Submarine Cable Maintenance and Security

A Detailed Technical and Social Report
for the Course
Telecommunications for Society

Submitted by: Rahul Naidu Boddeti
Roll No: VU22CSEN0100351

School of Technology
GITAM (Deemed to be University)

Date: November 27, 2025

Contents

1 Introduction

Submarine communication cables form the hidden infrastructure that enables global digital communication. While satellites are often credited in popular media as the backbone of worldwide connectivity, the reality is that more than 95% of all international data travels through undersea fiber-optic cables. These cables deliver the bandwidth, reliability, and low-latency performance required for modern society to function. Without submarine cables, global internet services, cloud computing, international finance, global supply chains, artificial intelligence computation, and even basic email communication would slow down dramatically or fail entirely.

The rapid globalization of communication began with the first transatlantic telegraph cable in 1858, but the modern era of undersea communication truly began with fiber-optic deployment in the late 20th century. Today, the world is interconnected through over 450 cables stretching across 1.4 million kilometres of seabed. Each cable typically contains multiple fiber pairs using advanced optical amplification technologies, enabling capacities ranging from 20 terabits per second to over 300 terabits per second in the newest systems.

Unlike terrestrial infrastructure, submarine cables are extremely difficult to access once deployed. They lie across vast, deep, and dynamic underwater landscapes. Despite their robust engineering, these systems face constant threats: geological forces, human maritime activity, aging components, and potential sabotage. Even a single cable break can reduce international bandwidth, interrupt financial systems, and affect millions of users worldwide. Because of these risks, submarine cable maintenance and security are considered critical components of national and international resilience.

The purpose of this report is to provide an in-depth, comprehensive, and academically rigorous exploration of submarine cable structure, vulnerabilities, maintenance practices, security risks, monitoring technologies, and societal importance. Each section contains detailed explanations suitable for academic submission, covering engineering, operational, environmental, and geopolitical aspects.

2 Detailed Structure of Submarine Cables

Modern submarine cables represent a blend of precision optics, advanced materials engineering, oceanography, and long-term durability design. A typical cable system consists of several layers, each serving a highly specific purpose.

At the center lies the optical fiber core. These fibers are crafted from ultra-pure silica and designed to minimize signal attenuation over thousands of kilometers. Each fiber is capable of transmitting dozens of wavelengths of light simultaneously using Dense Wavelength Division

Multiplexing (DWDM). This allows each pair of fibers to carry hundreds of gigabits or even terabits per second.

Surrounding the fibers is a gel-filled buffer tube, which prevents water intrusion and cushions the fibers against bending and mechanical shock. This tube is then surrounded by a steel or copper tube that houses the electrical conductor. This conductor plays a critical role: it powers the repeaters spaced along the cable's length. These optical repeaters regenerate weakened signals, enabling global communication across oceans that exceed 10,000 km.

Further layers include multiple protective coatings: polyethylene insulation, mylar sheaths, steel armoring (single or double), and sometimes an external tar-based or anti-fouling coating to resist corrosion and marine growth. Near shorelines, where human activity is high, cables are heavily armored. In deep-sea environments—far from ships and anchors—the cables may have minimal armoring to reduce weight and cost.

Every layer contributes to protection, durability, and operational longevity. However, no design can fully eliminate risks. Even the deepest and most protected cables face physical, environmental, and operational challenges.

3   Comprehensive Causes of Cable Faults

3.1   Human-Induced Damage

Human-related damage accounts for the majority of cable faults. The most significant contributors include:

1. Fishing Trawlers — Large trawl nets dragged across the seabed can snag cables, applying immense upward or sideways force. This not only snaps the cable but can pull several meters of cable from its buried position.

2. Ship Anchors — Anchors dropped inadvertently or during emergencies can hook onto cables. As ships drift or engines push forward, the anchor drags the cable along with it, often breaking the line and generating multi-kilometre disruptions.

3. Offshore Construction — Oil drilling platforms, underwater pipelines, coastal reclamation projects, and bridge construction frequently interfere with cable routes if coordination is inadequate.

3.2   Natural Causes

While less frequent, natural events often result in significant damage:

1. Underwater Earthquakes — Seismic shifts in tectonic plates can stretch, crush, or sever cable segments. The 2006 Hengchun earthquake near Taiwan famously damaged multiple cables, slowing internet traffic across Asia for weeks.

2. Submarine Landslides — Seabed sediment can collapse suddenly due to seismic triggers, dragging cables over long distances. Landslides create extreme tension and cause large-scale destruction.

3. Scouring and Seabed Movement — Ocean currents can gradually erode protective layers or expose previously buried cables.

3.3   Aging and Component Degradation

Over decades, cables experience:

- Insulation fatigue - Metallic corrosion - Optical fiber attenuation - Repeater malfunction

Although well-designed, no cable is immune to time and environmental pressures.

3.4   Intentional Interference

Geopolitical tensions have increased the possibility of intentional attacks:

- Physical cutting of cables - Underwater tapping by submarines - Cyber exploitation at landing stations - GPS spoofing to mislead ships into cable zones

These risks have made submarine cables a priority in national security frameworks.

4   Maintenance Practices and Repair Operations

Maintaining submarine cables is a continuous process involving monitoring, preventive inspection, and emergency repair. Cable operators deploy sophisticated systems to detect anomalies long before outages occur.

4.1   Real-Time Monitoring and Fault Localization

Operational centers continuously measure:

- Optical power levels - Latency fluctuations - Repeater telemetry - Power feed currents - Error-correction statistics

Tools like Optical Time Domain Reflectometry (OTDR) allow engineers to pinpoint fault locations within a few hundred meters even across thousands of kilometers.

4.2   Repair Ship Operations

When a fault occurs, a specialized repair vessel is dispatched. These ships carry:

- Cable tanks - Undersea grapnels - Robotic ROVs - Splicing labs - Dynamic positioning systems

Repair steps include:

1. Locating the damaged segment 2. Deploying grapnels to retrieve cable 3. Cutting the cable and removing damaged sections 4. Splicing replacement sections onboard 5. Lowering

repaired cable to seabed 6. Buried reinstallation in shallow waters

Repairs can take days or weeks depending on weather, depth, and equipment availability.

4.3 International Maintenance Agreements

Organizations such as:

- ACMA (Atlantic Cable Maintenance Agreement) - ASEAN Cable Maintenance System - Pacific Cable Maintenance Agreements

maintain fleets on standby to reduce response times and costs.

5 Security Considerations

Submarine cable security includes physical, digital, and geopolitical dimensions.

5.1 Physical Security

Measures include:

- Burying cables at landfall - Armoring shallow-water segments - Installing exclusion zones - Monitoring vessel traffic - Sonar-based detection

Some countries deploy naval vessels near strategic cable landing areas.

5.2 Cybersecurity Risks

Data can be intercepted at:

- Repeaters - Landing stations - Network switches

To prevent this, operators implement:

- End-to-end encryption - Biometric access control - Multi-factor authentication - Real-time surveillance

5.3 Geopolitical Risks

Major powers increasingly view cables as strategic targets. Incidents involving military submarines near cable routes have raised alarm globally. International treaties, coordination, and maritime law enforcement are becoming essential for cable protection.

6 Emerging Technologies

6.1 Autonomous Underwater Vehicles (AUVs)

AUVs now conduct:

- Periodic inspections - Seabed mapping - Early detection of cable exposure - Environmental analysis

They reduce reliance on repair ships and enhance predictive maintenance.

6.2   Distributed Acoustic Sensing (DAS)

DAS-equipped cables act as massive underwater microphones capable of detecting:

- Fishing activity - Vessel movement - Anchor drops - Earthquakes - Marine life behavior

This transforms submarine cables into multipurpose sensing systems.

6.3   AI-Driven Predictive Monitoring

Machine learning models identify anomalies, predict failures, optimize routing, and detect intrusion attempts. This improves reliability and reduces downtime.

6.4   Smart Environmental Cables

Future cables will include embedded sensors measuring:

- Temperature - Salinity - Pressure - Seismic activity

These systems enhance both communication and marine scientific research.

7   Impact on Society

Submarine cables support critical sectors:

- Banking and high-frequency trading - Cloud computing - Communication platforms - Remote healthcare - Education and research - National security - Disaster response systems

A disruption in major cables can cause:

- Economic losses - Slow internet - Financial transaction delays - Global market instability - Reduced communication capacity

The societal dependence on submarine cables is so profound that nations classify them as essential infrastructure.

8   Conclusion

Submarine cables are fundamental to global digital society. Their maintenance and security require continuous engineering, advanced monitoring technologies, international cooperation, and geopolitical coordination. As global data demand grows, the importance of these underwater networks will only increase. Ensuring their resilience is essential for global stability in communication, economy, governance, and societal development.