocean). With the new technologies currently being designed, scientists hope to explore more of the oceans and preserve them while also extracting precious metals and natural resources.

For the extraction of minerals and natural resources, there are few similarities between the three time periods. Dredging is a commonly used technique that is still considered useful for underwater mining. The bathysphere, SCUBA, seafloor observatories, and the *Deepsea Challenger* were designed to achieve a common goal throughout the three time periods: for humans to personally experience the depths of the oceans and document the details of the ocean floor. However there are significant variations between the different eras. Vehicles like the *Deepsea Challenger* and ice cutting ships use numerous technologies at once, including computers and Fledermaus to analyze and record data. A most significant difference is that private companies like Shell and XPRIZE have a vision for mapping the entire ocean by 2018.

Conclusion

Ocean mapping provides the foundation for understanding the ocean's depths and mankind's use of the oceans for commercial, military and natural resources extraction purposes. During the Contemporary World period (1945 to present), the United States and Europe have produced more sophisticated technologies to accurately map the ocean topography at greater depths for commercial, military, and mineral extraction purposes than the science and technological advancements in ocean exploration during the Age of Imperialism (1800-1920) and the Modern World Wars (1914-1945) periods combined. Many of the rudimentary technological devices from before 1945 have been improved and expanded. For example, SONAR started as a single beam of sound and is now being used in multibeam and sidescan ways. When designing the *Deepsea Challenger*, James Cameron and his team modeled it after the bathyscaphe. Therefore, the majority of the advances in ocean mapping technologies have occurred within the last 70 years. Specifically, these more recent technologies map areas in significantly more detail, are much more efficient, and can record depths greater than ever before. Technologies utilized since 1945 have focused on reaching and documenting the deepest points in the ocean. Contemporary World technologies such as SCUBA, submersibles, seafloor observatories, and the *Deepsea Challenger* allow scientists to experience the ocean depths.

Despite the progress by the United States and European countries between 1800 and World War II, and the tremendous technological and scientific advances in hydrography during the Contemporary World period (1945 to present), 95% of the ocean is yet to be mapped or explored. Ocean discoverer, explorer, and historian, Dr. Robert Ballard states, "… most people think the age of exploration is in our rear view mirrors. It's something that occurred in the 1700 and 1800s. Yet, in fact, it's in our future (http://www.perspectivesonoceanexploration.org/)." In conclusion, world powers like the United States, France, Germany, and Russia recognize the importance of uncovering the mysteries of the depths of the seas for their economic and military security, and claims to rights to natural resources.

Appendix

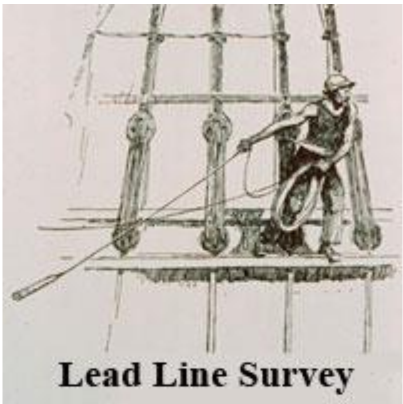

Figure 1: Lead Line Survey illustration ("History of Hydrographic Surveying").

Figure 2: Wire Drag Survey illustration ("History of Hydrographic Surveying").

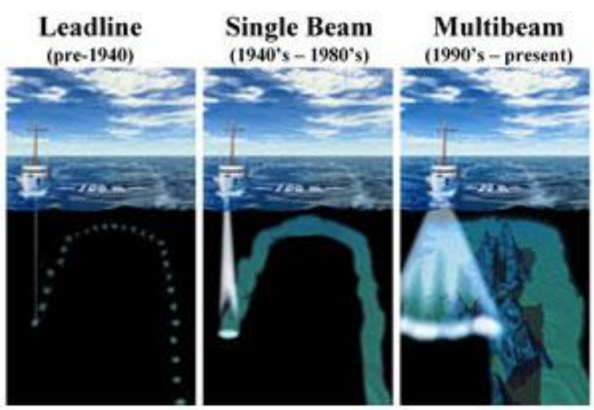

Figure 3: Comparison between Leadline, Single Bream, and Multibeam echo sounding devices ("History of Hydrographic Surveying").

Figure 4: Herbert Dorsey with the Dorsey Fathometer around 1930 (NOAA Photo Library) ("Age of Electronics (1923-1945)").

Figure 5: A bathythermograph ("Tool of the Times").

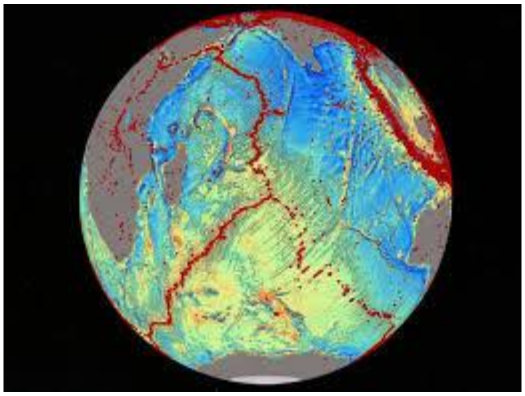

Figure 6a: A new marine gravity altimeter model of the central Indian Ocean, which is poorly charted. The red dots represent strong earthquakes, which together outline the locations of current seafloor spreading ridges (David Sandwell, Scripps Institution of Oceanography) (Gramling).

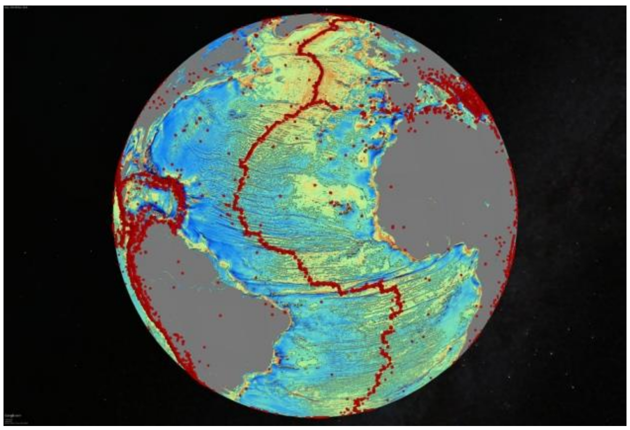

Figure 6b: A marine gravity altimeter model of the North Atlantic Ocean basin reveals tectonic history in sharp detail. Red dots show earthquake magnitude of 5.5 or higher (David Sandwell, Scripps Institution of Oceanography) (Witze).

Figure 7: The Autonomous Benthic Explorer is an AUV that has created some of the most detailed maps of the seafloor terrain ("History of Oceanography").

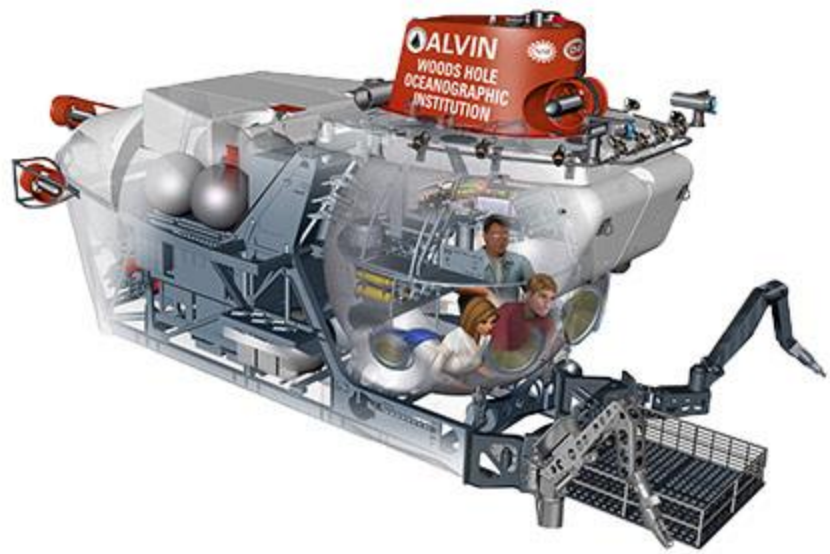

Figure 8: The Deep Sea Vehicle Alvin is an ROV that has allowed researchers to study the depths and find wreckages (Google Images).

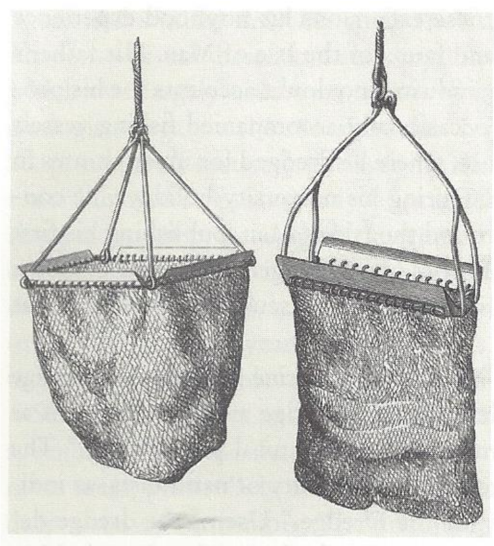

Figure 9: Muller's dredge (left) and Ball's dredge (right) (Rozwadowski).

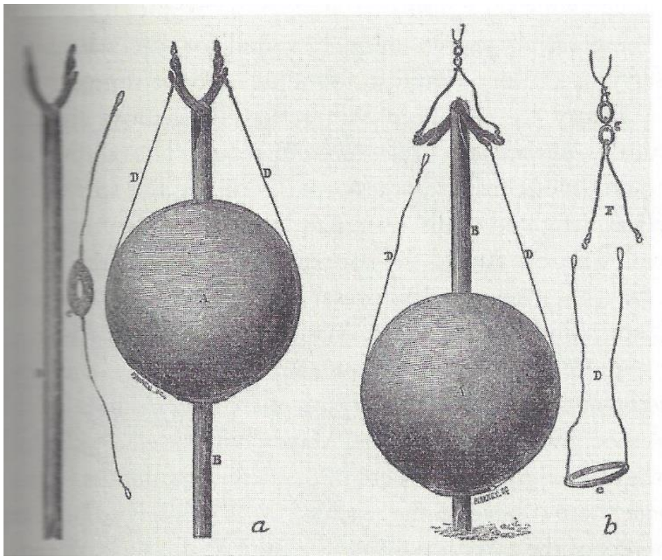

Figure 10: Brooke's deep sea sounding apparatus for bringing up specimens of the bottom. a. Ready for sounding; b. at moment of release on reaching bottom (Rozwadowski).

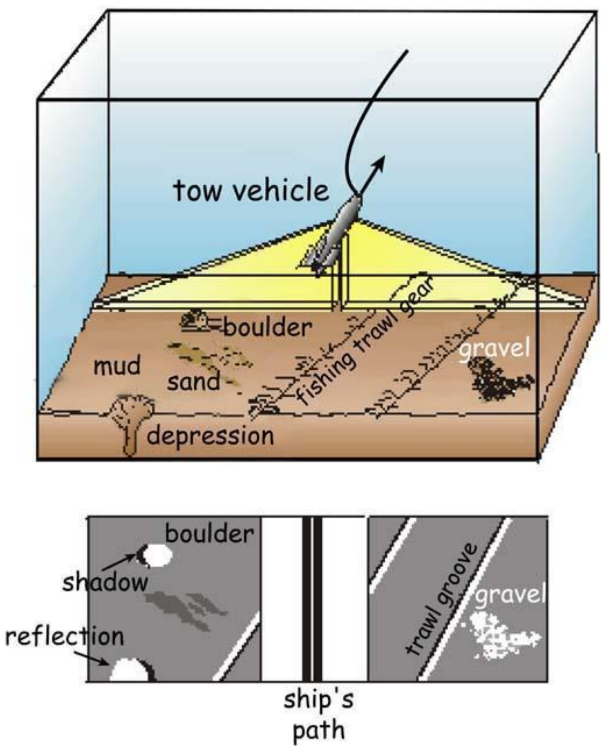

Figure 11: Schematic diagram of a sidescan SONAR towed instrument insonifying the seafloor (top) and the sidescan data recorded (bottom) (Embley).

Figure 12: Submarine cable images (Burns).

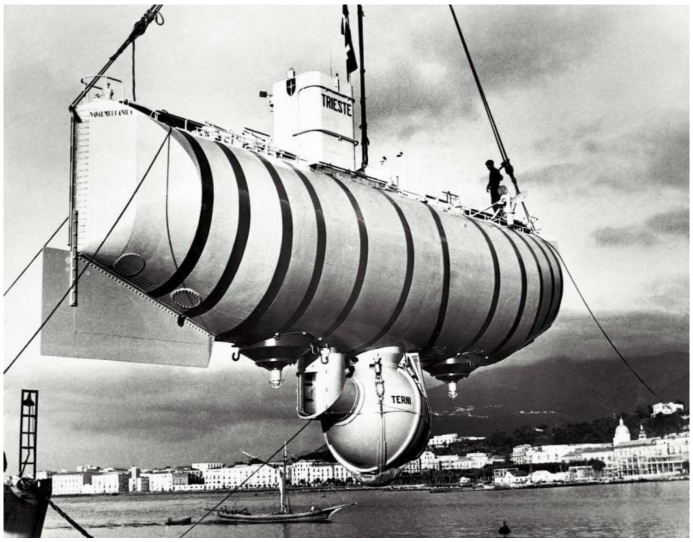

Figure 13: The Trieste, the bathyscaphe (Google Images).

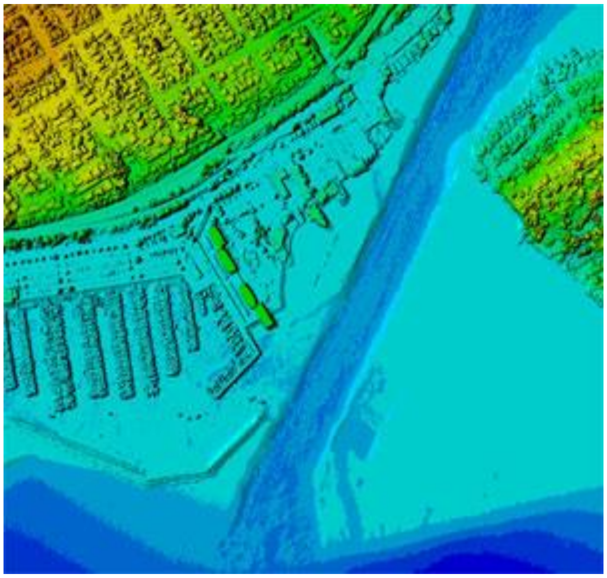

Figure 14: Lidar image of a port ("Lidar").

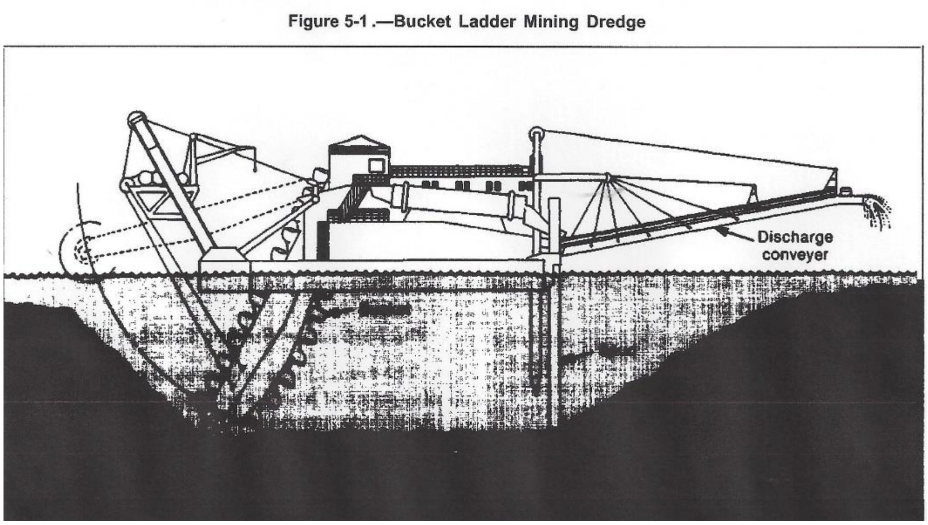

Figure 15: The bucket ladder dredge is a proven and widely used dredge for offshore mining (Office of Technology Assessment).

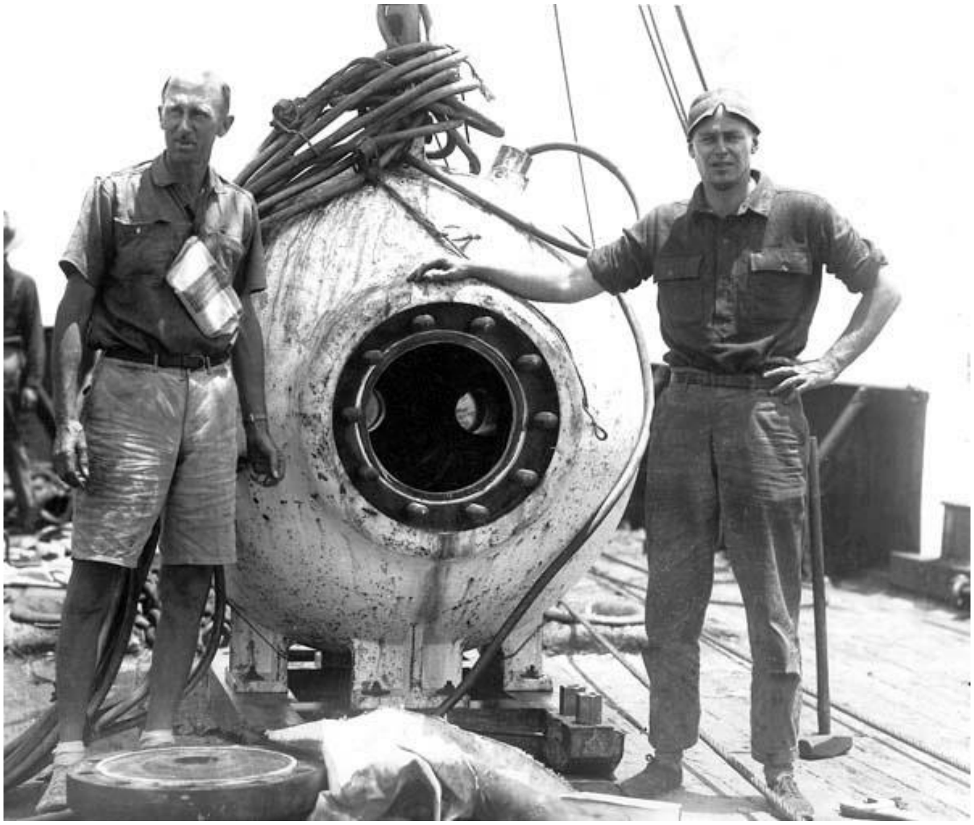

Figure 16: William Beebe and Otis Barton pose with their invention, the bathysphere (Ralph White/Corbis) (Lerner).

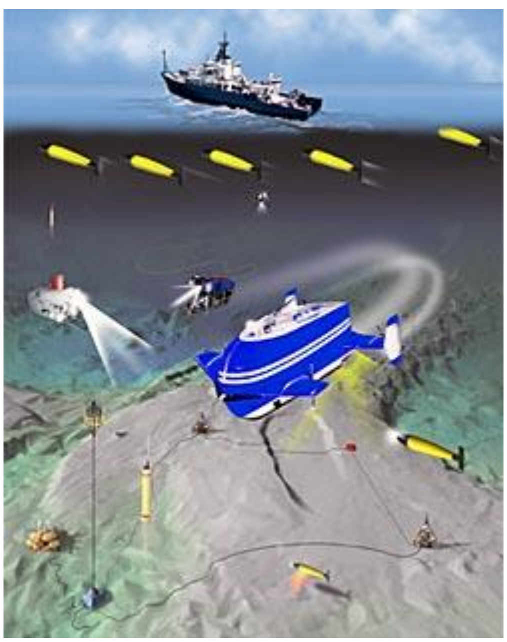

Figure 17: Components of a seafloor observatory ("History of Oceanography").

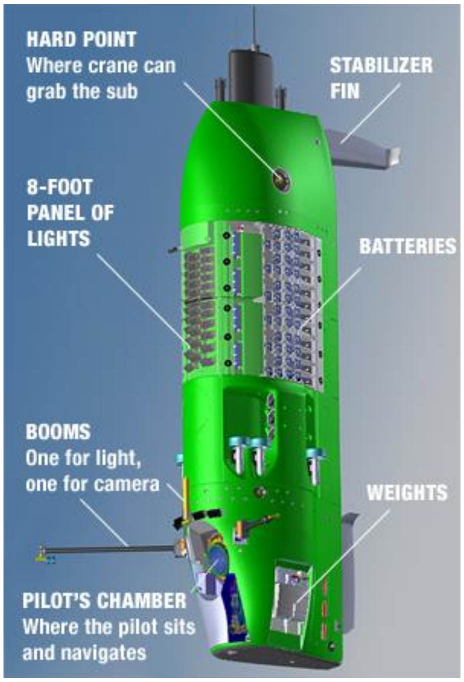

Figure 18a: An illustration of the Deepsea Challenger (Acheron Project Pty Ltd) ("Sub Facts").

Figure 18b: The Deepsea Challenger being lowered into Sydney Harbor on a test run ("Sub Facts").