

EFFECTS OF OFFSHORE GEOHAZARDS ON TRANSOCEANIC  
COMMUNICATIONS CABLES

Research Report prepared by

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## 1. Introduction

Fast, reliable international communication (telephone, internet, and other data transmission) has become extremely important for the effective functioning of governments and economies. While satellite technology provides some transmission capability, offshore cable systems carry 95% of international voice and data traffic (Nielsen, 2009). Such cables have characteristics of high reliability (more dependable installation and repair practices), high capacity (new technology with increased bandwidth), security and privacy (harder to eavesdrop on cables than satellite communications), as well as no delays, which are present in satellite technology (Carter, 2009). Communication through cable lines is also more cost-effective on major routes compared with satellite transmission

Cable technology has evolved significantly over time and while today's cables have more advanced materials and fabrication configurations that provide greater protection against potentially damaging influences, they are still quite vulnerable. Cables must be designed, routed, and placed so they can survive any number of potential damaging effects, including landslides, mudslides, and earthquakes (Nielsen, 2009). Transoceanic cable security is a relatively unexplored issue, and cable exposure to offshore geohazards such as landslides and seismic events has not been adequately explored. The potential for damage to offshore cable systems due to natural and/or manmade hazards was demonstrated during the Hengchun earthquake of December 26, 2006. Besides seabed displacement that severely damaged the Sina-US cable, Asia-Pacific Cable 1 & 2, FLAG Cable, Asia-Euro Cable and FNAL Cable, the earthquake triggered a one meter high tsunami. Thus, not only were the cables broken and severed, but other earthquake damage, including the effects of the tsunami, restricted the ability to conduct damage assessment and repair work. Restoration of the broken submarine cables took over a month (Aiwen, 2009).

This report describes the evolution of submarine cable installation and use, the extent of the cable system, and site characterization criteria used for placement of the cables. In addition the report presents an overview of cases where the effects of natural hazards caused damage and disruption to the cables.

## 2. History and Background

Underwater telegraphic communication had been conceptualized since the telegraph was first invented in the early 1800's. Nonetheless, the lack of both wire protection and installation methods prevented the concept from implementation until gutta percha, a natural thermoplastic, was invented in the 1850's (Burns, 2009). The first attempt to install an international telegraph link from England to France occurred in 1850, but was thwarted by a fisherman who accidentally cutting it. A second, successful attempt was made in 1851 and represented the first time that two countries separated by a body of water, could communicate by electric telegraph. As a result of this success, a boom started in the installation of submarine cables, but these crossings were limited to the Irish Sea, North Sea, Mediterranean Sea, and Black Sea (ISCPC, 2009). Later, cables

joined Europe and the United States and Canada. They took hours to transmit messages and many only lasted a number of weeks before failing (Hayes, 2008). In 1858, the first transatlantic cable was placed, connecting Newfoundland and Ireland, but it failed because the cable snapped. After three more attempts, a successful crossing was finally made in July of 1866 (Carter, 2009). In the 1920's, radio superseded cable for voice, but compared to cable-based transmissions, it was unreliable and had a very small capacity (Carter, 2009). In the 1940's, the repeater was invented, allowing for voice capabilities over cable to improve, and allowed for longer distances to be possible for communication. In 1956, the first submarine cable incorporating repeaters was invented. (ISCPC, 2009). Figure 1 is a more distinct showing of the progress of the cable over its lifetime.

Cable	Year	Speed or capacity
Atlantic, Ireland–Newfoundland	1858	A few words per hour
Atlantic, Ireland–Newfoundland	1866	6–8 words per minute
Long cables with automatic transmitting equipment	1898	40 words per minute
Newfoundland–Azores	1928	2500 characters per minute (~400 words per minute)
TAT-1	1956	36 telephone channels
CANTAT	1961	80 telephone channels
TAT-3	1963	138 telephone channels
TAT-5	1970	845 telephone channels
TAT-6	1976	4000 telephone channels
TAT-8	1988	Two fibers/cable, 280 Mb/s/fiber
TAT-9	1992	Two fibers/cable, 560 Mb/s/fiber
TAT-12/13	1996	Two fibers/cable, 5 Gb/s/fiber
TAT-14	2001	Four fibers/cable, 16 wavelengths/fiber, 10 Gb/s/wavelength
Apollo	2002	Four fibers/cable, 16 wavelengths/fiber, 10 Gb/s/wavelength

Figure 1. Timeline of Cable History and Capacity

The TAT-1 was this first successful transatlantic telephone cable system. Initially it had a capacity of only 36 calls, or channels, at one time and was very expensive, limiting only the wealthy to have this privileged communication (Carter, 2009).

The cables evolved through the 1950's and were improved to be made from a modern lightweight coaxial cable which had a high-tensile steel core and polythene outer skin for insulation (ISCPC, 2009). This development allowed for improvement in the quality of calls in the 1960's to the 1970's. The first international optical fiber cable connected the UK and Belgium in 1986, and the first fiber-optic, transatlantic cable (TAT-8) was placed and went into operation in 1988 (Carter, 2009). A fiber-optic cable is comprised of multiple pairs of fibers, which allowed for the capacity to increase to about the equivalent of 40,000 simultaneous calls on each fiber pair. Each fiber pair within the cable has the

capacity to carry digitized information, including video (Carter, 2009). Figure 2 shows the extent of the existing offshore cable routes currently in use.

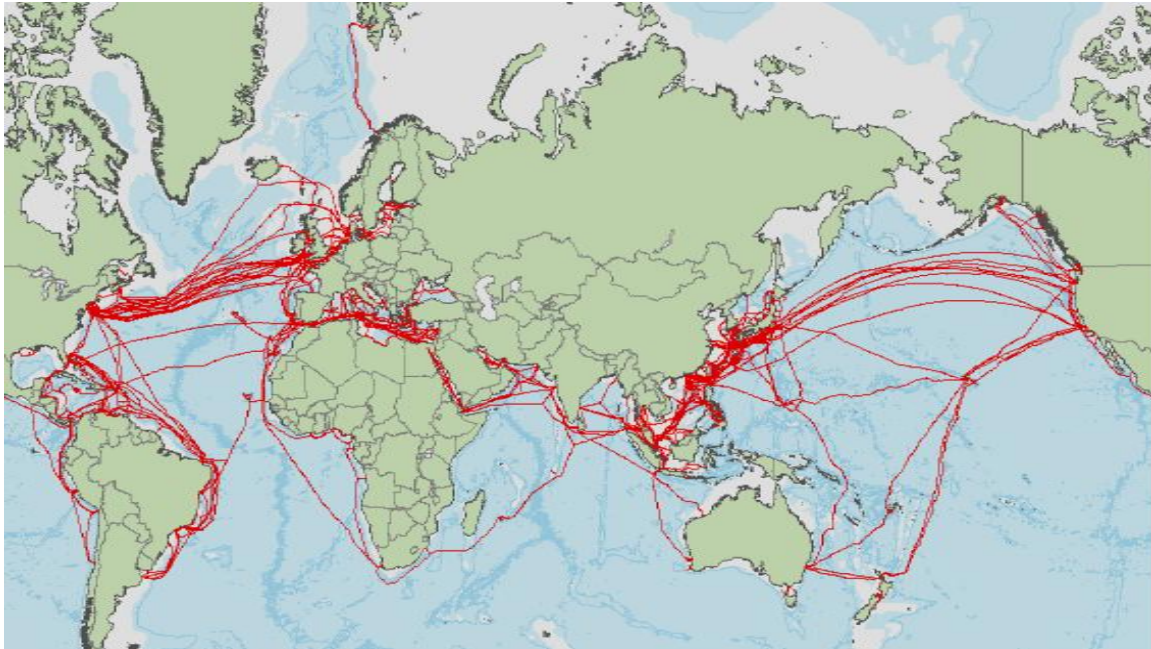


Figure 2: International Offshore Cable Routes  
(From Global Marine Systems Ltd.)

### 3. Site Characterization for Cable Placement

A number of considerations are involved with the engineering selection of locations for cables, both in terms of their onshore location and offshore route. First, there must be suitable beach approach for the shore end (Histed, 1979). The desk top study is the first step in route planning and it is primarily a data search to evaluate potential landing points. Often times, it is common to begin communicating with local authorities and other users near the prospective landing points. The characteristics that describe a suitable beach end are sometimes at odds with each other and balancing the characteristics creates a lengthy process when planning the route. There is a need to connect efficiently to selected cities or stations and therefore key restrictions must be remembered when planning a route. The cable must be protected from geologic and human hazards, potential repair scenarios must be considered, conflicts with other users of the seabed must be minimized and impacts on any sensitive environmental receptors, for example reefs, and must be minimized (Axelsson, 2008). Second, the site must be easily accessible by road for installation equipment to reach it, and ultimately for operational access. Third, there must be electrical power availability at the site. In addition, the coastline should be relatively free of trawler fishing activities and anchoring facilities (Histed, 1979). Figure 3 is an example of an AT&T building where there is a submarine cable termination in Puerto Rico.



Figure 3. Termination building for offshore cable (TD-2) in Puerto Rico (from Shore.Net, 2009)

While we are provided the ability to take satellite images and airphotos with new technology, in most cases, the single most useful data source for pipeline route selection is black-and-white stereoscopic aerial photography for terrestrial (land-based) pipelines and cables. LIDAR (Light Detection and Ranging) imagery is a highly accurate and rapid method for detecting and measuring both the top of the vegetation canopy and the ground surface below. It is very useful when designing long pipelines over varying terrain (Mollard et. al., 2008). Airphoto terrain analysis relies on the recognition of landforms and more importantly landform changes over time (Mollard et. al., 2008).

For offshore route mapping, it is important to explore the surrounding seabed to be sure there are no other obstacles in the way; for example existing cables or fishing gear and shipwrecks. The application of multi-beam here is essential because it is the way bathymetric data of the underwater sea bed is acquired and makes it much easier to get the topographic survey. The topographic survey is ideal for planning a route because it shows the contours and depths along the seafloor. Since cables are very delicate and must be placed at a certain speed depending on the topography, they are very restrained from where and how they are placed. The flattest path is preferred because the process of laying the cables is least difficult. In one case, the multi-beam was very useful because it helped discover a narrow, deep ditch right along a planned cable route and forced another route to be planned for the cable (Liu et. al., 2005). It is important to have this surveying technology so that the safest cable route can be planned in order to eliminate potential damage from the cable as well as extend the cable's life span.

#### 4. Methods of Installation and Configuration

The process known as Hydroplow embedment process (jet plowing) is the common proposed method of installing submarine cables. This method allows for simultaneous laying and embedment of submarine cables in on continuous trench by using a towed hydraulically-powered jet plow device. At the shoreline, horizontal directional drilling is implemented in order to transition from the land cable construction to the submarine cable installation as well as to minimize environmental impacts along the shoreline. In order to install a section of pipe below ground to a point near the high water mark on the beach or a short distance off shore, a drill rig is set up on land near the shoreline. Finally, at the end point of the drill hole, it will be excavated and a trench box will be installed. Then, the submarine cable will be pulled through the drilled section and passed along to the jet plow. Here, the submarine installation begins. Figure 4 shows part of the cable laying process in 3-D.

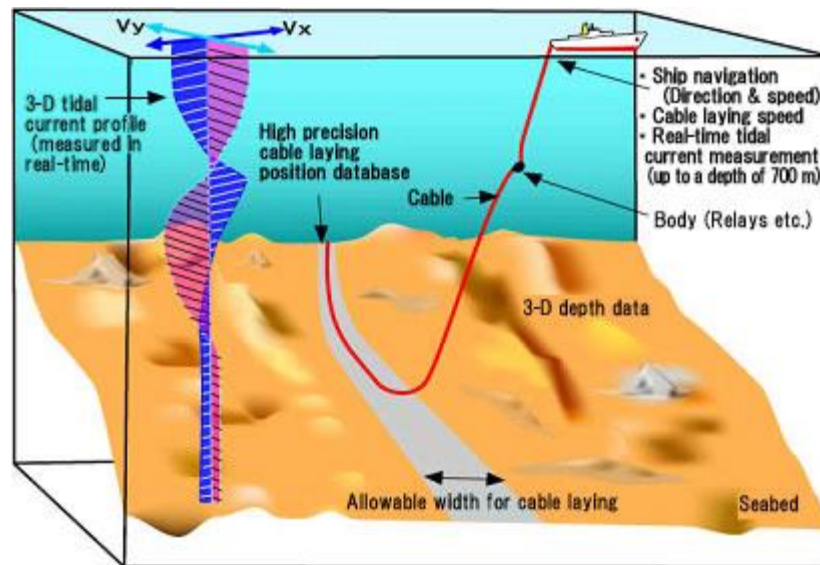


Figure 4. 3-D view of cable laying  
(NTT World Engineering Marine Corporation)

Typically, cables are buried 1 to 3.5 meters in the seabed until the water reaches 2000 meter in depth, which is usually deep enough to avoid shallow water hazards such as fishing. On occasion, the burial depth may increase to about 10 meters for extra protection in areas where shipping, fishing and other maritime activities occur with regularity (Carter, 2009). The burial depth must be deep enough for protection, but as shallow as possible to allow repairs if needed.

For the submarine phase of the cable installation, there are cable-laying ships specifically designed for laying submarine cables. Sea plows are often employed (dragged behind the ship) to dig trenches in which the cables are placed (Fig. 5).



Figure 5. Sea plow and cable ship about to bury submarine cable (from ISPC 2009)

In order to bury the cable, the soil is temporarily loosened by the plow's water nozzle and carefully creates a narrow trench in which the cable can lay. As the plow progresses the cable is fed into the trench from the back end of the plow as it advances across the ocean floor. It is important to mitigate any disturbance to the seabed; therefore the cable is buried about eight feet below the ocean floor. At that depth, there is no effect on any uses of the seabed or marine environment. Once the cable is placed, the marine sediments resettle over the cable, closing the trench with minimal disturbance to the seabed (Nantucket Electric, 2009).

These trenches are less than a meter in width and vary in depth depending on location and how deep in the water it is. When closer to shore, the burial depth is deeper than burial depth located farther from shore. Eventually, the cable simply lies right on the ocean floor.

First, the cables must be brought ashore by a “messenger“ (actual human being or a robotic machine) and flotation bags are attached to the cable about every thirty feet as it leaves the ship. Once the cable is in position, the bags are cut away from the cable, allowing it to sink. Figure 6 shows the cable being carefully monitored by works to be sure the ship is releasing the cable as necessary.



Figure 6. Workers directing cable off ship into ocean (from ISPCPC)

Once the cable is secured on land, the cable is transferred from the bow of the ship to the stern, the ship continues on, paying out the cable along the chosen route. There are pairs of wheels on the ship that grip the cable as it is released off of the ship into the water. The engine can control the speed of cable payout up to eight knots and maintain tensions of up to 25,000 pounds (Bonds et al., 1979). It is very important that meticulous navigational checks are made throughout to ensure that the system is laid along its planned route with repeaters in planned position (Figure 7).



Figure 7. Navigational System in Cable Laying Ship (from France Telecom)

Among the other factors that must be considered in placing the cable, there are sea life, chemicals, electric corrosion, abrasion, seabed movement, transient impacts, sustained force, and a relatively recently identified threat, terrorism (Nielsen, 2009). The remainder of this report will focus on the threat posed by offshore geohazards to these cables.

##### 5. Threats to Transoceanic Cables due to Offshore Geohazards

As previously noted, a significant threat to submarine cable integrity is seabed movement, which includes that resulting from natural geohazards such as landslides, earthquakes, tsunamis, and volcanic activity. Also, chemically, there are substances that can easily disintegrate cables and cause failure in the connection. Since cables are buried shallow in the seabed sediment, it is necessary to find routes with the least seismic risks so the cables are not as prone to breakage (Nielsen, 2009).

There are a variety of geohazards that impact cables, some of which include earthquakes consisting of fault rupture or liquefaction, volcanoes, landslides, gulying and soil erosion, karst-limestone or karst-gypsum (resulting in sink holes), and river channel migration. Most of these hazards have design and construction requirements in order to mitigate the damage on cables. If there is no present solution, routing is suggested to avoid the vicinity of the geohazard. Some design suggestions involve special trench design, soil improvements, or simply maintaining sufficient depth of burial. There are also special cable protection designs that are similar to a protective casing that is formed around the cable to add extra protection, but this usually makes the cables too heavy;

therefore it is only used in cases where the cable is at a higher risk of damage. For example, when fishing is at a high rate or where ships are prevalent. This makes accessing the cable inconvenient, especially for repairs when the cable must be repositioned (Nielsen, 2009).

There are a few documented cases of natural geohazards impacting offshore cables. On November 18, 1929, a magnitude 7.2 earthquake occurred at an estimated depth of 20 km beneath the sea floor at the southern edge of the Grand Banks (mouth of the Laurentian Channel, Northwest Atlantic). Soon after, a tsunami was triggered, but analyses show that the tsunami was a result of a slope failure rather than the earthquake itself. An orderly sequence of breaks occurred in the transatlantic cables, running from North America to Europe, passing south of Newfoundland, at distances up to 500 km from the epicenter of the earthquake. Twelve cables in total were affected by this slope failure and snapped from the turbidity current generated by the slump on the continental slope. Ultimately, the landslide was transformed into a turbidity current carrying mud and sand that flowed eastward up to 1000 km along the Atlantic seafloor.

In August of 2005, Hurricane Katrina flooded coastal facilities, triggered submarine landslides, and formed strong, eroding currents and waves (Nielsen, 2009). These landslides and powerful waves and currents can either break or bury the cables so that they do not work or are extremely difficult to find. As a result, there are more offshore platforms and they are built close enough so that a ring of unrepeatable submarine cable systems can connect a number of platforms without any submerged repeaters, as these are very costly. Repeaters are used in design of longer cables in order to receive and retransmit signals so they can cover longer distances. (Arnos, 2009). In this case, because the cables aren't very long, repeaters aren't needed at locations where the cables are submerged.

On December 26, 2006, in an area of the Luzon Strait, south of Taiwan, large earthquakes, Hengchun and Sumatra, and its aftershocks hit. This Strait contained nine submarine cables, seven of which were severed. It was not until February of 2007 that all of the cables were reported as repaired (NANOG42, 2008). The shift in tectonic plates caused sudden, unexpected movement and as a result, the cables broke. The result of these cable breakages was indirect economic loss. Figure 8 shows the epicenters and the effected cables.



Figure 8. Effected Cables from Taiwan Earthquakes (From Aiwen, 2009)

Internet connections became extremely slow in accessing overseas websites and any connections other than to the Chinese mainland were debilitated. Not only were internet connections affected, but also voice communication and other telephone services. Furthermore, the aftershock of the earthquake brought serious, inclement weather causing repairs to take longer and be more difficult. (Aiwen, 2009).

## 6. Conclusion

Delicate cables require that their planned routes protect them from any possible hazards. With such a high reliability on them and their use being 95% of international communication means, it is important that they are protected. First, finding a cable route can be complicated with the different seafloor contours and ditches. The newest technologies can help in discovering these hazards before the cable is even placed so they can be avoided. Also, in the first stage of cable research (the desk top study), routes planned can be researched for percentages of natural hazards and fishing and shipping activities so these can be avoided. Avoiding dangerous routes can help extend the lifespan of the cable. This is more than ideal since the process of laying the cable is so meticulous and lengthy.

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