Submarine Cable Industry Trends

Challenges and Opportunities

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October 13th, 2023

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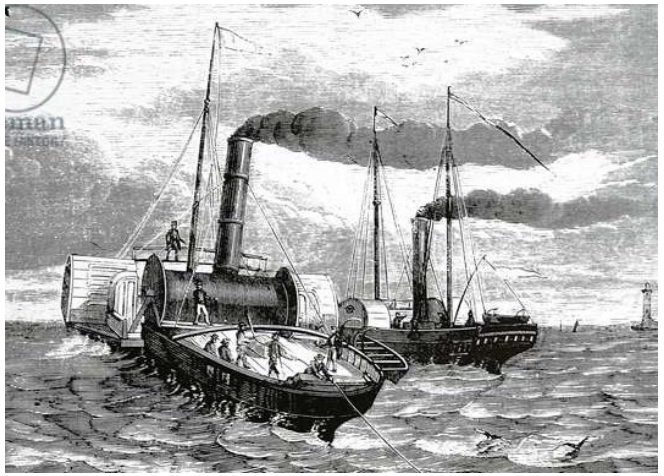
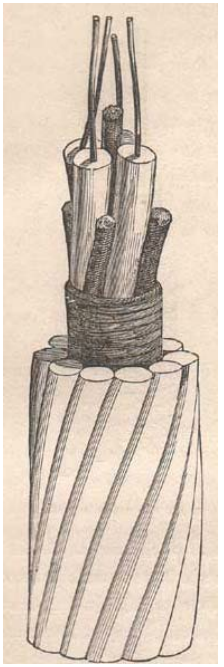
Introduction to Subsea

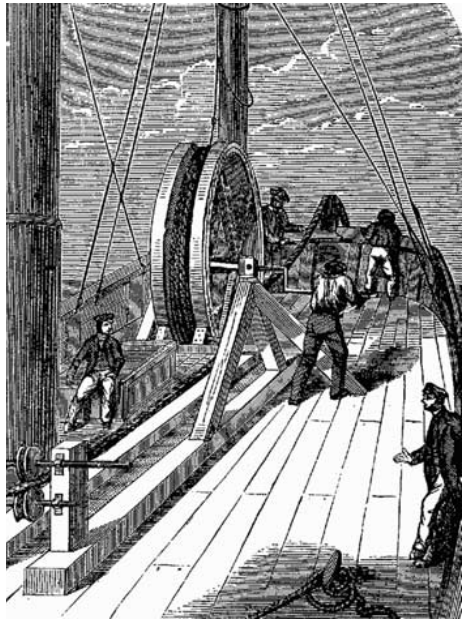
Submarine Cable Systems - the beginning

The Goliath and the Widgeon laying the first submarine cable between Dover and Calais



- **First submarine cable UK-France deployed in 1850**
  - Useful life 11 minutes

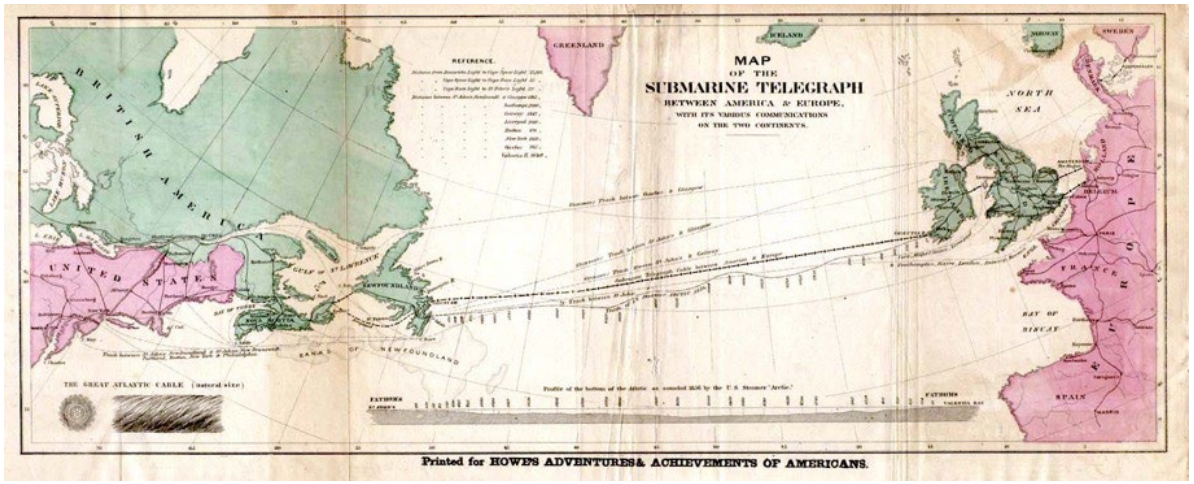




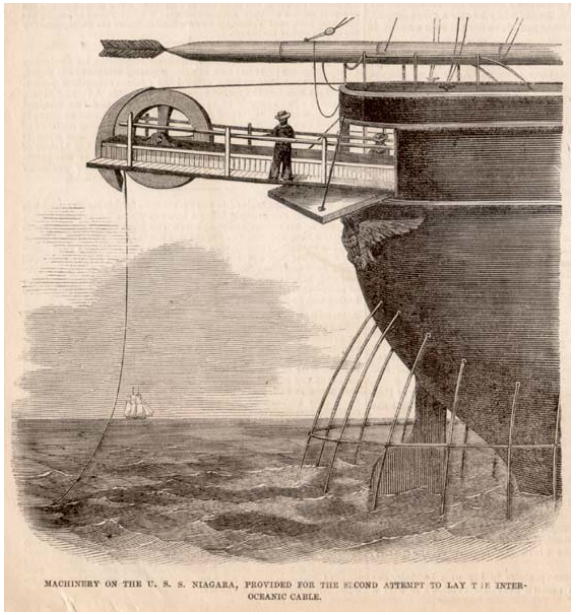
- **Second UK-France deployed in 1851**
  - First commercially successful undersea cable
  - 25 miles total length, weighing 7 tons / mile

Introduction to Subsea

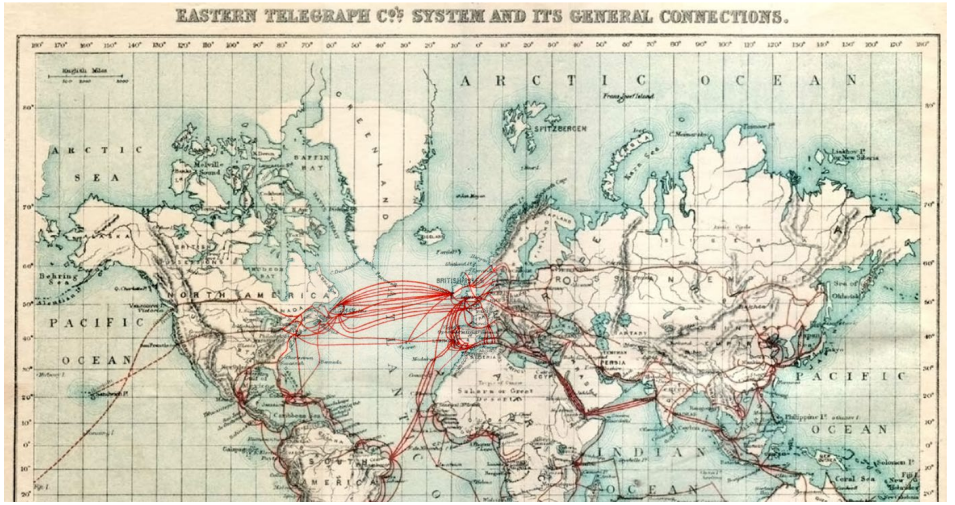
Submarine Cable Systems - the beginning



- **First transatlantic cable in 1858**
  - First message August 1858 sent by Queen Victoria to US President James Buchanan
    - 98 words and took 17 hours to transmit
  - Declared the 8th wonder of the world
  - Lasted 3 weeks but proved the concept


MACHINERY ON THE U. S. S. NIAGARA, PROVIDED FOR THE SECOND ATTEMPT TO LAY THE INTER-OCEANIC CABLE.

- **By 1901 cables spanned the globe**

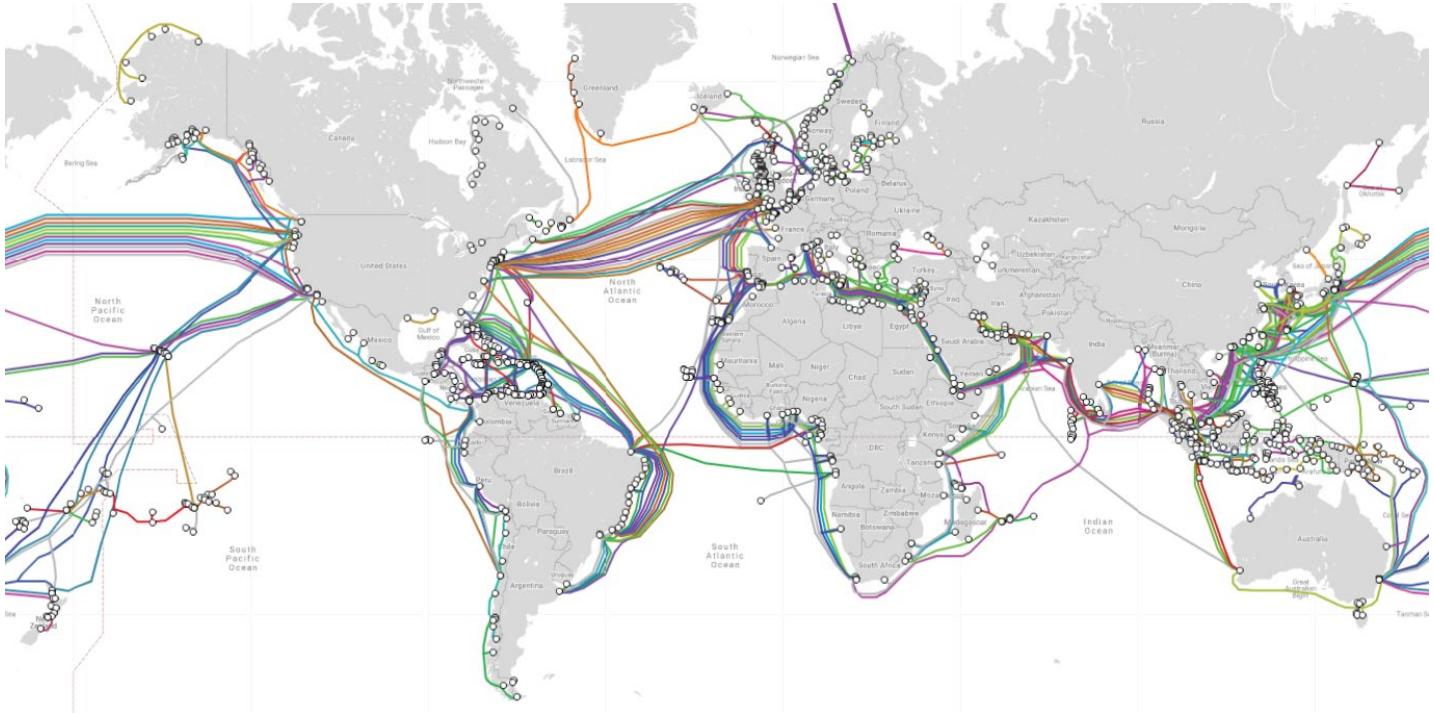


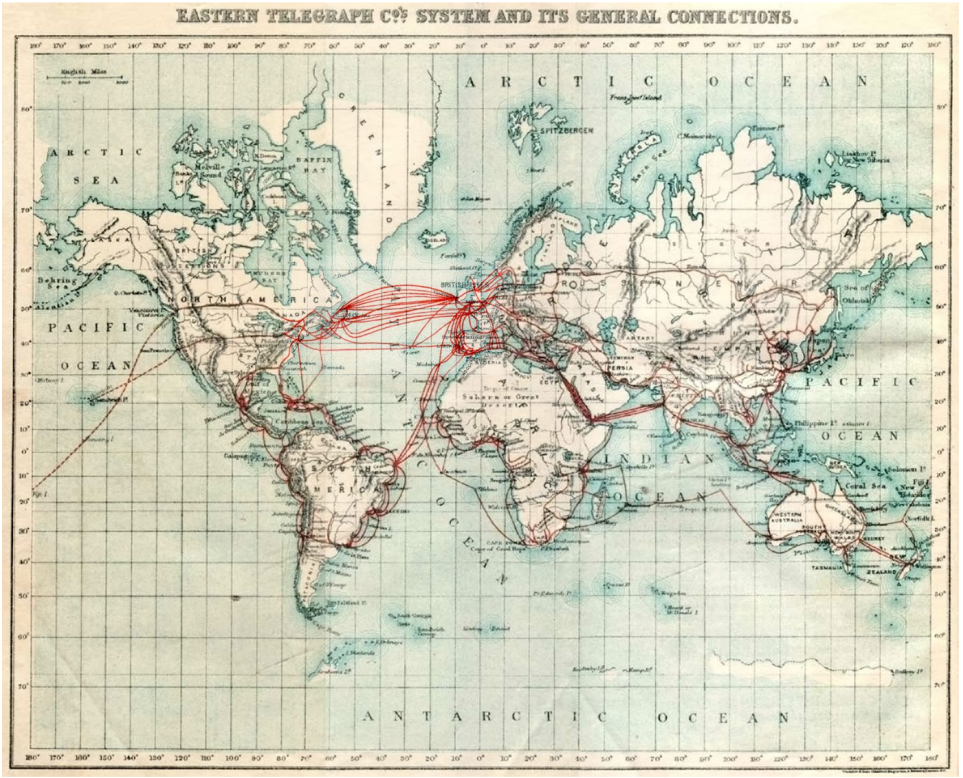
Introduction to Subsea

Submarine Cable Systems - today

Submarine cables deployed globally

- **https://www.submarinecablemap.com/**
- **>450 in-service cables**
- **1.4 million kms of cable**
- **1,400 landing points**

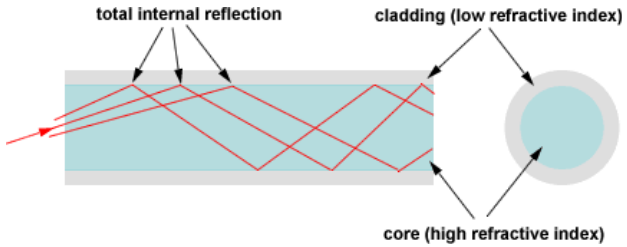




- **Carry >99% international traffic**
- **High reliability, 25-year lifetime**
- **Deployed to 9000m water depth**
- **Up to 20,000kms in length**

Introduction to Subsea

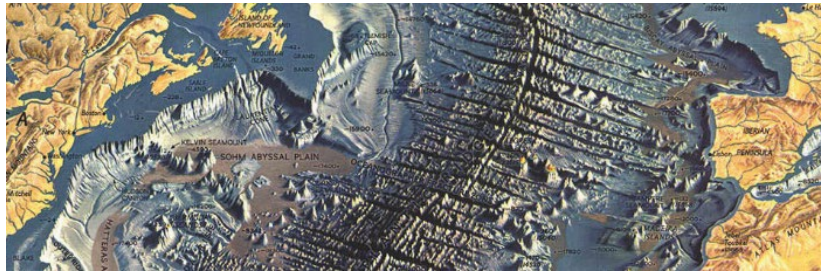
Submarine Cable Systems - FAQs



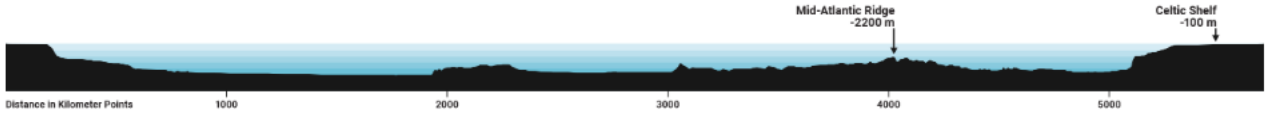
- **How do cables work?**
  - Submarine cables use fibre-optic technology - lasers transmit pulses of light down glass fibre which carries the data to receivers at far end of cable by total internal reflection.
- **How big are the cables?**
  - In deep water a cable is as wide as a garden hose. The filaments that carry light signals are extremely thin - roughly the diameter of a human hair.
  - These fibers are sheathed in a few layers of insulation and protection. Cables laid nearer to shore use extra layers of armoring for enhanced protection.
- **Do the cables lie on the bottom of the ocean floor?**
  - Cables are armoured and buried under the seabed for protection in shallow water, in deep sea (>1000m) they are laid directly on the ocean floor.
- **How are cables laid?**
  - Cables are laid by specialist marine vessels capable of deploying and recovering to 9000m.
- **What about satellites?**
  - Satellites are used to reach areas not yet connected with fibre. They are also useful for distributing content from one source to multiple locations.
  - Otherwise fibre optic cables carry far more data, far quicker and are far lower cost than satellites.

Introduction to Subsea

Submarine Cable Systems - FAQs



- **Where are the cables laid?**
  - Cable route engineering is critical
  - Considerable care is taken to ensure cables follow the safest path to avoid fault zones, fishing zones, anchoring areas, and other dangers. A marine survey is key to the determine the safest route.



- **Who owns the cables?**
  - Cables were traditionally owned by telecom carriers who would form a consortium of all parties interested in using the cable (eg Japan-US built in 2001 with 24 consortium parties).
  - In the late 1990s, a lot of entrepreneurial companies built many private cables but struggled when the dot.com bubble burst in 2000 (Global Crossing, Flag, TGN).
  - Both the consortium and private cable models still exist today, but one of the biggest changes in the past few years is the investment by Content Providers in new cables.
  - Content providers such as Google, Facebook, Microsoft, and Amazon are major investors in new cables. Ongoing massive bandwidth growth between data centres means owning new submarine cables makes sense for these companies.

Introduction to Subsea

2Africa

- **2Africa project announced in 2020**
- **>45,000kms**
- **46 landings, 33 countries, 3 continents**
- **3x total network capacity of cables to Africa today**
- **Intended to reach 3 billion people (36% global population)**
- **Consortium of 8 companies**

China Mobile International

FACEBOOK

orange

stc

telecomegypt

vodafone

WIOCC

Africa's Hyperscale Infrastructure

Challenges – Meeting the Growth expectations

- Shannon limit and the current wet plant design doesn't have lots of growth potential
- Wet plant: SDM, MCF, C+L
- Fit for purpose design with increased standardization and focus on lowest unit cost
- Sustainability issues
- Encouraging entrepreneurs and carriers – to participate in cable developments

Challenges – Providing continuity of service

- Increasingly congested sea bed
- Accurate maintenance; outage metrics
- Build in restoration over terrestrial routes
- Environmental considerations and power consumption

Svalbard fiber cable

Undersea cable connecting Norway and Arctic satellite station is mysteriously damaged

- An undersea comms cable connecting Svalbard and mainland Norway has failed
- The disruption could prove disastrous as there is now only one connection left
- If the other cable fails, the island will be completely cut off from the mainland
- The cables power a huge Arctic satellite station and bring internet to Svalbard
- It comes as Britain's most senior naval officer warned that Russia may look to cripple such vital undersea communications wires supporting the UK

- **Longyearbyen in Svalbard at 78° North is an ideal location to support polar orbiting satellites.**
- **All 14 daily passes of a typical sun synchronous orbit are visible with satellite contact every 7 and 17 minutes**
- **Wetplant available after telelcom buble burst**
- **Currently underutilized**

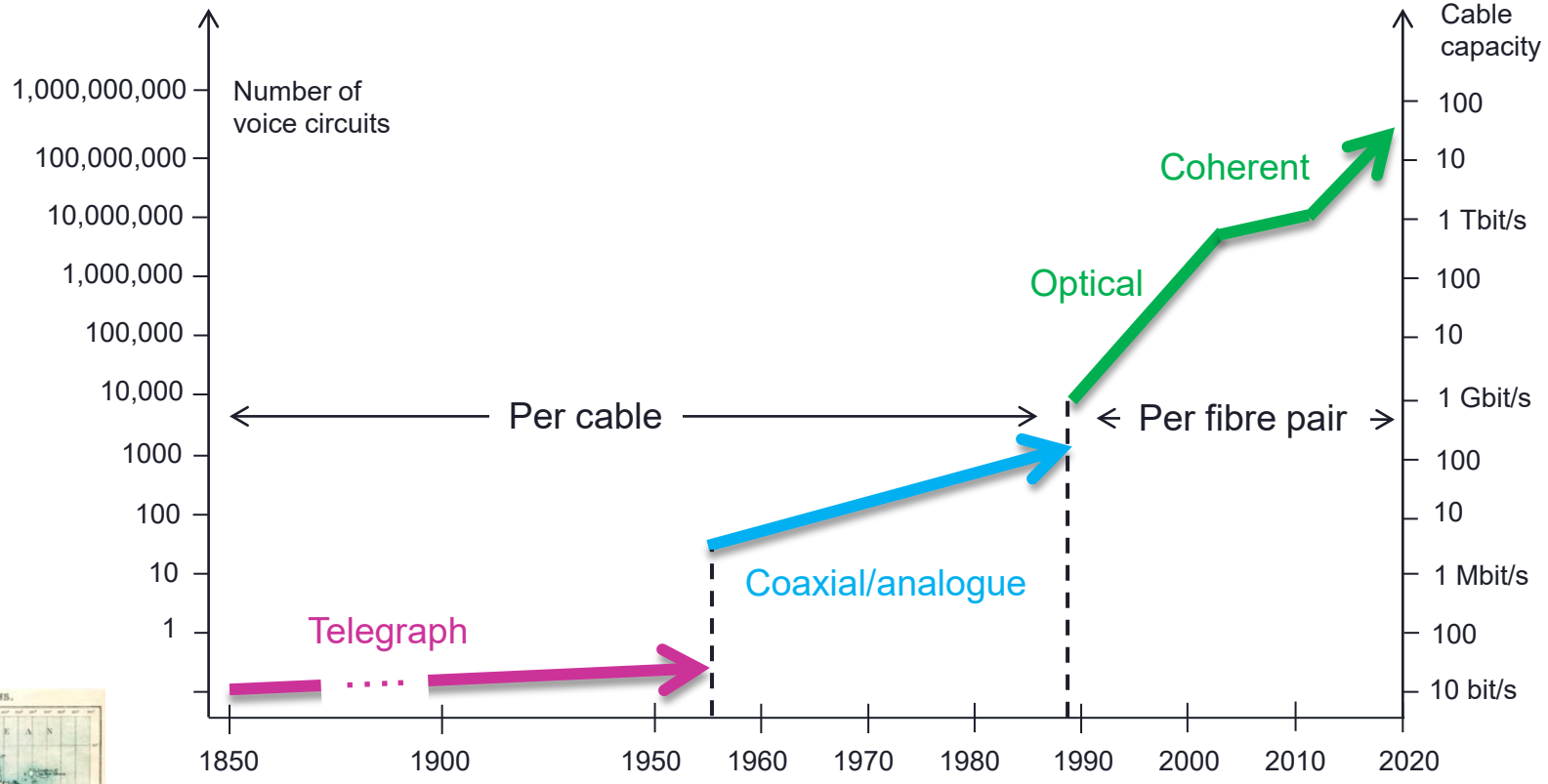
Source: Daily mail January 2022

Challenges – Regulatory and Permitting

- Increased MDA
- Geopolitics
- Cabotage
- Critical Infrastructure Designation
- Cable Corridors

Introduction to Subsea

Submarine Cable History - Three generations

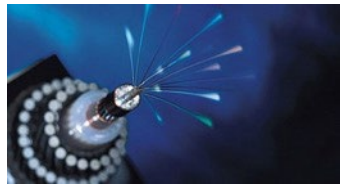


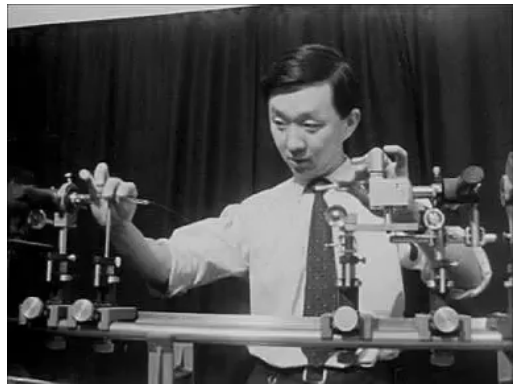
- By 1910 400,000kms cable laid
- Development of cable industries in UK, France, Germany & Japan
- Marine capabilities improving

- After WWII co-axial technology proven
- Development of undersea repeaters and new cable
- Telegraph to telephony

Introduction to Subsea

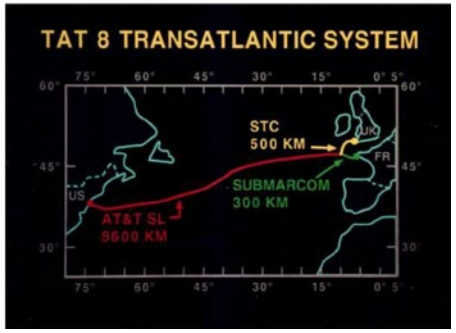
From Telegraph to Coaxial to Optical



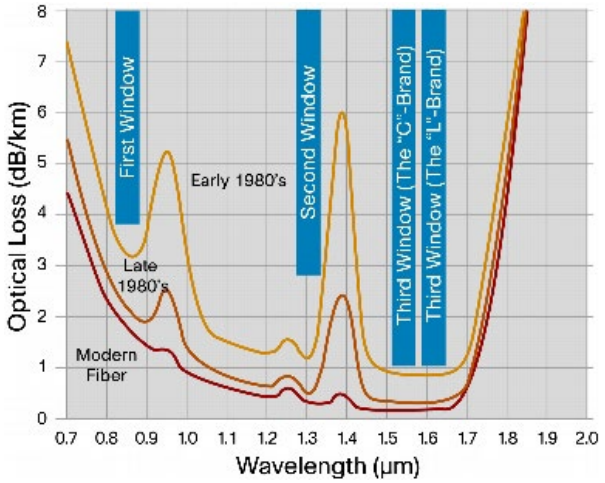


Charles Kao at STL February 1966

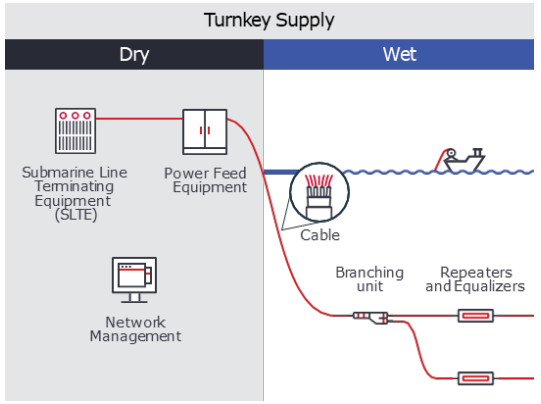
- **Discovery of semiconductor lasers working in the optical window in 1962**
- **Single mode fibre breakthrough in 1966**
- **4km system deployed in North London operating at 140Mb/s in 1977**
- **Four major research centres worked in parallel**



- **First optical transatlantic system in operation 1988**
  - Operated in 1310nm window
  - Capacity per fibre pair 1 x 280Mb/s
- **Second generation operated in 1550nm window**
  - Capacity per fibre pair 1 x 560Mb/s



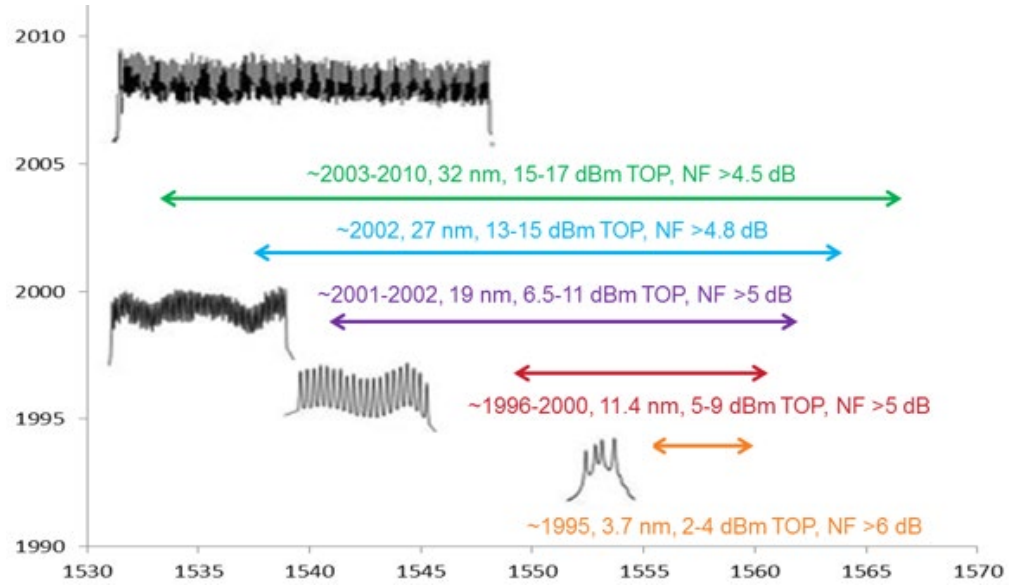
- **All undersea repeaters were regenerative**
- **Turnkey supply only**

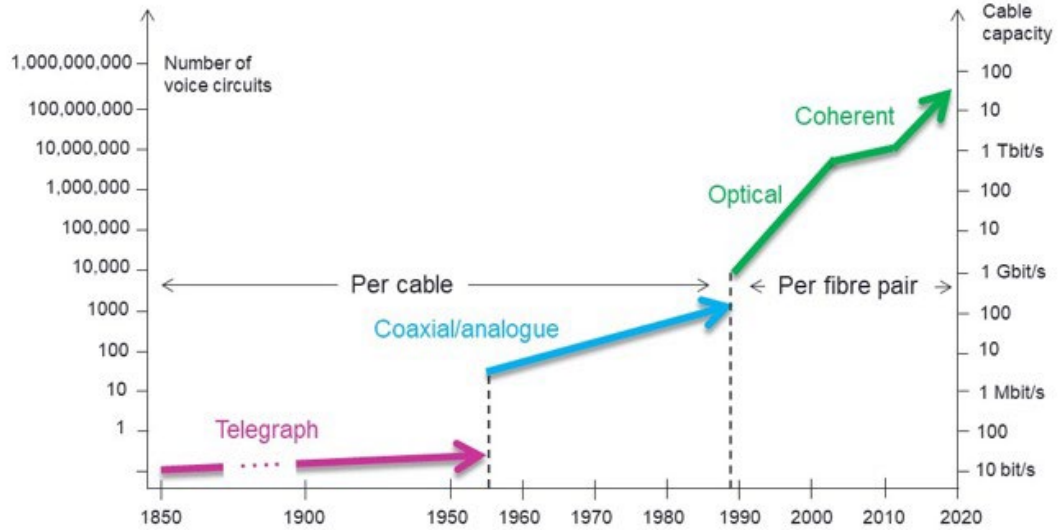


Introduction to Subsea

Undersea Optical Amplifiers

- **Introduction of optical amplifiers (EDFAs) in 1995**
  - No electrical regeneration, purely optical amplification
  - Wet plant independent of modulation format and bit rate
  - Initially narrow bandwidth, 4nm
- **Dual-stage optical amplifier for wider bandwidth followed**
  - Enabled Dense Wave Division Multiplexing (DWDM)
- **Optical amplifier bandwidth increased further**
  - By 2000, fibre pair capacity 20-40Gb/s
  - By 2010, up to 10x100G, 1Tb/s per fibre pair
  - Capacity increase 2000x in 20 years

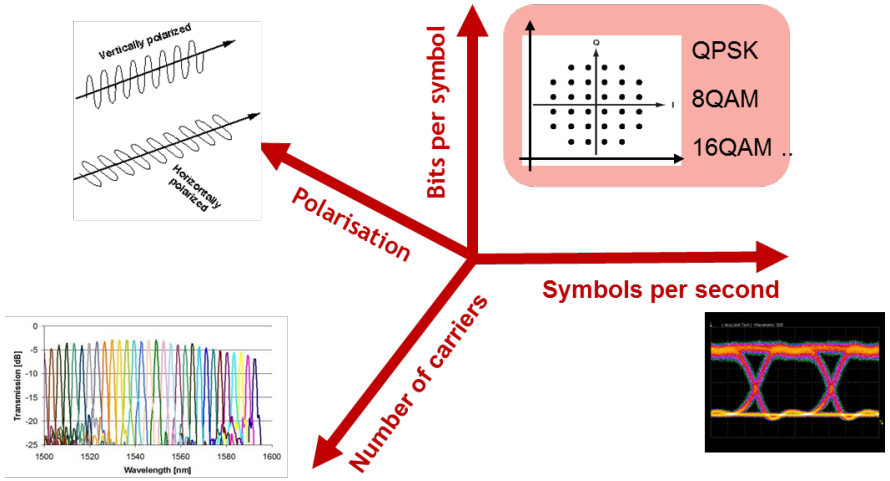


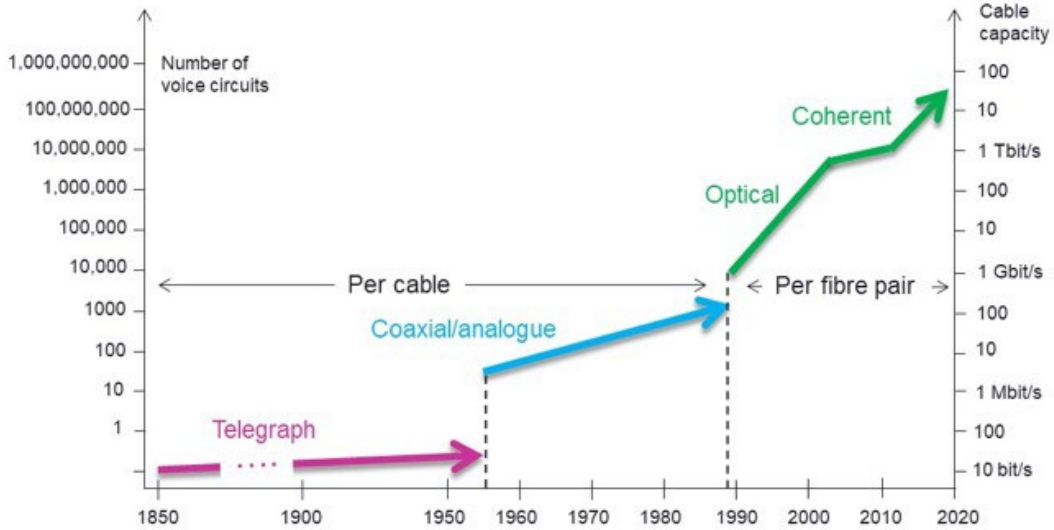


Introduction to Subsea

Coherent Technology

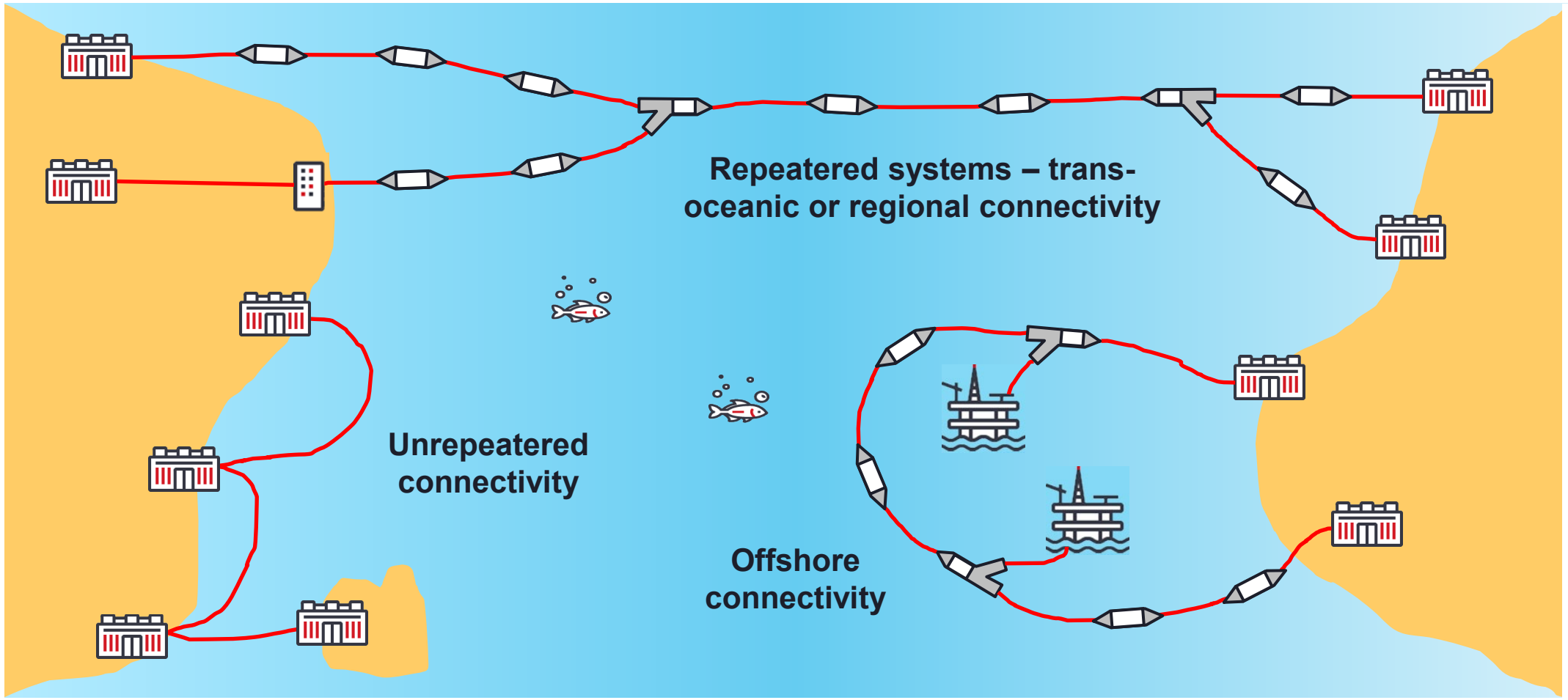
- **Continuous growth of silicon integration**
- **Fabrication of powerful processors running at very high speed**
- **Enabled the use of digital signal processing (DSP) for:**
  - Polarization multiplexing
  - To move to higher order modulation formats in phase domain
  - Spectral shaping
  - More complex Forward Error Correction (FEC)
- **Dramatic growth in spectral efficiency**
  - Increased baud rate, number of carriers, bits/symbol
  - Capacity x10
- **Today:**
  - 400Gb/s per channel
  - 44 channels per fibre pair => 20Tb/s
  - 12 fibre pairs on a cable => 240Tbps





Introduction to Subsea

System Configurations

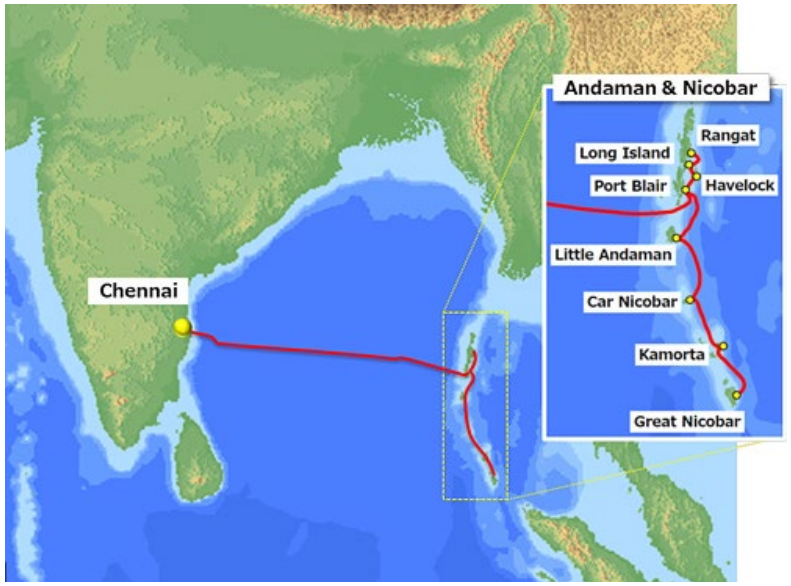


Introduction to Subsea

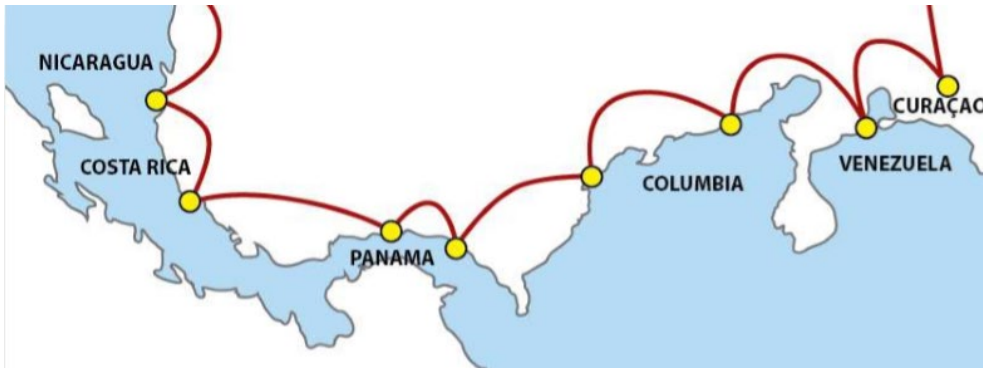
Unrepeatered Configurations - up to 450kms

Island connections

Island festoon



Coastal festoon

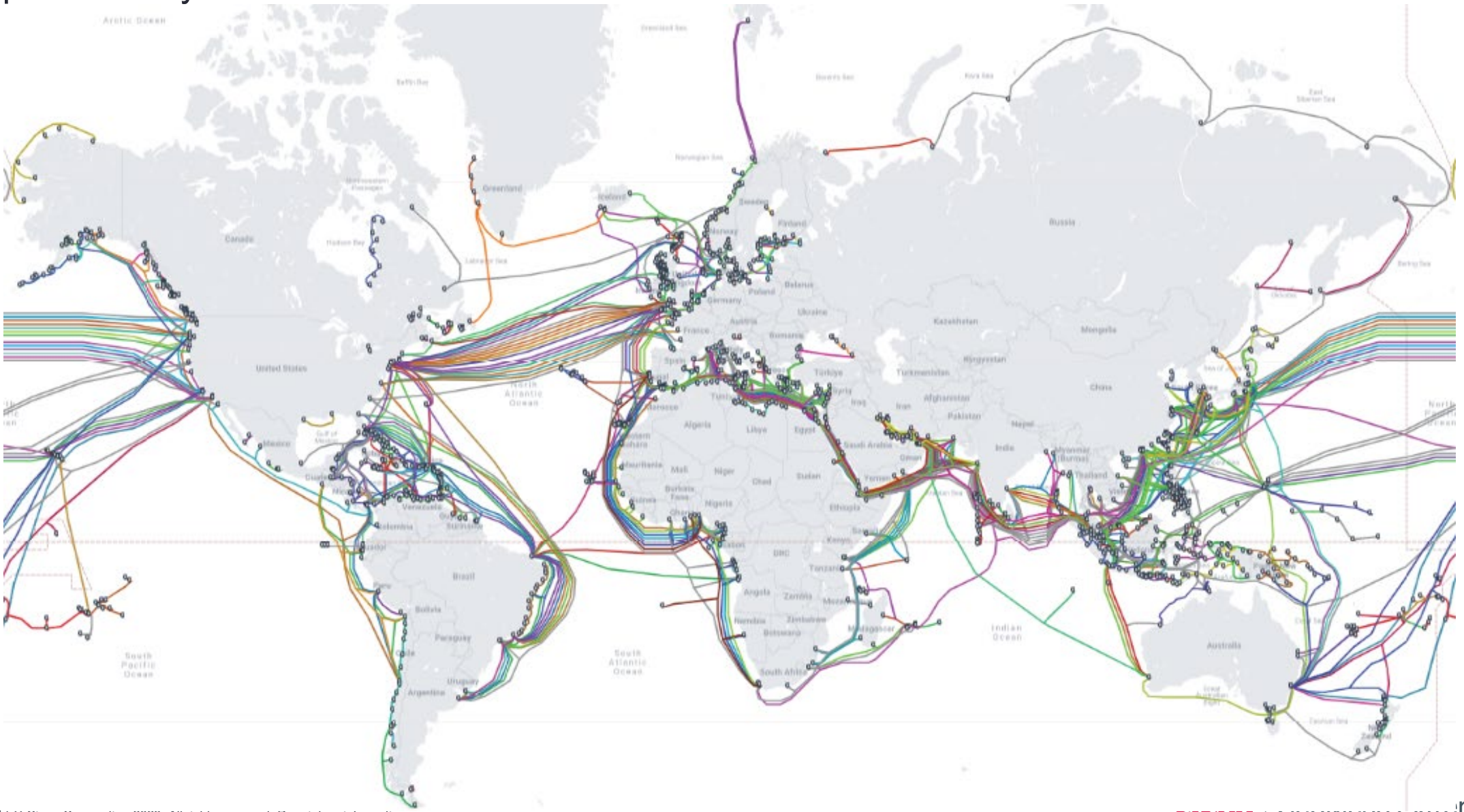


Connecting oil rigs

Introduction to Subsea

Repeatered Systems

>90% submarine market



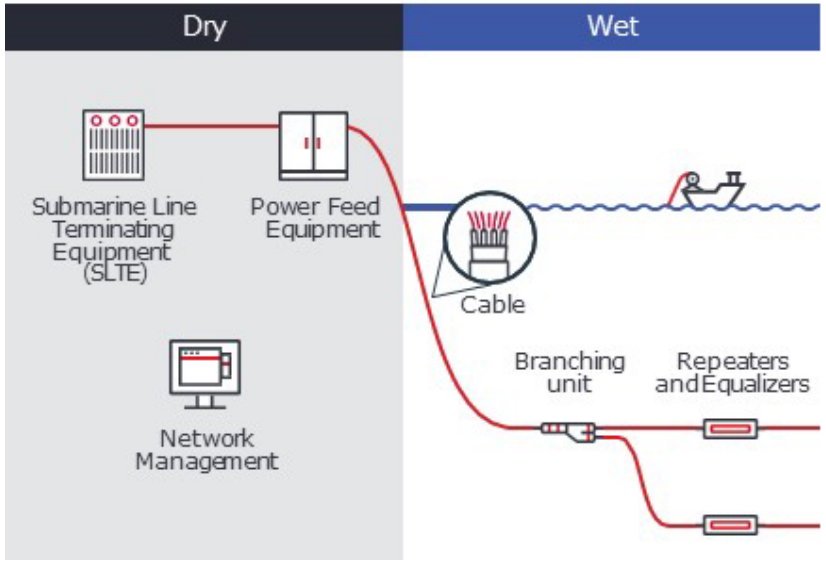
Introduction to Subsea

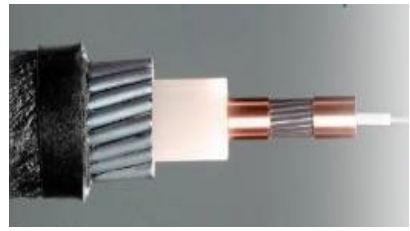
Block diagram

Power Feed Equipment (PFE)

Marine Operations

Submarine Line Terminating Equipment (SLTE)





Cable

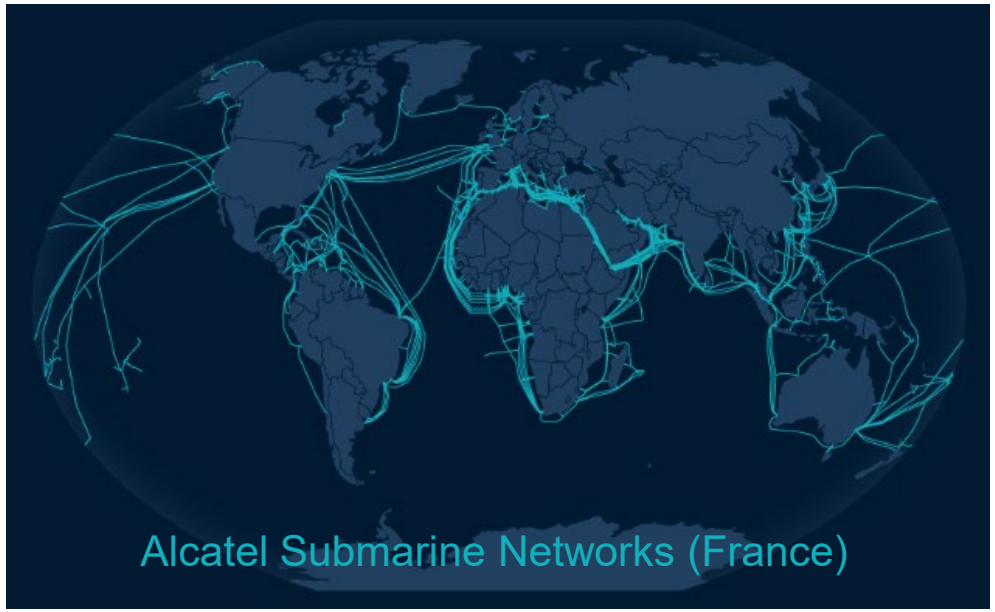
Network Management System (NMS)

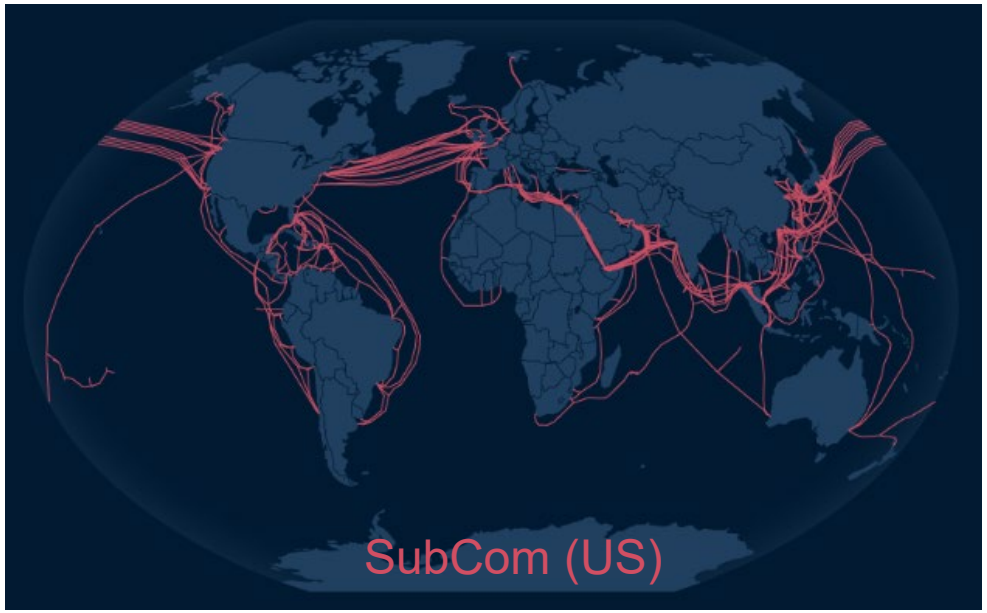
Branching Units

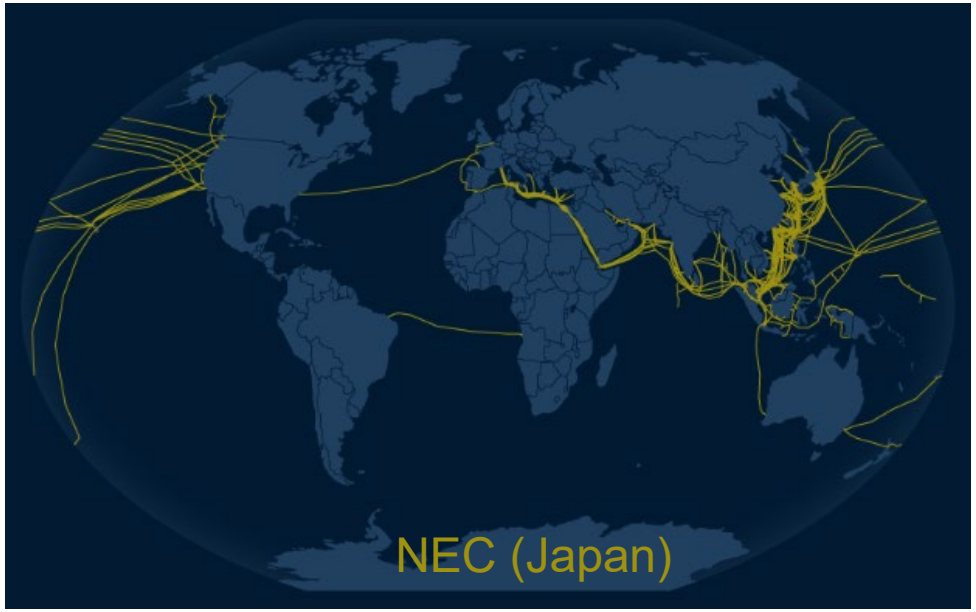
Repeaters

Introduction to Subsea

Wet plant suppliers – the big three



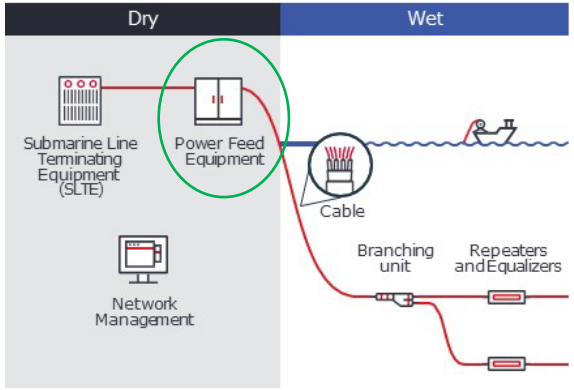




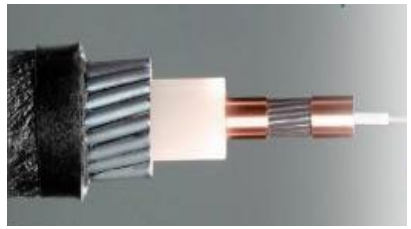
Introduction to Subsea

Power Feed Equipment (PFE)

- **PFE provides power to submerged plant**
- **Stable direct current to line with a very high degree of control**
- **Current fed via the inner conductor of the cable**
- **Normally 4 x redundancy for reliability and maintainability**
  - Modules are fully duplicated
  - Double-end feeding model – system can be powered from either end in the event of failure
- **Power feed budget to determine required PFE voltage and line current**
  - Largely dependent on number of laser pumps and resistance of cable
- **PFE delivered as part of wet plant deployment**
- **Modular in design, up to 18kV**
- **Full alarm logging, monitoring and safety features**
- **Earth monitoring and switching**
- **Electroding feature to detect position of cable breaks**



Introduction to Subsea
Cable



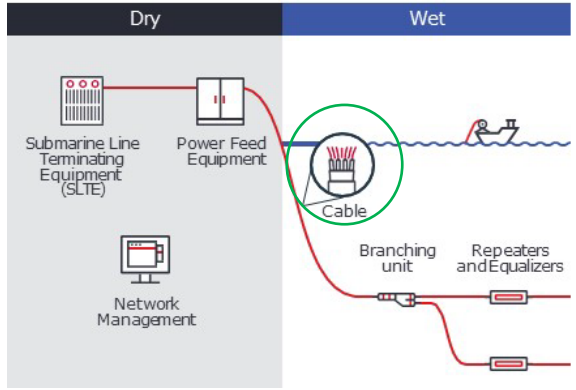
- **Primary function to protect the fibres**
- **Fibres housed in loose tube surrounded by first layer of armour**
- **Power conductor and high-density polyethylene insulation to 17 or 21mm depending on application**
- **Deployable and recoverable from 8000m**
- **Highly crush resistant**
- **Full range of armouring**

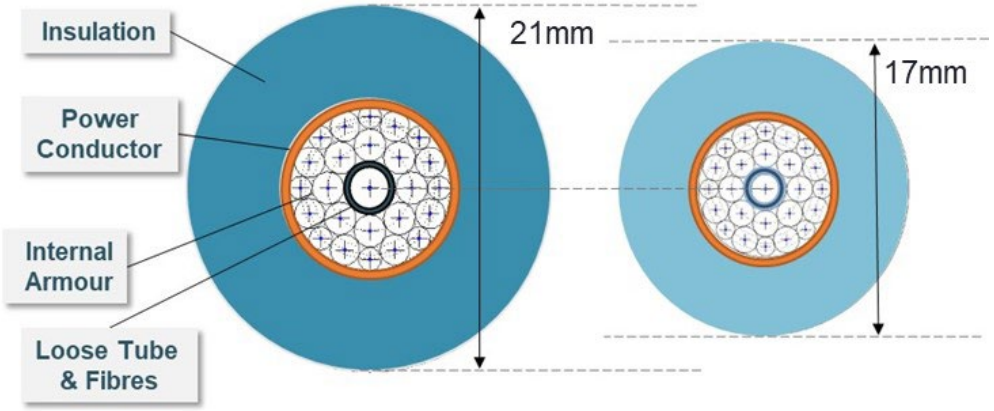
Lightweight (LW) – deep water (>2500m)

Lightweight protected/armour (LWP/LWA) to 2500m

Single Armour (SA) up to 1500m water depth

Double Armour (DA) to 200m water depth



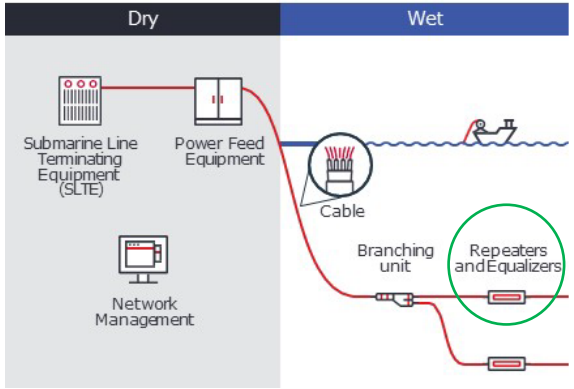


BU tails and fibre count >16fp

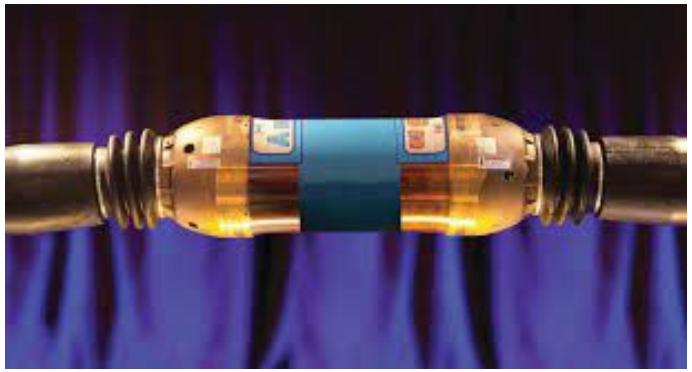
Fibre count <=16fp

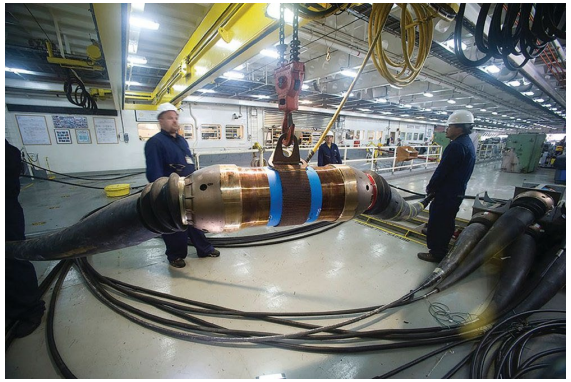
Introduction to Subsea

Repeaters



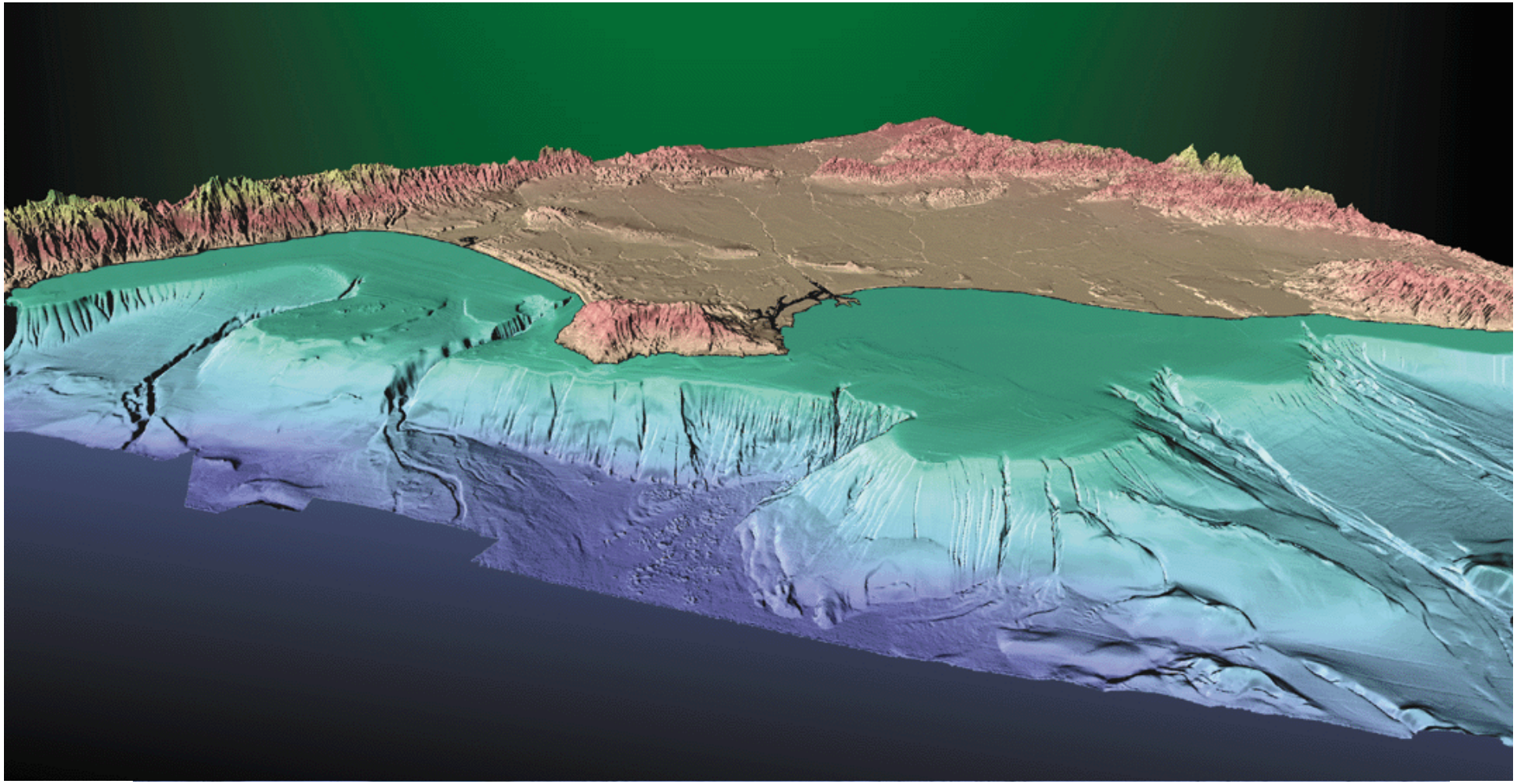
- **Amplify the optical signal**
- **Robustness up to 8000m**
  - Pressure, water, hydrogen aggression
- **Reliability**
  - 25 years life-time
  - All components qualified to ensure reliability
- **Optical design**
  - Maximum optical bandwidth (up to 40nm)
  - Ability to monitor health of components in service throughout lifetime
  - Flexible powering for system reconfiguration in fault conditions





Introduction to Subsea

Marine Operations



The world is not flat… nor is the seabed…

Sources: Google Maps; Nasa

Introduction to Subsea

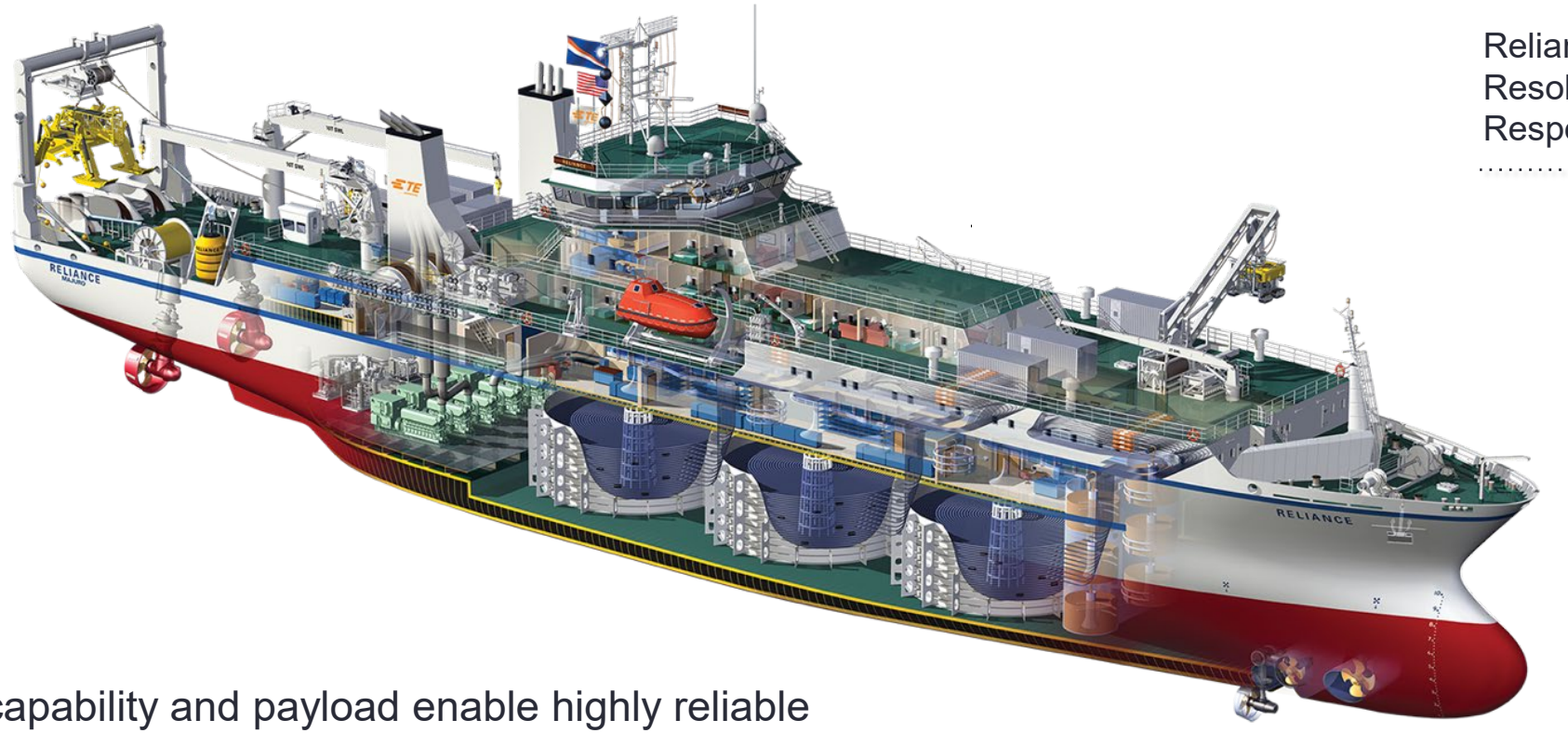
Marine Operations

Introduction to Subsea

SubCom Fleet: Reliance Class

RELIANCE CLASS SHIPS

Reliance	Decisive
Resolute	Dependable
Responder	Durable

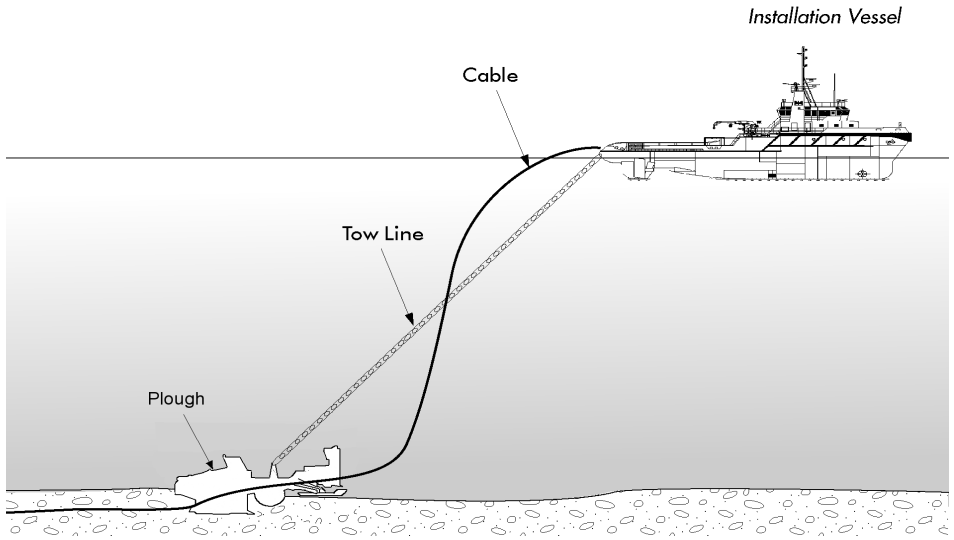


- Size, capability and payload enable highly reliable cable installation and maintenance services
- Using dynamic positioning technology, these ships can maintain static position for lay and repair operations, under most severe conditions, and operate with improved fuel economy and reduced crews
- 140m long, ½ the size of the Titanic

Introduction to Subsea

Cable Burial

- **Primary tool for burial is a plough deployed from a main lay vessel**
- **Burial is normally necessary for all submerged plant laid in water depths of less than 1000m**
- **New generation ploughs can bury up to >3m where required**



Introduction to Subsea

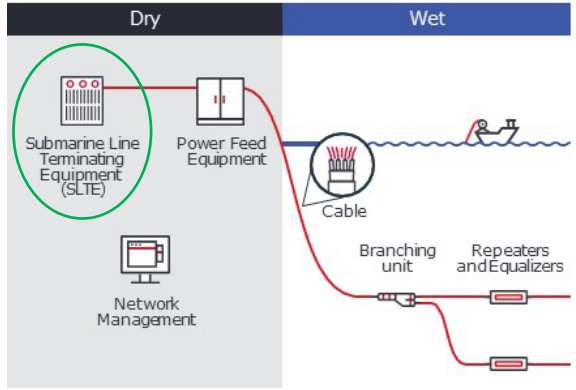
Cable Burial

Introduction to Subsea

Cable repair

Introduction to Subsea

Submarine Line Terminating Equipment (SLTE)

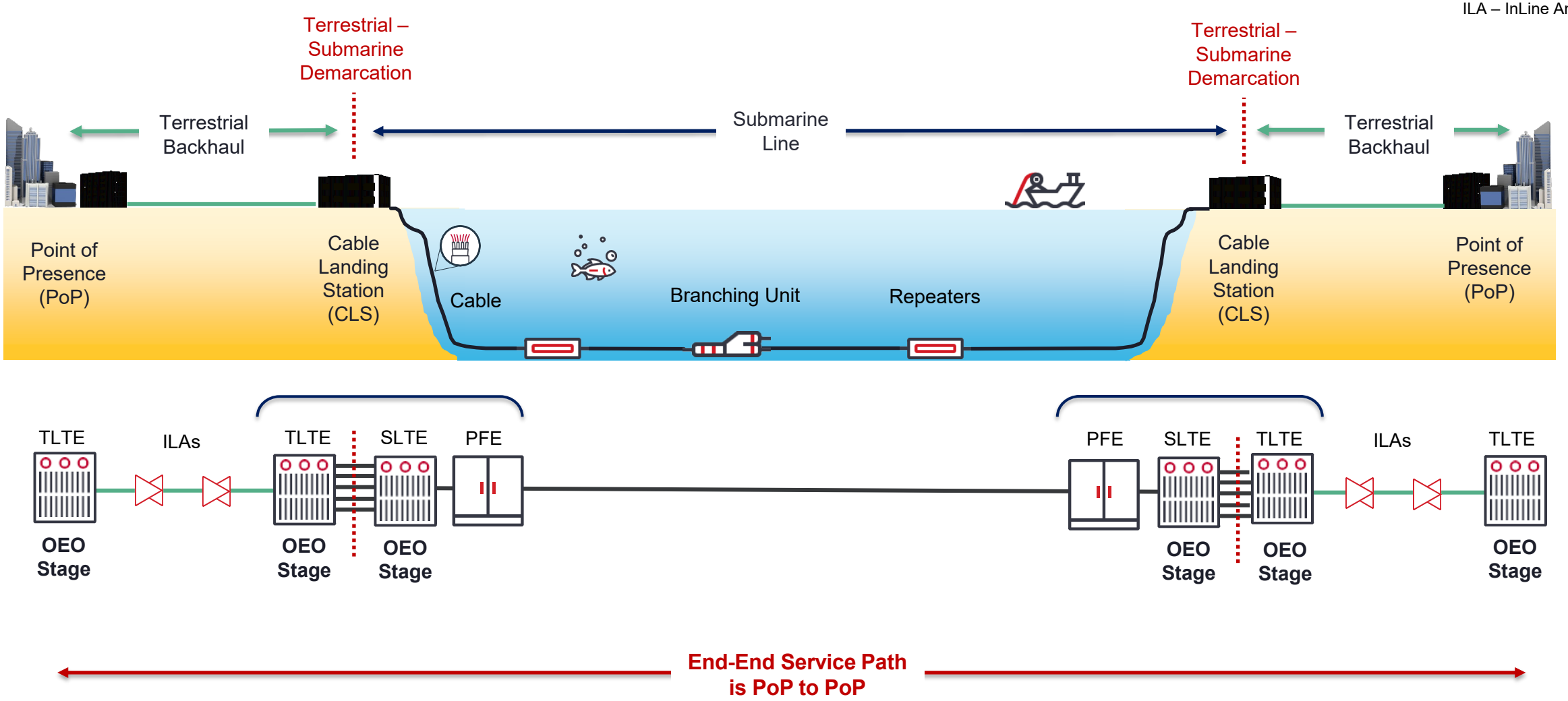


- **Key requirements**
  - Extreme capacity, >10,000kms transmission, flexibility and connectivity
- **SLTE functionality includes**
  - Single channel transponders transforming client interfaces at 10G, 100G or 400G into ultra high-performance transmission signals up to 800G
    - Software configurable with different constellation shaping (QPSK, 16QAM, 64QAM)
    - Support different pulse shapes (Nyquist, Frequency Division Multiplexing (FDM)
    - Encoding/decoding techniques including Soft Decision Forward Error Correction (SD FEC)
  - Manage chromatic dispersion compensation through digital signal processing for both pre and post compensation
  - Optical multiplexing/demultiplexing
  - Automatic pre-emphasis control
  - Noise loading source
  - Wide bandwidth optical amplifiers (up to 40nm in C band)

- **SLTE may be provided by Wet Plant Vendor or by 'Upgrade' vendor such as Ciena**

Submarine System Configuration

TLTE – Terrestrial Line Terminating Equipment
SLTE – Submarine Line Terminating Equipment
PFE – Power Feed Equipment
OEO – Optical–Electrical–Optical
ILA – InLine Amplifier



Principle of GeoMesh to eliminate unnecessary OEO

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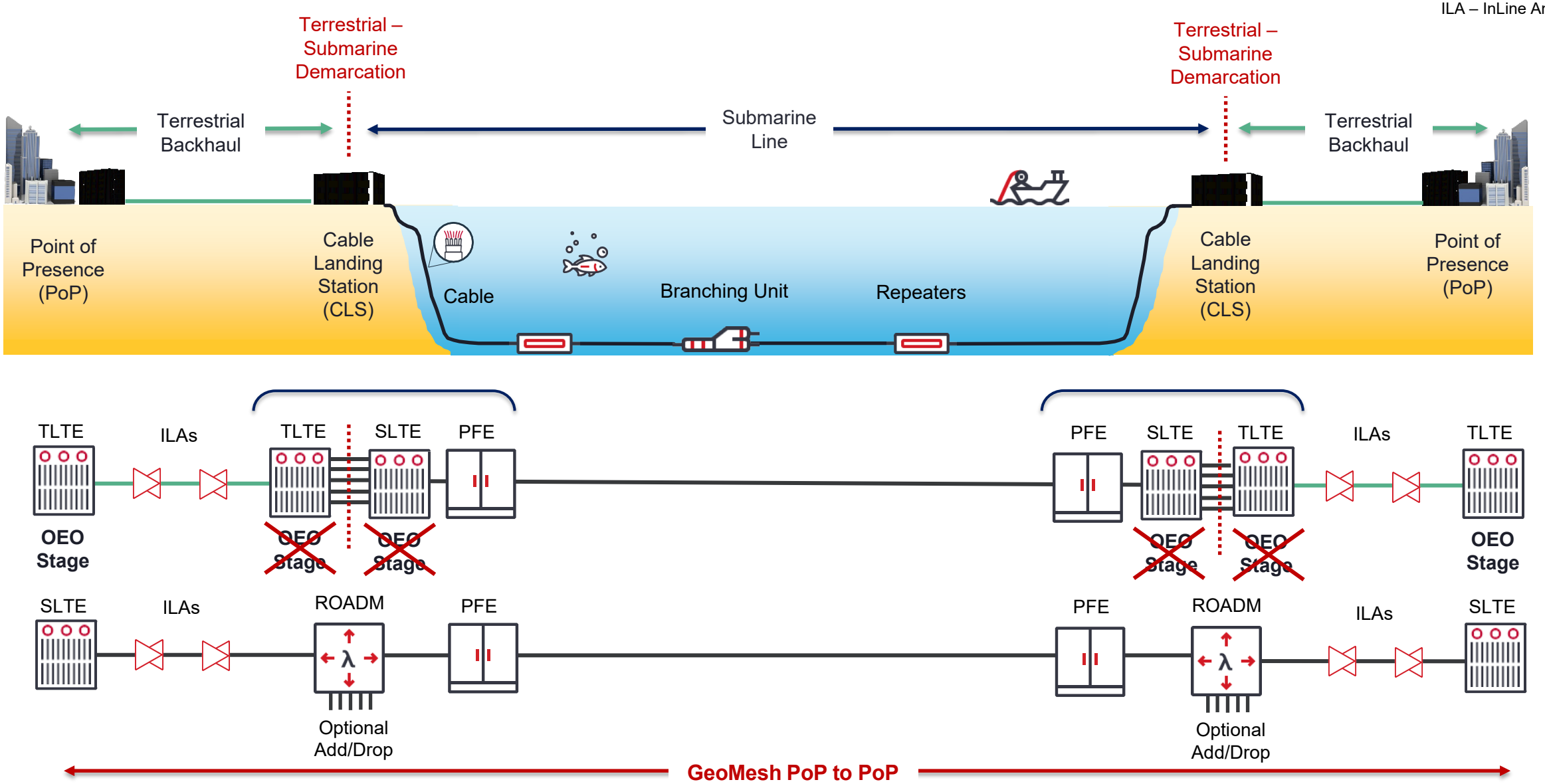
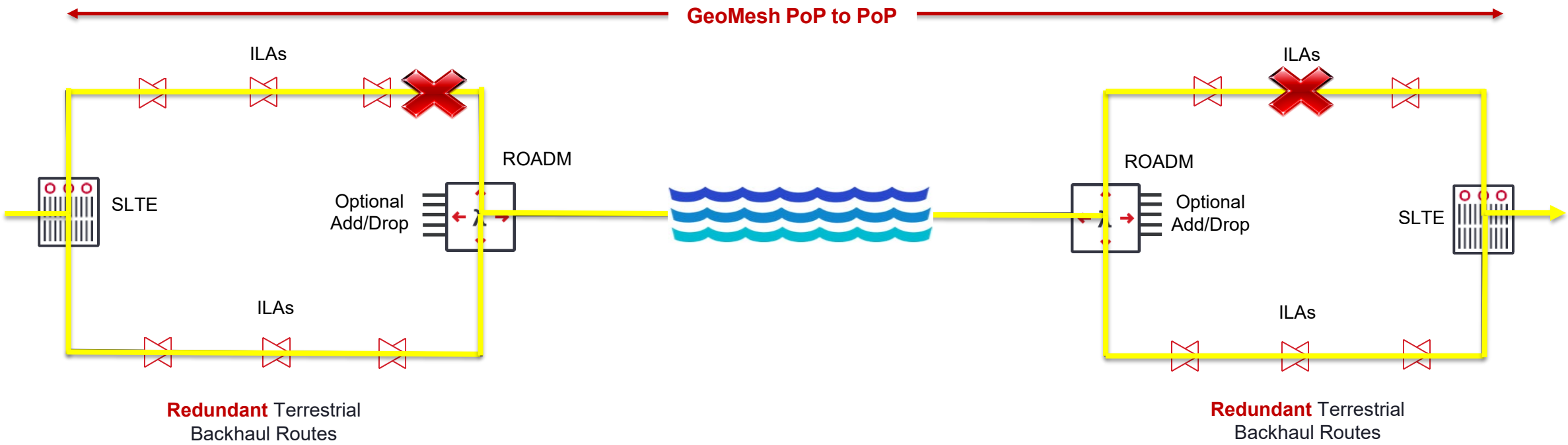


GeoMesh Configuration

Protected Backhaul – Trunk Switching or Control Plane Restoration



- Normal working route with two redundant terrestrial backhaul routes
- Power failure in west ILA site -> Traffic automatically recovered with OPS on redundant route
- Cable cut on east route -> Traffic automatically recovered with OPS on redundant route

Dual Fault Resiliency – Sub 50ms trunk protection switching

Thank You

Video links

Ellalink:
https://youtu.be/NIVHgtN_kkA

Plow:
https://youtu.be/9hEDTRU_F2s

Subcom submarine cable repair
https://youtu.be/r3tPI0qbLaE