About
Submarine Telecommunications Cables
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1840: Telegraph cables start to be laid across rivers and harbours, but initially had a limited life.

1843-1845: Gutta-percha (a type of gum found in a Malaysian tree) was brought to Britain and starts to replace other materials that were used for electrical insulation, thus extending the life of the cable.

1850: 1st international telegraph cable laid between UK and France, followed by a stronger cable in 1851.

1858: 1st transatlantic cable laid between Ireland and Newfoundland by Great Eastern. This failed after 26 days and another was laid in 1866.
A Brief History – 2

- 1884: 1st underwater telephone cable - San Francisco to Oakland
- 1920s: Short-wave radio superseded cables for voice and telex traffic, but capacity limited and affected by atmosphere
- 1956: Invention of repeaters (1940s) and their use in TAT-1, the first transatlantic telephone cable, began an era of rapid and reliable transoceanic communications
- 1961: Beginning of a high quality global network
- 1986: 1st international fibre-optic cable connects Belgium to the UK
- 1988: TAT-8, the 1st transoceanic fibre-optic cable system, connects the USA to the UK and France
Comparing Old and New

Early Cable Systems:

- 1866: 1st transatlantic cable carried telegraph messages at seven words a minute and cost £20 for 20 words
- 1948: Telegram cost reduced to 4 pence a word for transmission across the Atlantic
- 1956: 1st transatlantic telephone cable (TAT-1) initially had capacity of 36 telephone calls at a time. Each call cost US$12 for the first 3 minutes

Modern Cable Systems:

- 1988: 1st transatlantic fibre-optic cable, TAT-8, carried 40,000 simultaneous phone calls, 10 times that of the last copper-based telephone cable
- Today, a single cable can carry millions of telephone calls, together with huge amounts video and internet data
Submarine Cable – Telegraph Era

- conductor - usually copper
- insulation - *gutta percha* resin
- cushioning - jute yarn
- inner protection - wire armour
- jute wrap to contain wire
- outer protection - wire armour
- jute wrap to contain armour

Harvesting *gutta percha* resin
Source: Porthcurno Telegraph Museum

Atlantic cable 1866
Source: Porthcurno Telegraph Museum
Modern Submarine Cable

- Optical fibres - silica glass
- Core for strength and fibre separation - polyethylene/fibreglass
- Jacket - polyethylene
- Conductor - copper
- Jacket - polyethylene
- Protective armour - steel wire
- Outer protection and wire containment - polypropylene yarn

- Construction varies with manufacturer and seabed conditions
- Cables may have no armour in stable, deep-ocean sites or one or more armour layers for energetic zones, e.g. coastal seas

Source: Ericsson
Early Cable Ships

**Goliath**: lays 1st international cable, UK-France, 1850-1
*Source: Illustrated London News*

**Great Eastern**: laying cable off Newfoundland, 1866
*Source: Canadian Government*

**John Pender**, named after pioneer cable maker, 1900
*Source: Cable & Wireless*

**Monarch**: laid 1st transatlantic telephone cable, 1955/6
*Source: www.atlantic-cable.com*
Cable Repair in 1888

[A] Cable ship trailing grapnel to retrieve cable followed by [B] securing of the cable ready for repair

Source: *Traité de Télégraphie Sous-Marine* by E. Wüschendorff, 1888
Modern Cable Handling Methods

Bringing the cable ashore
*Source: Global Marine Systems*

Cable and repeaters inside a cable ship
*Source: TE SubCom*

ROV used for cable inspection, recovery and burial
*Source: TE SubCom*
Fibre-optic submarine cables rely on a property of pure glass fibres whereby light is guided by internal reflection.

Because the light signal loses strength en route, repeaters are required at regular intervals to restore it.

Repeaters are now based on optical amplifying technology, which requires short lengths of erbium-doped optical fibre to be spliced into the cable system. These are then energized by lasers that cause them to ‘lase’, thus boosting the incoming light signal.
Typical Submarine Cable System

Source: UK Cable Protection Committee and Alcatel-Lucent Submarine Networks
Cable Size

- Cables are small: deep-ocean types, without protective armour, are typically 17-20 mm diameter – the size of a garden hose or beer bottle cap.
- Armoured fibre-optic cables may reach 50 mm diameter.
- In contrast, submarine oil/gas pipes can reach 900 mm diameter, and fishing trawls typically range over 5,000 – 50,000 mm wide.
- One of the longest cable systems is the South East Asia - Middle East - West Europe 3 system (SE-ME-WE-3), with a total installed length (including branches) of almost 40,000 km.

Deep-sea cable, (black) sectioned to show internal construction; fine strands at top are optical fibres used to transmit data.

Modern fibre-optic cable in hand (for scale) and relative to 600 mm diameter subsea pipe.

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Joint Boxes and Repeaters

Modern Fiber Optic Joint Box and Repeaters (roughly to-scale)

Bend Limiter/Buffer | Flexible Coupling | Amplifier Section | Flexible Coupling | Bend Limiter/Buffer

Approx. 6'

Bend Limiter | Splice Case | Flexible Coupling (Armadillo) | Amplifier Section Variable, 28” to 58”

Max. Approx. 14.5’

Source: Lonnie Hagadorn
Submarine Cables and Satellites

Advantages of cables
- High reliability, capacity and security
- Insignificant delay compared to satellite
- Most cost-effective on major routes, hence rates cheaper than satellites

Carry >95% of transoceanic voice and data traffic

Advantages of satellites
- Suitable for regions that are vulnerable to disasters
- Provide wide broadcast coverage, e.g. for TV
- Suitable for minor routes such as links between small island nations

Carry <5% of transoceanic voice and data traffic
Coastal Cable Routes

- Near the shore, cables need protection from shipping, fishing and other activities.

- To reduce risk, cables and protection zones are identified on nautical charts.

- A cable protection zone is a legal entity where activities harmful to cables are banned.

- Cable burial in water depths up to 2000 m is also a key protective measure.

Chart with protection zone for Southern Cross cable terminal in New Zealand

*Source: Telecom NZ*
Installing a submarine cable typically involves:

- Selection of provisional route
- Obtaining permission from the relevant authorities
- Full survey of route and its final selection
- Design cable system to meet conditions of selected route
- Laying the cable, including burial in appropriate areas
- In some cases, a post-lay inspection may be necessary
- Notification of cable position to other marine users
Cable routes are carefully surveyed and selected to minimize environmental impacts and maximize cable protection.

Seabed mapping systems accurately chart depth, topography, slope angles and seabed type.

Source: NIWA
Guided by the route survey, specially designed ships are used to accurately place cables on or beneath the seabed.

Shallow water laying may be aided by divers; Deep water laying may involve remotely operated vehicles.

Source: Alcatel-Lucent Submarine Networks
Cable Burial - 1

- Cables may be buried in a narrow (<1 m wide) trench cut by water jet or plough.
- The plough lifts a wedge of sediment so that the cable can be inserted below.
- Burial speed depends on cable type and seabed conditions.
- For an armoured cable, the burial speed is about 0.2 km/hr.

A plough being prepared to start the burial of a cable.

Source: Seaworks, NZ
Cables are typically buried 1 m and exceptionally up to 10 m beneath the seabed to protect against trawl fishing, ships anchoring and other activities.

Burial may extend from the shore to about 2000 m water depth, which is the present limit of trawl fisheries.

Burial may locally disrupt the seabed along a narrow path and form turbid water. The extent of this is dependent upon burial technique, seabed type and wave/current action.

In the absence of cable-based studies, analysis of seabed disturbance from fishing and other activities suggests that impacts are short-lived (months) where waves/currents are active, but possibly longer-lived in deeper, less turbulent water.
In the event of a fault, the cable has to be recovered from the seabed so that a replacement section can be spliced in:

Source: Alcatel-Lucent Submarine Networks
Recognizing the value to humanity of international communications, cables are protected by international treaties:

- 1884: The International Convention for the Protection of Submarine Cables
- 1958: The Geneva Conventions of the Continental Shelf and High Seas
Modern international law extends the special status of international cables to all uses:

- Telecommunications
- Power
- Scientific
- Military
The international treaties establish universal norms:

- Freedom to lay, maintain and repair cables outside of a nation’s 12 nautical mile territorial sea
- National obligations to impose criminal and civil penalties for intentional or negligent injury to cables
- Special status for ships laying and repairing cables
- Indemnification for vessels that sacrifice anchors or fishing gear to avoid injury to cables
- Obligations of cables crossing earlier laid cables and pipelines to indemnify repair costs for crossing damage
- Universal access to national courts to enforce treaty obligations
The International Tribunal for the Law of the Sea, Hamburg, Germany

Source: Stephan Wallocha
Legal boundaries of the ocean from Territorial Seas to Exclusive Economic Zone and onto the High Seas

Note: The numbers in (brackets) refer to treaty articles

Source: Doug Burnett
ATOC/Pioneer Seamount scientific cable with attached anemones (*Metridium farcimen*) located in 140 m water depth off California

*Source: Monterey Bay Aquarium Research Institute*
Properly laid, fibre-optic cables have a neutral to benign impact on marine environment.

A cable’s small size means its “footprint” is small, especially compared to submarine pipelines or trawl dredge.

Cables are substrates for marine organisms with recovered cables yielding key specimens for scientific collections.

Telecommunications cable with encrusting marine organisms

Source: Glaucio Rivera
Scientific tests undertaken in the UK show that:

- Cables are fully colonised by marine organisms in 1-2 months depending on conditions
- Cables are essentially non-polluting

Diver checks lengths of fibre-optic cable (C) and plastic pipes (P) that act as controls to check rates of colonisation by marine organisms

Source: Dr K. Collins, Southampton University
Coils of cable have been placed off Maryland and New Jersey to form artificial reefs.

These reefs have attracted many marine organisms that range from algae to fish.

To be successful, reefs must be stable, non-toxic, last for 20-30 years and provide habitats.

Submarine cable coiled to form an artificial reef on the continental shelf off the US state of Maryland. This picture shows colonisation by starfish, mussels and other organisms that may help biodiversity & fish stocks.

Source: © Compass Light
Cable Protection Zones as Sanctuaries

- Zones that are created to protect submarine cables could act as marine sanctuaries, thus improving biodiversity and fish stocks.
- An effective zone must contain habitats that are suitable for fish and other marine life, exist long enough for ecosystems to develop and be policed to prevent illegal fishing.

Experiment to count fish to test if a cable protection zone acts as a marine sanctuary

Source: Leigh Laboratory, University of Auckland
Observing the Ocean

- Ocean observatories are being developed for the long-term monitoring of the marine environment.
- Observation sites will be linked via submarine cables that will provide power for equipment and data transfer to shore.
- Covering many parts of the world, observatories will help detect and warn of natural hazards, measure ocean response to climate change, undertake research and develop technologies.

Source: Neptune Canada and OOI

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Published cable fault data show that from 1877 to around 1960, 16 whale entanglements were noted – mainly involving sperm whales.

Since that period there have been no reported incidents of marine mammal entanglements.

This change in part reflects improved materials and laying techniques.

Compared to telegraph cables, modern cables are stronger, laid under tension with less slack, and are often buried below the seabed in water depths down to 2000 m.

Sperm whale begins dive off New Zealand

Source: NIWA
Faults caused by fish restricted mainly to telegraph cables (pre-1964)

Attacks could be due to cable smell, colour, motion or electro-magnetic field

In 1985-1987, a domestic fibre-optic cable installed in the Canary Islands was damaged by sharks in 1-2 km water depth

These attacks were verified by the presence of shark teeth that were found embedded in the cable

The cable design was subsequently improved with the inclusion of metal tape sheathing in 1988

There is no evidence of faults caused by fish (including sharks) on systems that use this improved cable design
Submarine cables are exposed to natural hazards in all water depths.

In depths to around 1000 m, the main hazards are human activities with natural effects causing under 10% of cable damage incidents.

Natural hazards dominate in water depths greater than 1000 m. These include:

- Submarine earthquakes, fault lines and related landslides - break or bury cables
- Density currents - break or bury
- Currents and waves - abrasion, stress and fatigue
- Tsunami, storm surge and sea level rise - damage coastal installations
- Extreme weather (e.g. hurricanes) - break or bury
- Rarely, icebergs or volcanic activity
Typhoon Morakot struck Taiwan from 7-11 August 2009, when almost 3 m of rain fell in the central mountains.

This caused rivers to flood and carry vast amounts of sediment to the ocean.

So much sediment was discharged that dense sediment-laden currents formed and flowed across the seabed, breaking several cables en route.

While records of such events are too short to identify trends, the enhanced precipitation of Typhoon Morakot is consistent with warmer air and ocean temperatures.

Typhoon Morakot masks Taiwan as it releases a deluge to set off submarine mud flows that broke cables.

Source: MODIS Rapid Response, NOAA
Effects of Climate Change

Cables may be exposed to risks arising from global warming via:

- Rising sea level due to thermal expansion of ocean and melting ice
- Increased windiness and wave/current activity
- More intense storms, rainfall and floods
- Changes in offshore activities, e.g. growth of renewable energy schemes

The global distribution of temperature anomalies for winter 2010. The colder than normal winter in the USA, Europe and Russia is clear, but so is the warmer than average Arctic and much of the Southern Hemisphere. This helped make 2010 the joint warmest year on record. The scale is degrees cooler/warmer than the 1951-1980 average temperature.

Source: Goddard Institute of Space Studies, NASA
Submarine cables are coming into increasing contact with other seabed users, especially fishing and shipping industries.

Sonar image of 25m wide trawl scars, Nova Scotian shelf
*Source: A. Orpin, NIWA*

Trawl scars, Chatham Rise
*Source: M. Clark, NIWA*
Around 70% of all cable faults are caused by fishing and anchoring activities

Around 12% are caused by natural hazards, e.g. current abrasion or earthquakes

Most faults are caused by human activities in less than 200 m water depth

Faults in more than 1000 m water depth are mostly caused by natural events
Cable Damage From Fishing

Illegal fishing in cable protection zone

Cable damaged by trawl gear

Cable snagged and moved by trawl gear

Sources: Seaworks and Transpower NZ
Global pattern of external aggression cable faults, 1959-2006

Source: TE SubCom
Coastal seas are increasingly used for energy projects (wind, tide and wave power), resource extraction and environmental protection (marine sanctuaries, marine protected areas, etc.)

ICPC strongly supports constructive interaction with other seabed users to ensure harmonious access to the coastal seas and ocean.

Offshore wind farm, Middelgrunden, Denmark
Source: © LM Glasfiber
Cables and the Future - 1

“Prediction is very difficult, especially about the future” - Niels Bohr

TECHNOLOGY

- Cable design and operations are constantly evolving. New systems are smaller with greater capacity and reliability

- Further development of ocean observatories will rely on new cable technology. This is likely to include integrated environmental sensors and docking modules to enable submarine survey vehicles to download data and recharge

- Submarine cables, with sensors to detect chemical and physical changes, are planned for maritime and coastal defenses
ENVIRONMENT

- In some regions of the world, submarine cables are likely to be exposed to more natural hazards related to changing climate.
- Climate change may also affect other marine activities such as fishing, with potential impacts on cables.
- Measures to preserve biodiversity, ecosystems and resources via various protection zones in national waters and the high seas, may impinge upon cable passage.
- The ocean, especially the coastal seas, will be subject to increased human activities due to expansion of renewable energy schemes.
The ICPC is very concerned about:

- Coastal State encroachment on traditional freedoms under UNCLOS to lay, maintain and repair international cables
- Resolution of Continental Shelf boundaries under UNCLOS
- Lack of national legislation to implement UNCLOS obligations to protect international cable infrastructure beyond territorial waters
- Restrictions on international cables that are imposed without any scientific basis to appease local constituencies, some of which regard submarine cables as an alternative revenue source
This booklet was prepared in collaboration with UNEP (United Nations Environmental Programme) and was published in 2009.

It provides an objective, factual description of the submarine cable industry and the interaction of submarine cables with the marine environment.

A copy can be downloaded by clicking here
Glossary

- **Armour**: steel wires placed around cable for strength and protection
- **Coaxial cable**: two concentric conductors separated by an insulator; enabled telephone calls over long distances using analogue technology
- **Fibre-optic cable**: Optical fibres encased in protective tube that is also a power conductor for repeaters. Enables telephone, video and data communications over long distances using light; has much greater capacity, reliability and signal quality
- **Repeater**: Submersible housing containing equipment that is needed to boost the signal at regular intervals on long submarine cable systems; powered from the cable terminal
- **ROV**: Remotely Operated Vehicle – a submersible tool that works on the seabed to inspect, bury or recover the cable
- **Telegraph cable**: Copper wires insulated with gutta-percha, wrapped in India rubber and steel wire
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## Acknowledgements

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