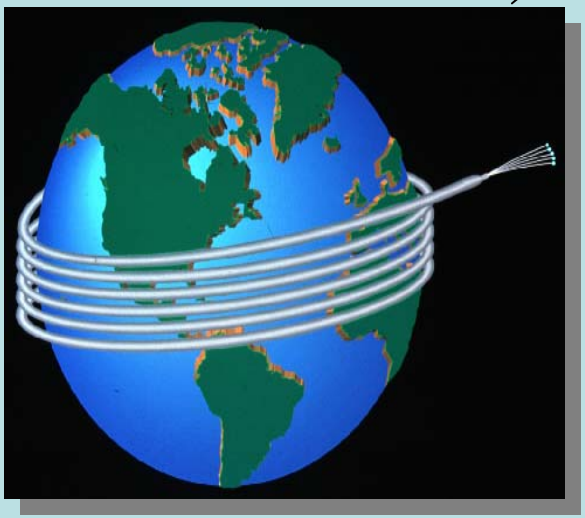
Summary of Undersea Fiber Optic Network Technology and Systems



By Adam Markow

Senior Telecom Analyst

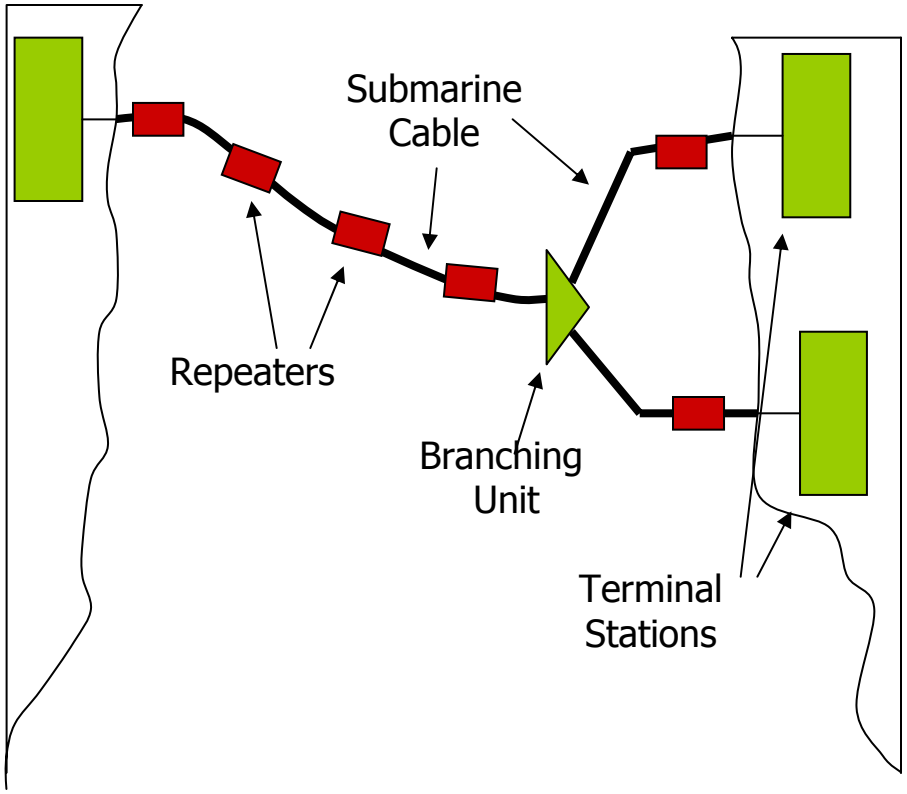
The source of many of the slides is from – The David Ross Group http://www.davidrossgroup.com

A view of the Global Submarine Cable Network (TeleGeography)

Undersea System Elements

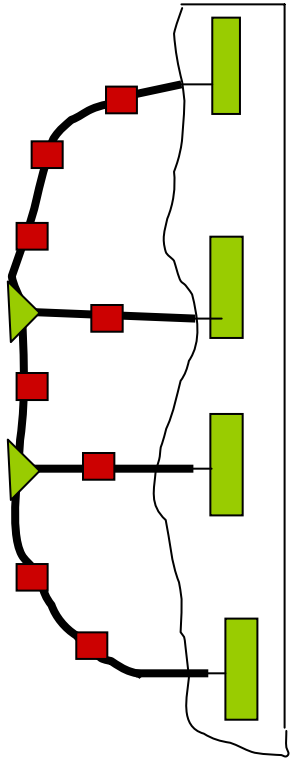
Repeatered Examples

Transoceanic Network



Coastal Network

Using the same elements



Undersea System Elements - *Non-Repeatered Examples*

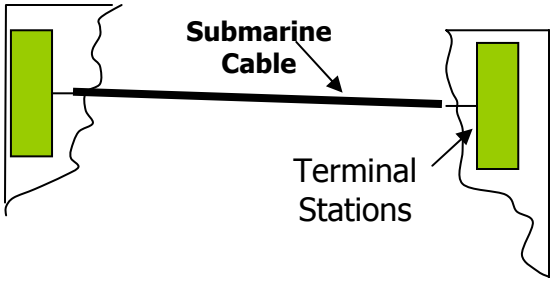
Repeaterless vs. Repeatered:

- Limited to <400 km span lengths
- Sometimes, but not always
  - Less expensive initially
  - More flexible long term
  - Less expensive to operate & maintain
  - More complex to upgrade
- Historical advantages of repeaterless offset today by current market oversupply of repeatered production capability and inventory

The choice between repeatered & repeaterless must be made on a case by case basis

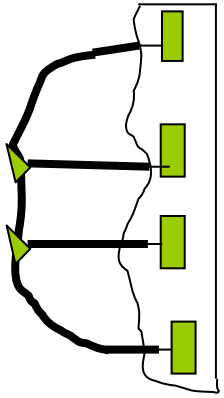
Source – The David Ross Group
http://www.davidrossgroup.com

Inter-island Network

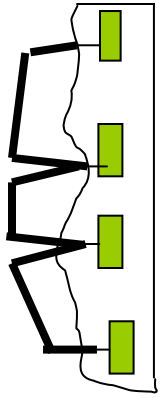


Coastal Networks

Using the same elements

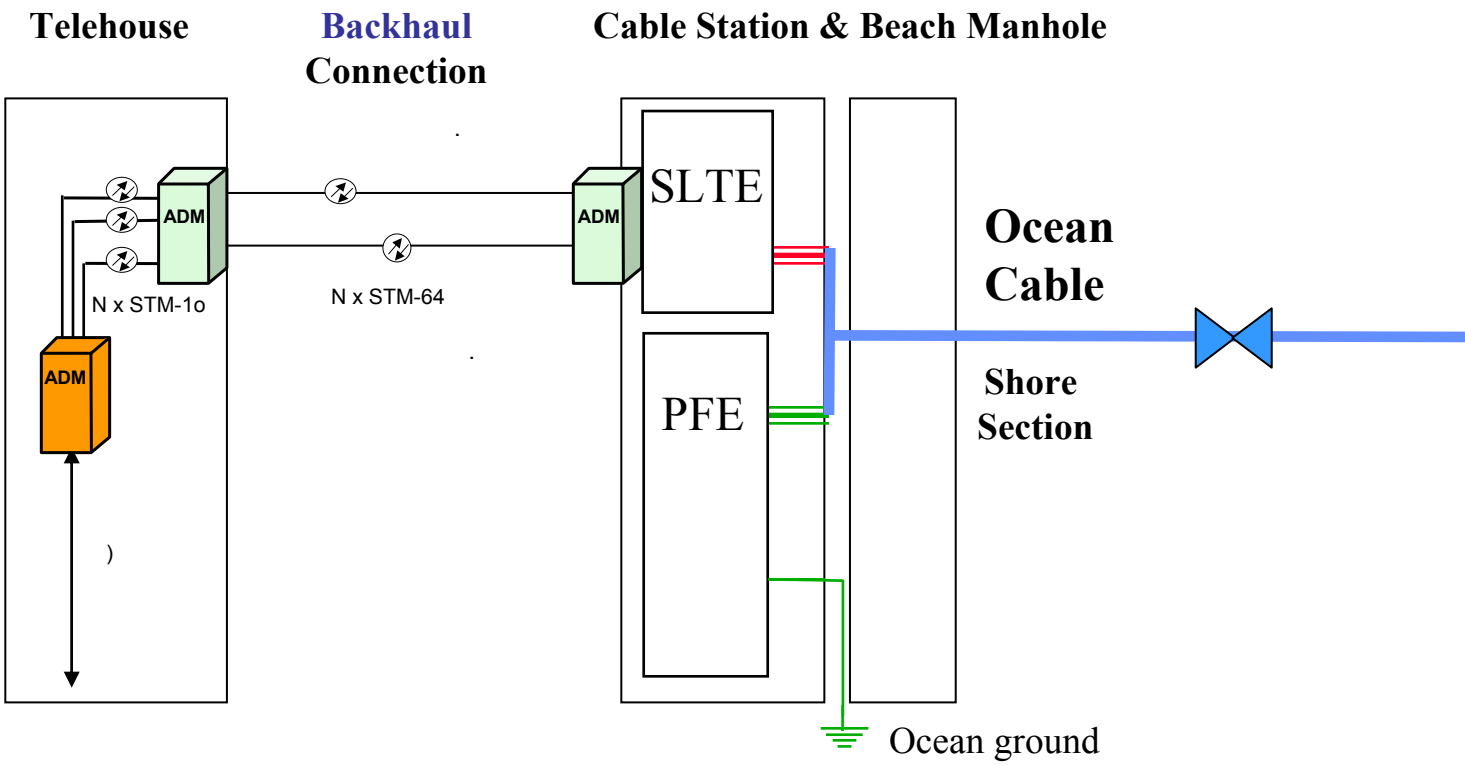


Trunk & Branch



Festoon

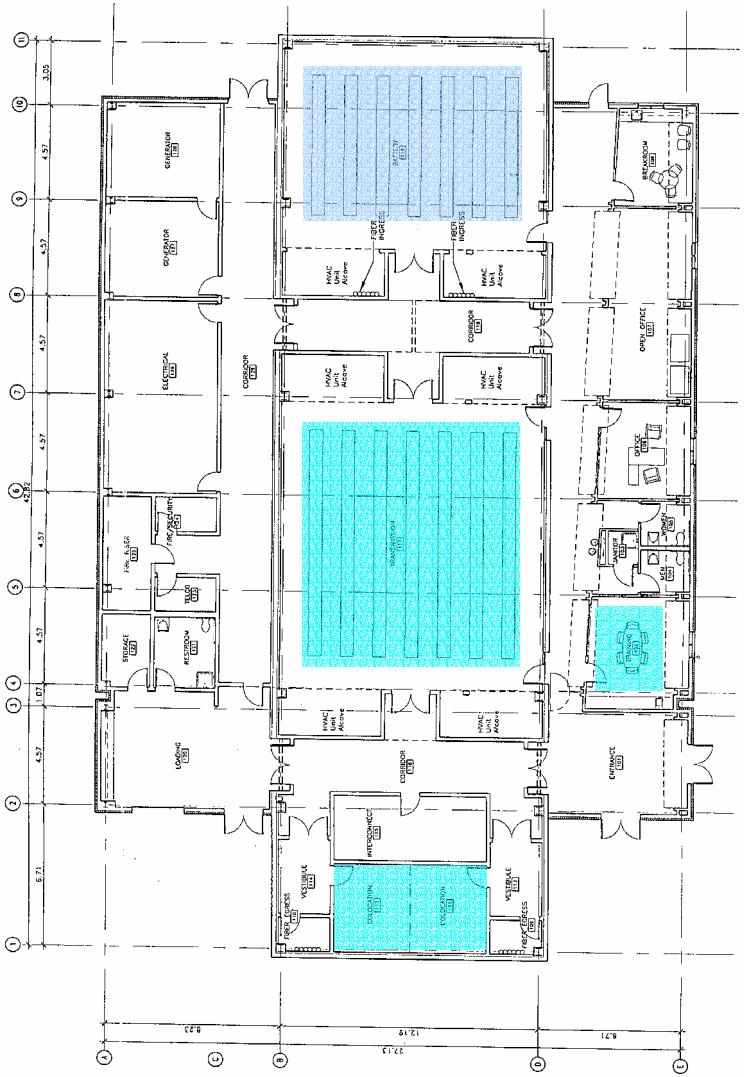
Connecting a Terrestrial Network with and Undersea System



SLTE – Submarine Line Termination Equipment.

PFE – Power Feed Equipment (pushes constant current of ~1.5 A across undersea cable link from CS to CS)

Cable Station Floor Plan



GCL Cable Station Requirements:

At least 17,000 square feet (~1900m^2) of total area

Raised floor, with minimum load tolerance of 500 kg/m^2
Useable height of at least 2.5m
Dual cable vaults
DC -48v power, with battery backup for at least 1 hour.
Diesel Engine emergency backup
HVAC to maintain room temperature between 22 - 24C
Ring Ground
Fire/smoke detection, with connection to emergency/control center
24 hour access for maintenance and repair

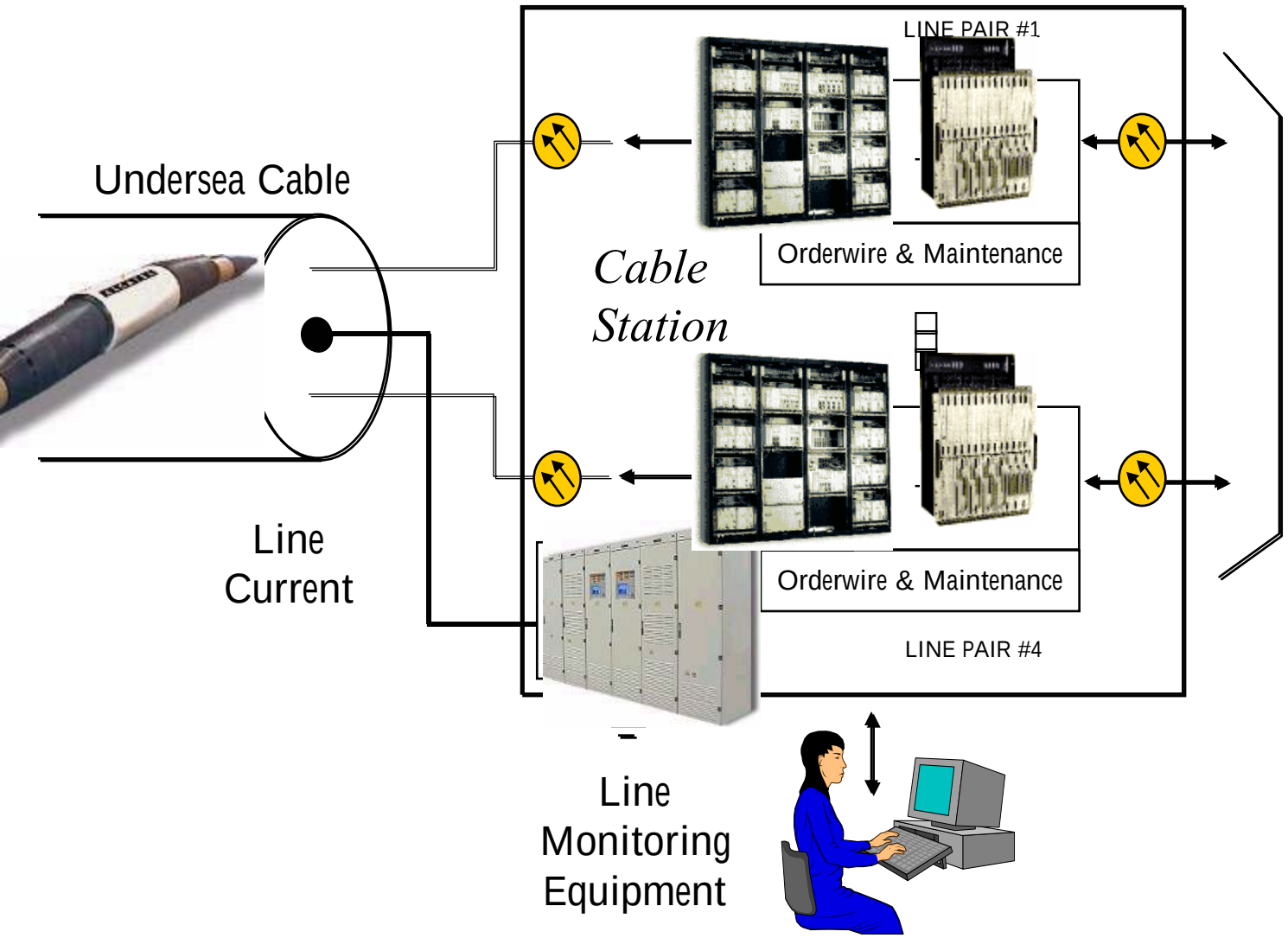
Battery

Transmission Equipment

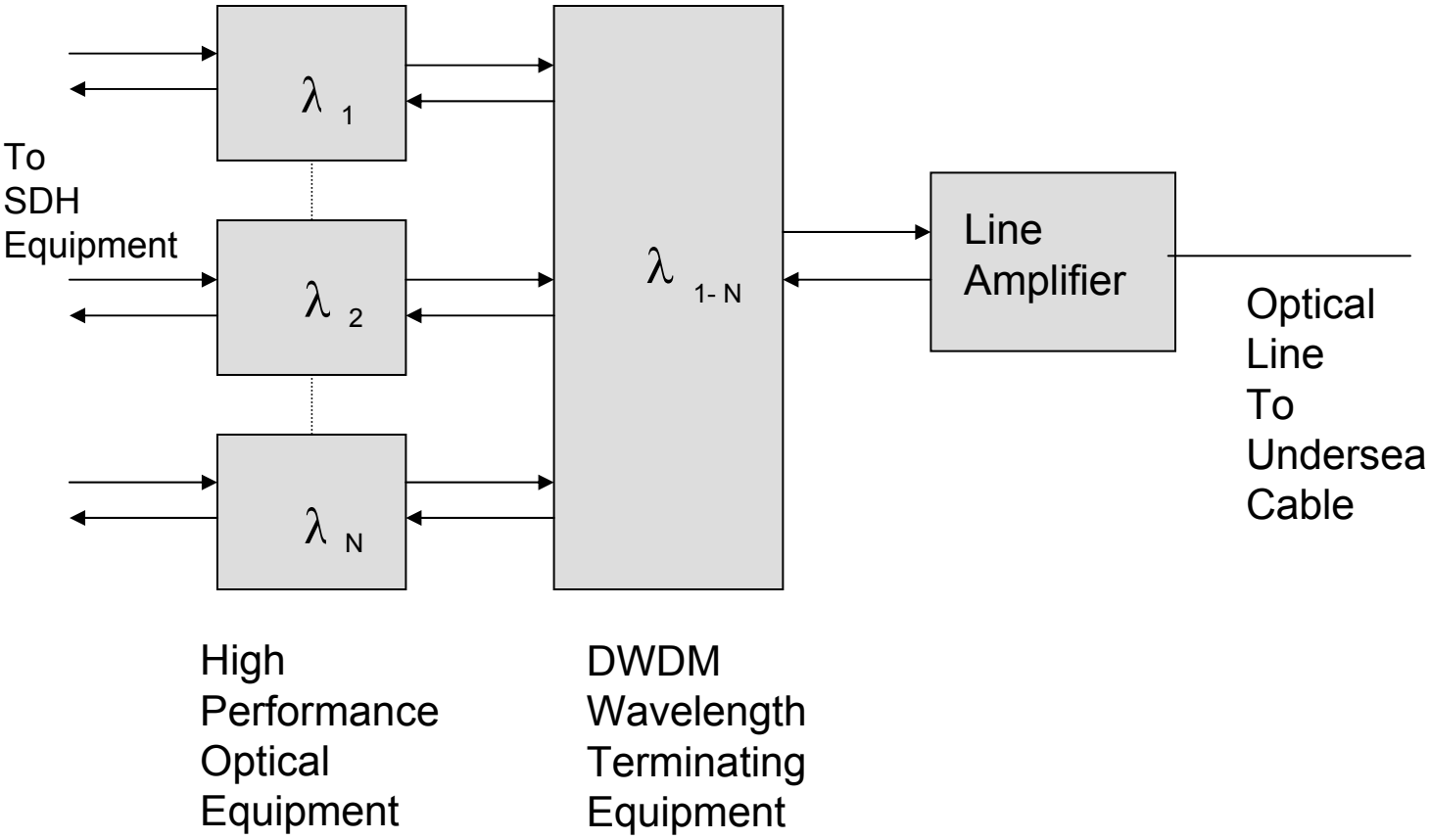
Collocation for backhaul

Meeting/training room

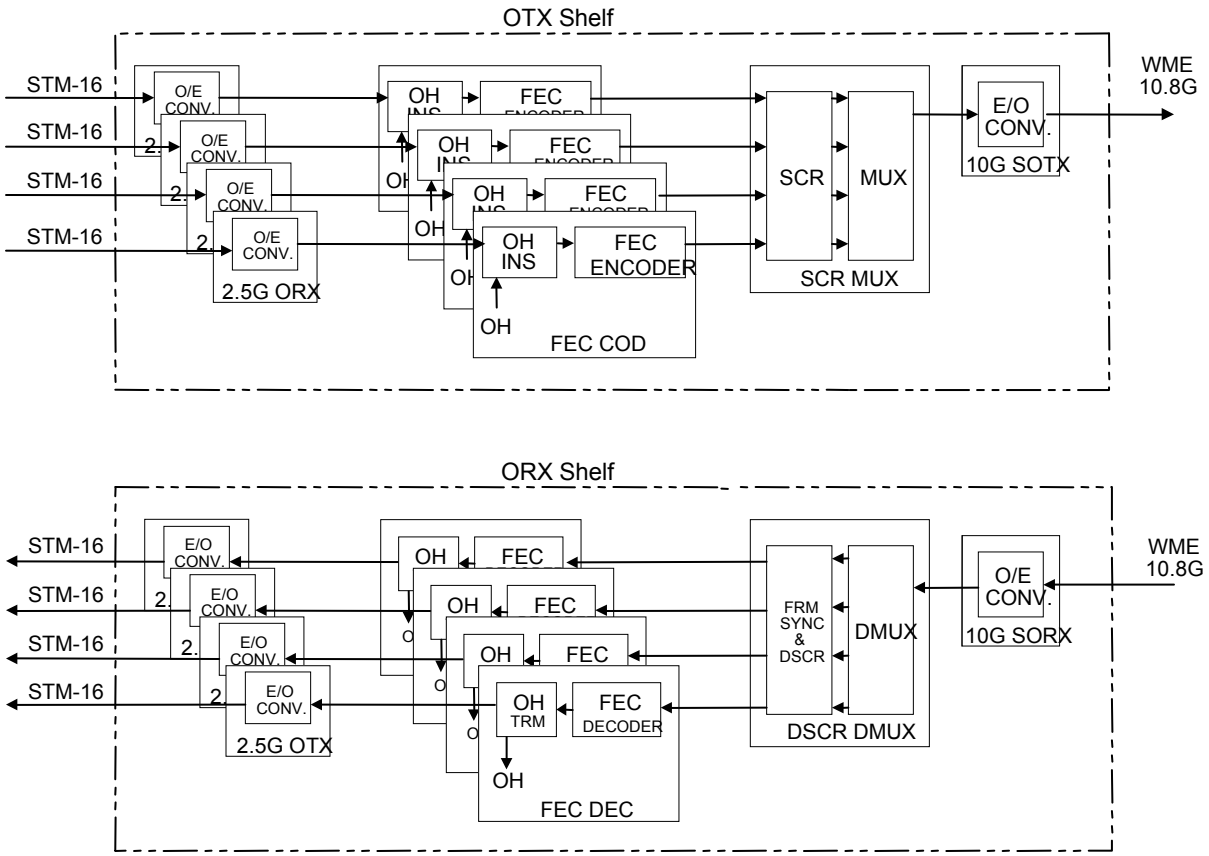
Cable Station Transmission Components



Land Plant – Line Terminating Equipment



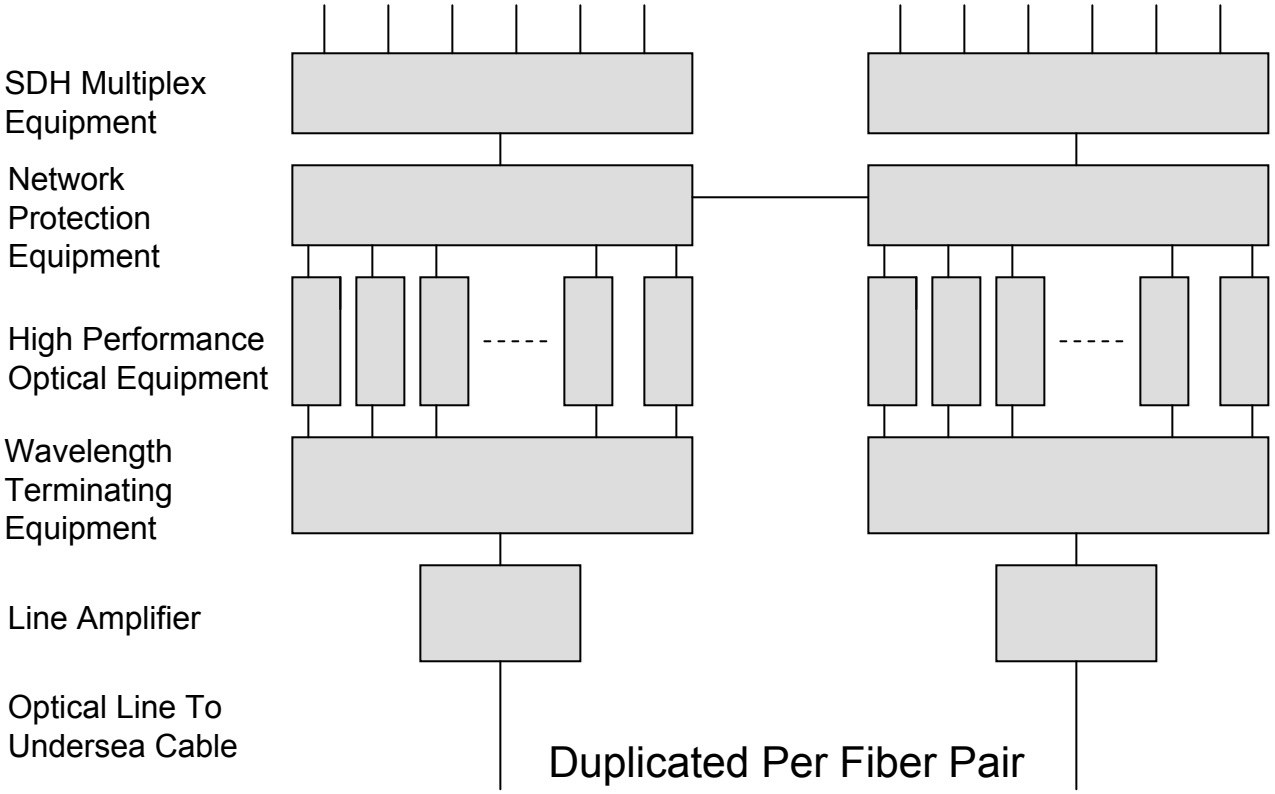
Land Plant – Line Terminating Equipment



Source – NEC

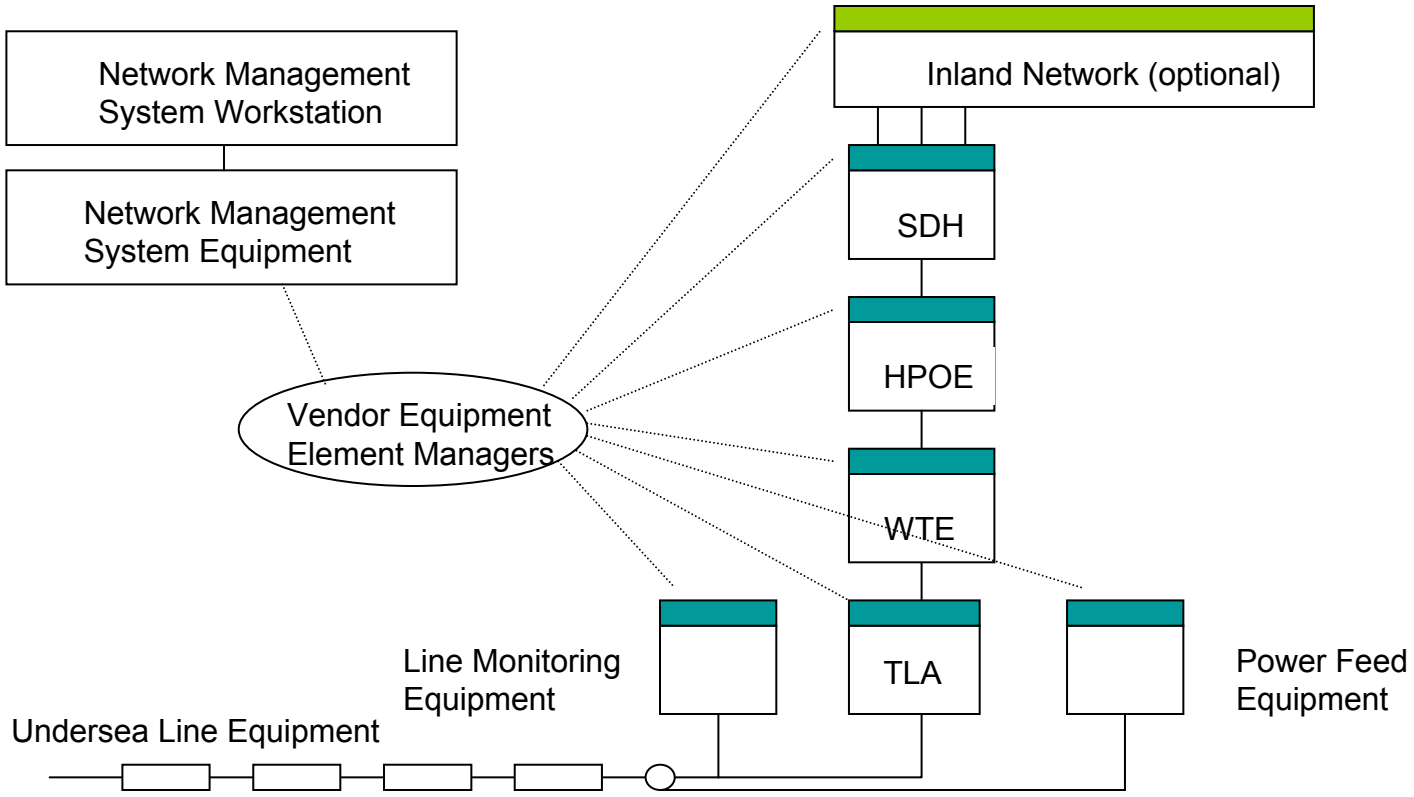
Source – The David Ross Group
http://www.davidrossgroup.com

Land Plant – SDH Ring Terminal



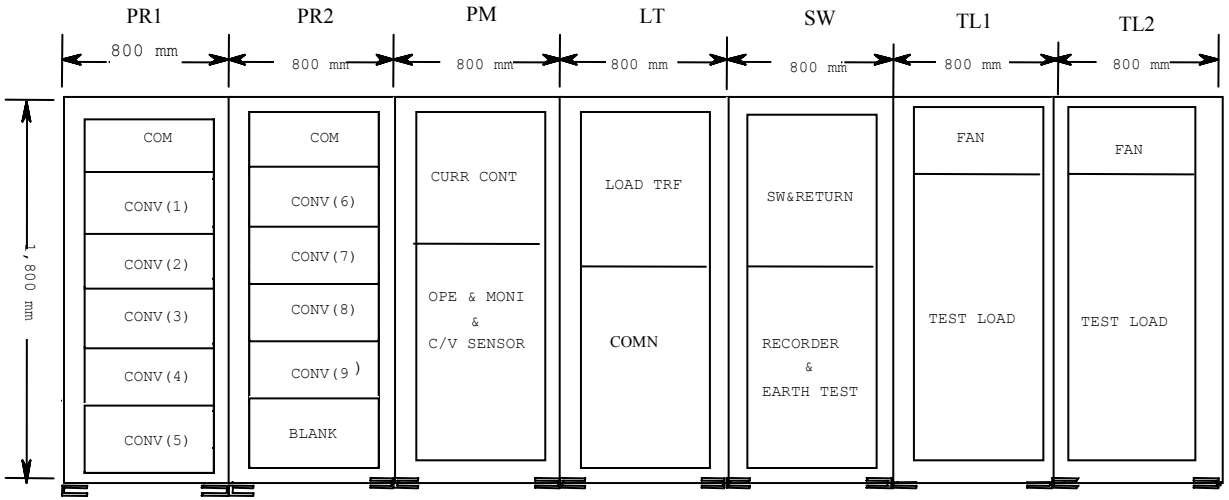
Source – The David Ross Group
http://www.davidrossgroup.com

Land Plant – Network Management Equipment



Source – The David Ross Group
http://www.davidrossgroup.com

Land Plant – Power Feed Equipment



*The depth of the frame: 600mm

HV PFE Configuration

Source – KDD SCS

Cable Station and Beach Manhole
2025 Taft Street - Hollywood, Florida

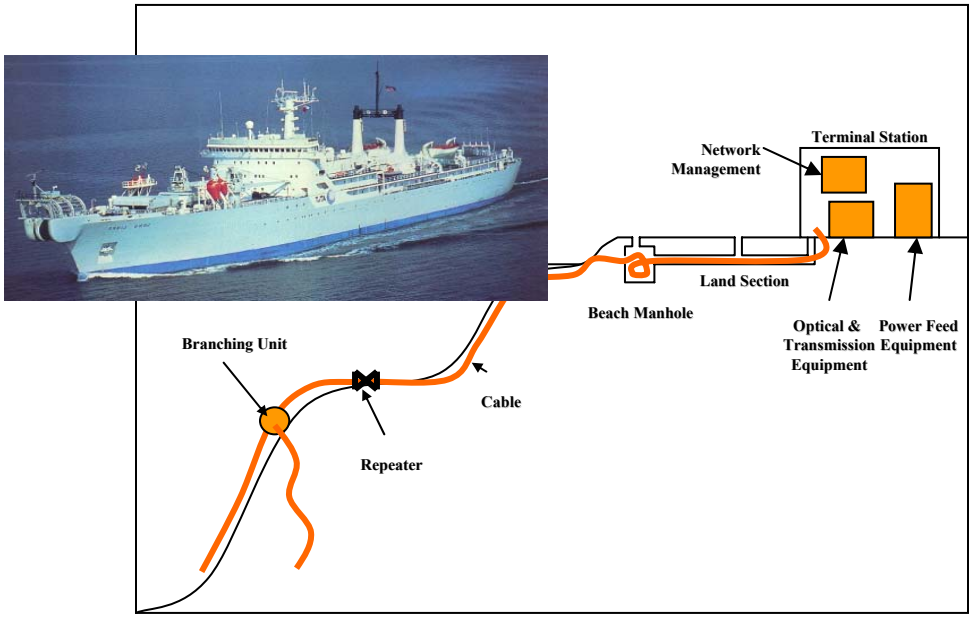
Global Crossing Backhaul in Hollywood, Florida

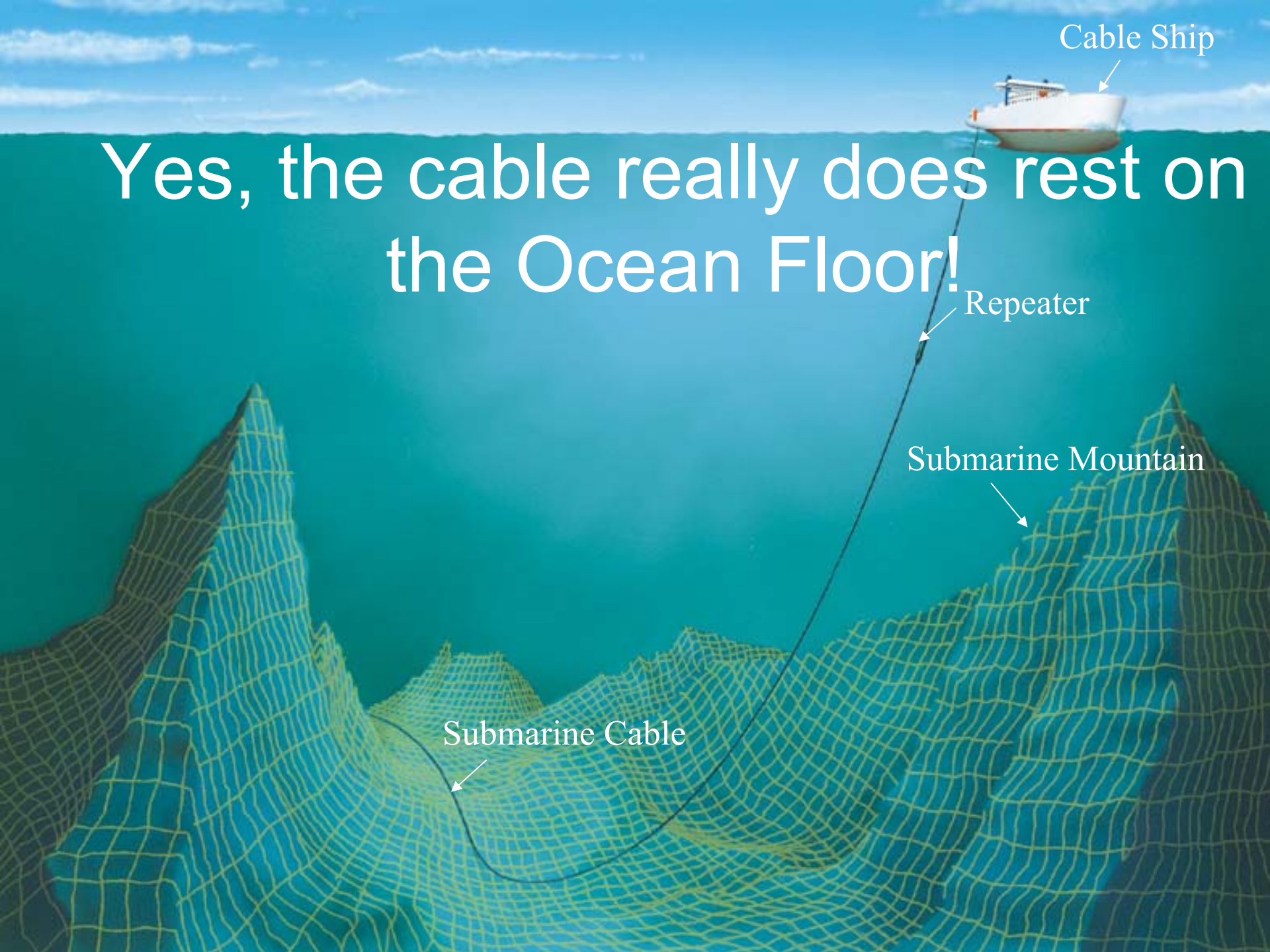
The optronic connection that starts at Optical Distribution Frame (ODF) in the **Cable Station** and then continues to the ODF at the City Service Point, the **Telehouse**.

Then a separate connection of the circuit is made to the frame of the carrier who will then take traffic back to the end customer premise.

Undersea Cable Landing Configuration

- **Submerged Plant**
- **Beach Manhole**
- **Shore Section**
- **Land Sections**
- **Terminal Station**
- **Terminal Station Equipment**




Cable Ship
Yes, the cable really does rest on the Ocean Floor!
Repeater
Submarine Mountain
Submarine Cable

terremark
Worldwide, Inc.

- South America Physical Map
- South America ERZ border at 12 nmi
- South American Crossing Segments are mostly *outside* of the ERZ

ERZ = Economic Resource Zone

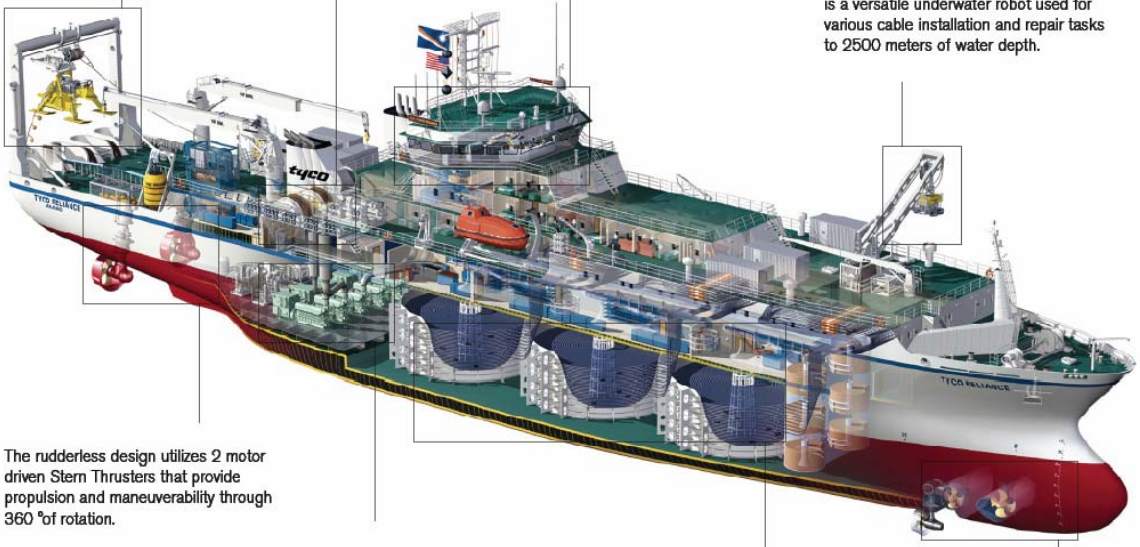
Installing a Submarine Cable System

Source – The David Ross Group
http://www.davidrossgroup.com

CS Long Lines

LONG LINES
YEAR OF BUILD: 1963
LENGTH: 155.91’
BREADTH: 21.19’
DRAUGHT: 8.17’
DEPTH: 13.87’
FLAG: UNITED STATES OF AMERICA
SHIPBUILDER: DEUTSCHE WERFT HAMBURG
COUNTRY OF BUILD: FEDERAL REPUBLIC OF GERMANY
STATUS: IN SERVICE/COMMISSION

Cable Ship Profile – Tyco Telecom

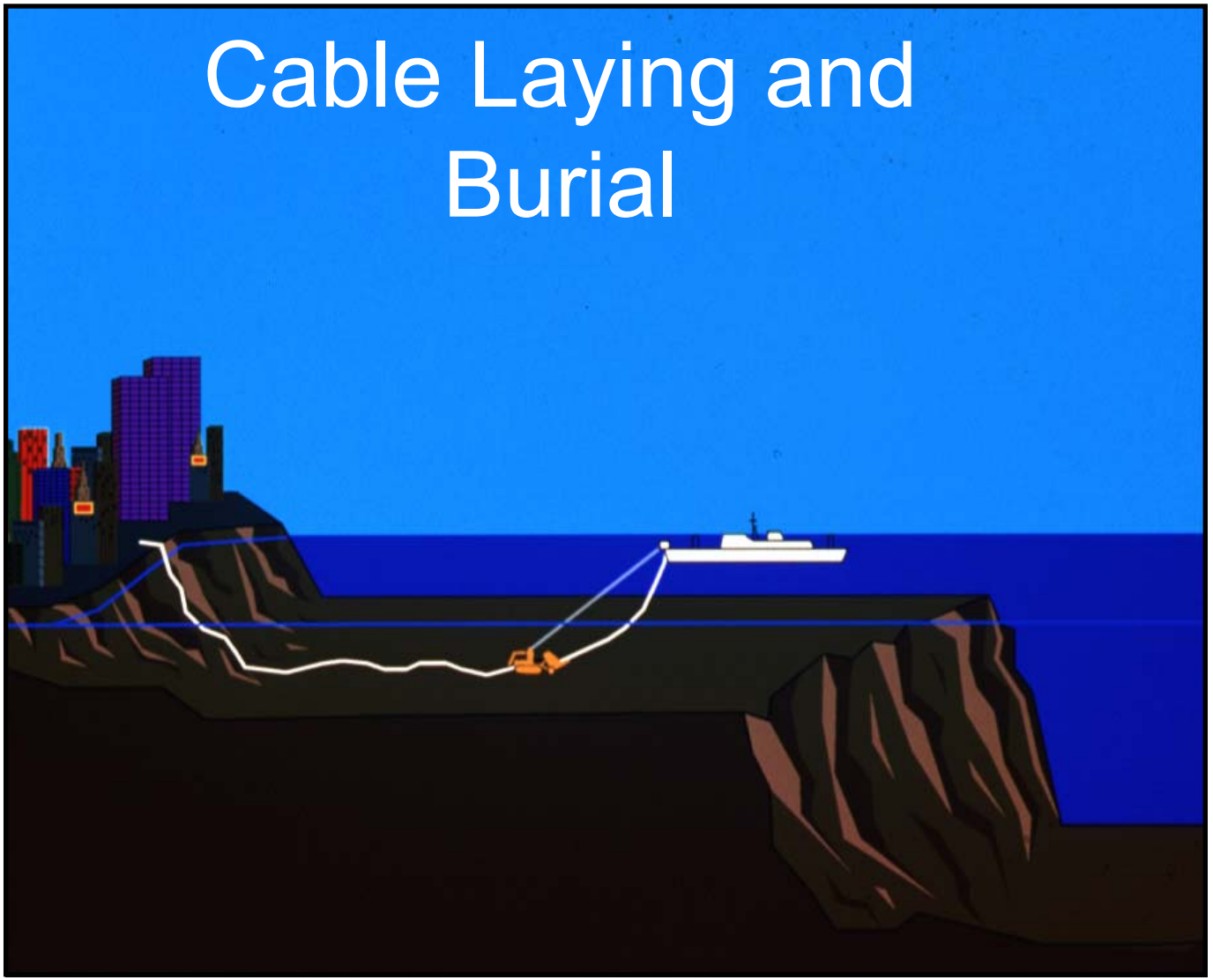


Our Reliance Class Fleet

CS Tyco Reliance	CS Tyco Dependable
CS Tyco Responder	CS Tyco Decisive
CS Tyco Resolute	CS Tyco Durable

terremark
Worldwide, Inc.
where the Internet meets the world™

Cable Laying and Burial



Phases of Cable System Network

Planning, Finance & Procurement

- Carrier Partnership
- Business Plan
- Preliminary Network Design & Desktop study
- Finance
- Procurement
- Survey
- Route engineering
- Network engineering

Deployment

- License & Permits
- Terminal Station Construction
- Manufacturing- Undersea and Land Plant
- Undersea Plant Assembly & Load
- Undersea Installation
  - Shore end and cable burial
  - Deep water i
  - Branching unit
  - Final Splice
- Terminal Station Installation
- Commissioning & Acceptance
- Service

Service, Operations & Maintenance

- System Provisioning
- Station & NOC Operations
- Cable Maintenance agreement (Cable recover, splicing, repair, relay, rebury)
- Network Upgrades

Survey Vessel

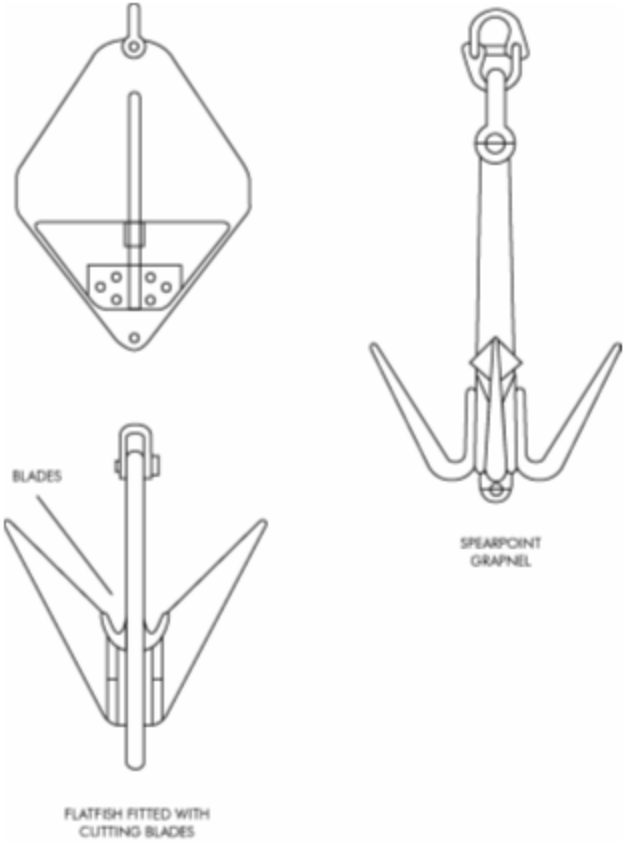
Installation Ship

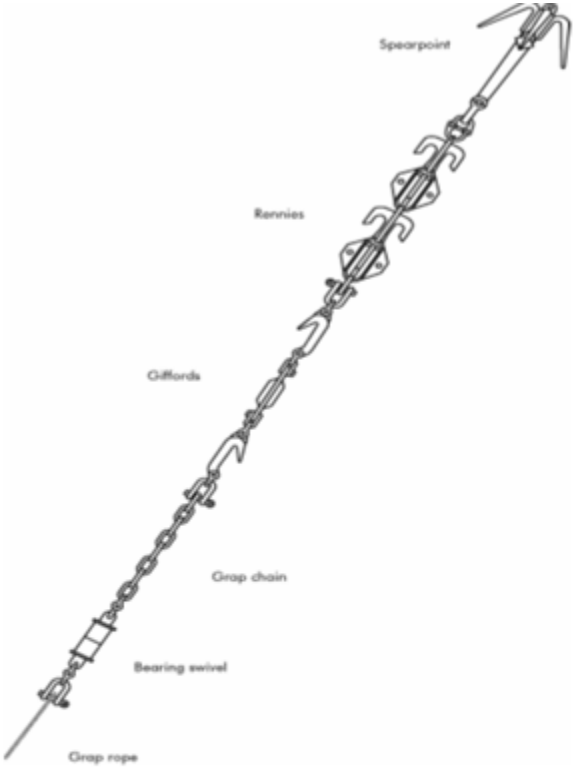
Sea Plow for Cable Burial Operation

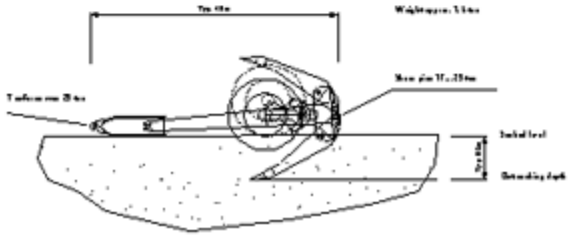
Maintenance Vessel

St. Croix Shore End - SAC,2000

If the cable should break, the cable must be hooked…





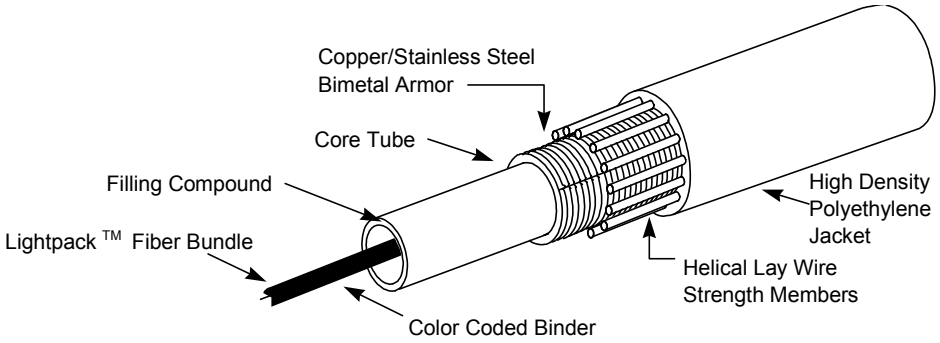


Land Plant

- Land Cables
- Terminal Stations

Land Plant – Land Cables

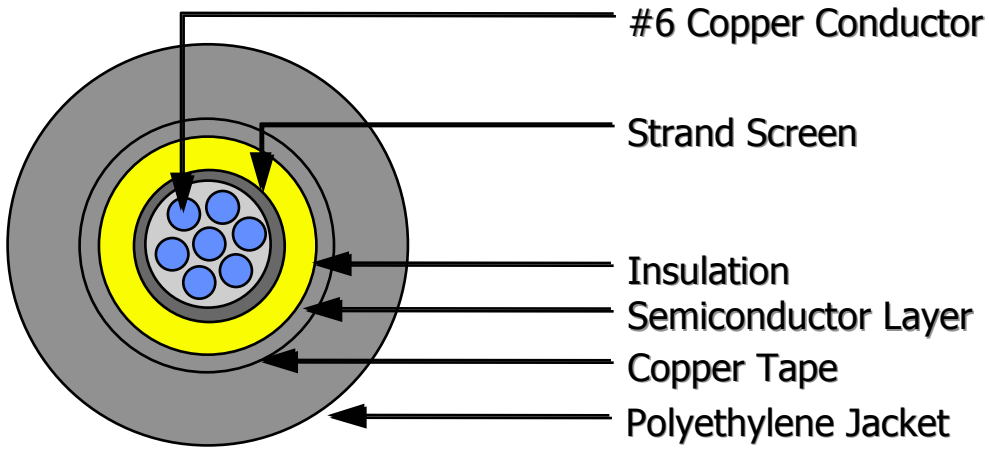
Fiber Cable



Source - Tycom

Land Plant – Land Cables

Power Cable



Source - Tycom

Land Plant – Terminal Station Equipment

- Line Terminating Equipment
  - High Performance Optical Equipment
  - Wavelength Terminating Equipment
  - Line Amplifiers
- SDH Network Protection Equipment
- SDH Multiplex Equipment
- Line Monitoring Equipment
- Network Management Equipment
- Power Feed Equipment
- Synchronization Equipment
- Test Equipment

Terminal Stations

- Typically terminate undersea signals, and interface with domestic network
- Most often very close to beach
- Construction & features very similar to other telecom offices, such as Central Offices, but include some unique aspects
- In multi-point coastal systems, costs can become significant element of network cost.
- Large stations cost $10-$15M. Very small stations <$5M.
- Permissions and Rights Of Ways associated with construction and beach access, plus actual civil construction, together often dominate overall network construction schedule
- In small, regional networks, alternate more efficient options (prefabricated huts) may be possible

Source – The David Ross Group
http://www.davidrossgroup.com

Undersea Plant

- Cable and Fiber
- Repeaters
- Equalizers
- Branching Units
- Marine Installation

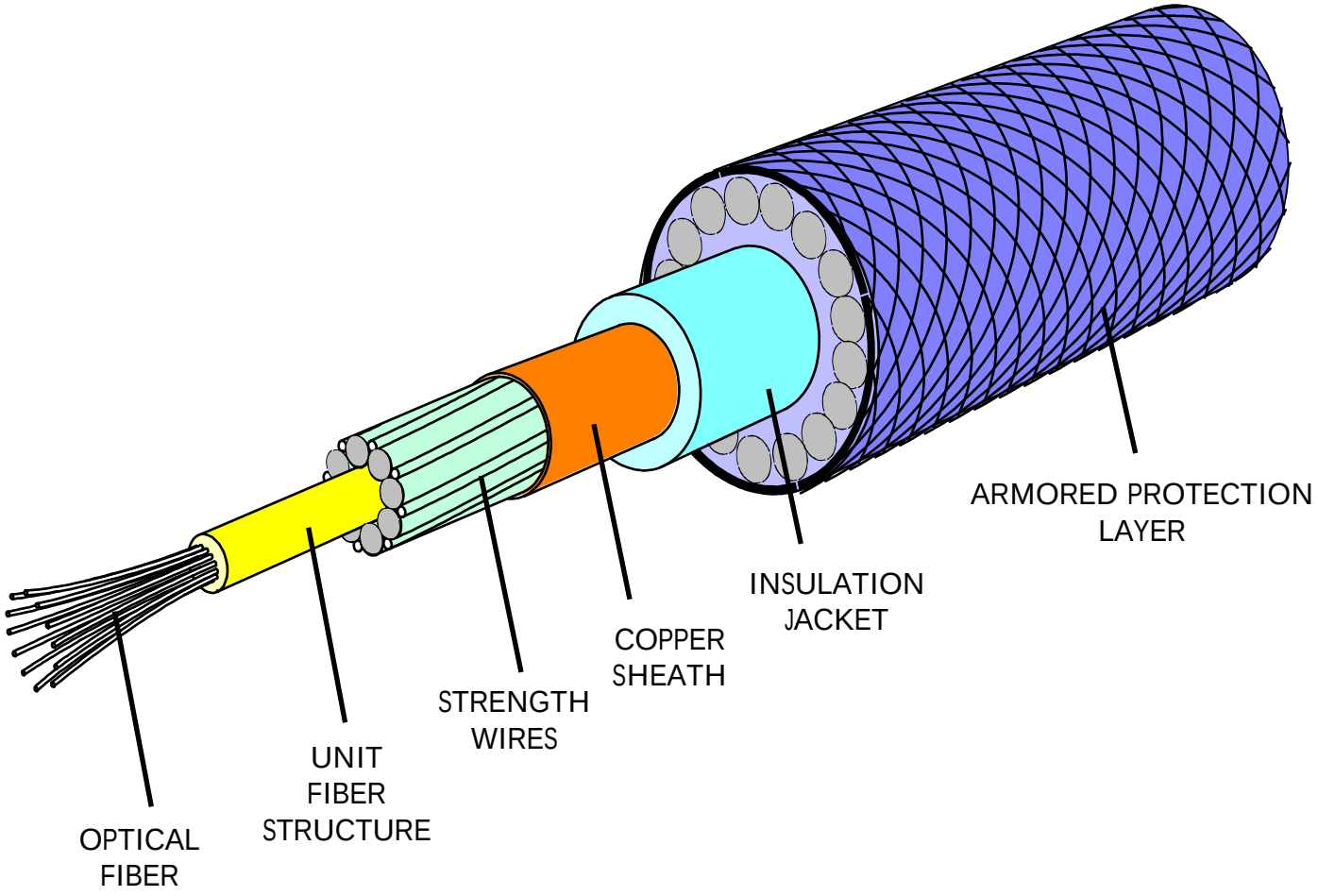
Undersea Plant

- Cable and Fiber
  - Specified for each span of each system
  - Typically 1 to 4 types of cable depending on type of environmental protection needed
  - Typically 1 to 3 types of fiber depending on required management of optical transmission properties
  - Network costs vary widely depending on types of cable (increase dramatically in vulnerable areas)

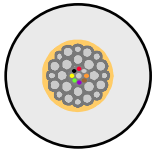
Submarine Fiber Cables

Comparison of Coaxial and Fiber Optics Cable

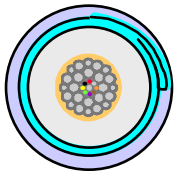
Undersea Optical Cable
Tyco “Standard” design < 2000



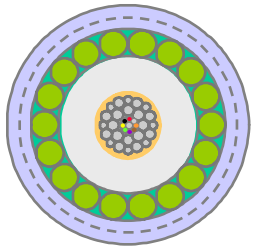
Undersea Plant – Cable Types



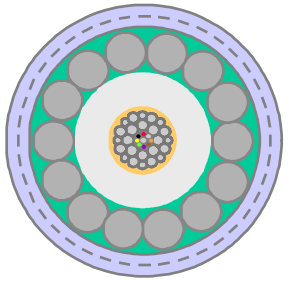
LW
(Lightweight)



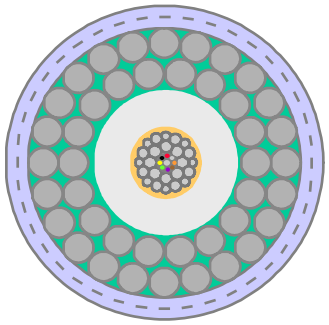
SPA
(Special Purpose Armor)



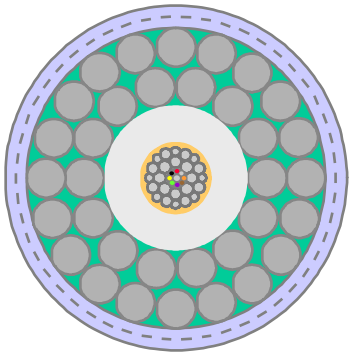
LWA
(Light Wire Armor)



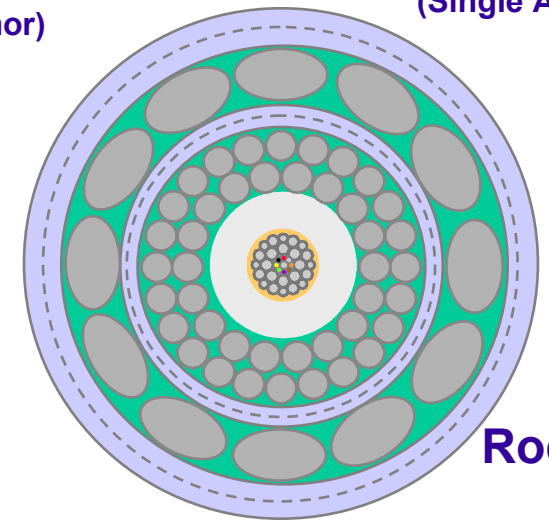
SA
(Single Armor)



DA-HS
(Double Armor, High Strength)



DA-HA
(Double Armor, High Impact)



Rock Armor

Source – Tycom

Various Cables and Applications

- **Undersea Cable Types:**

Undersea Cable	Typical Application
Double Armored (DA)	Beach Joint to 400 Meter Depth
Single Armored (SA)	400 to 900 Meter Depth
Light-Wire Armored (LWA)	Buried
Special Application* (SPA)	900-2,000 Meter Depth
Light Weight (LW)	>2,000 Meter Depth

- **Power & Ground Cable**
- **Land Cable**

*Fish Bite Protected Cable

Undersea Plant – LW Cable

- Lightweight cable
  - Used in deep water where hazards are minimal
  - Comes in three outer diameters
    - 10-12 mm, used in non-repeatered systems
    - 17-19 mm, used in several recent repeatered systems
    - 21-23 mm, used in repeatered systems wherever the additional size is deemed necessary or desirable
  - Cost varies in proportion to size.

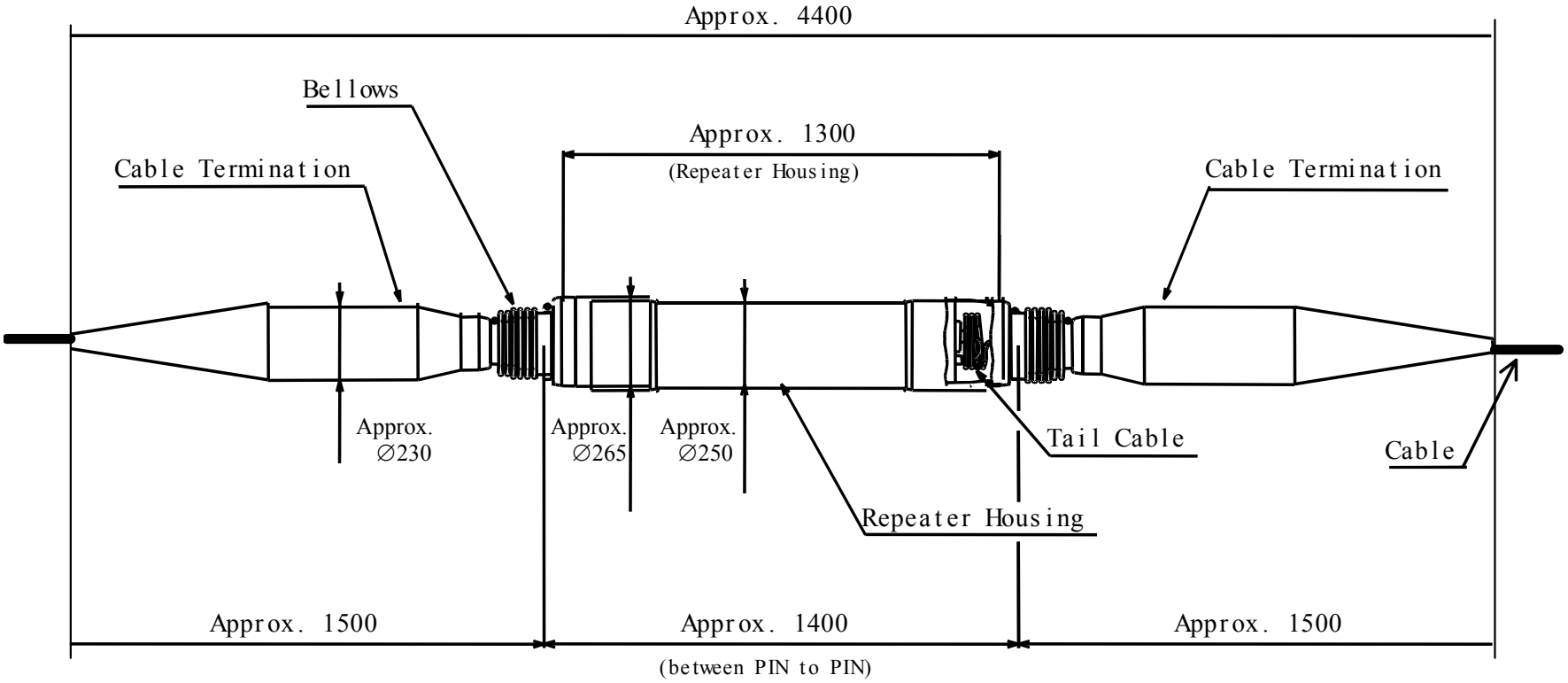
Undersea Plant – Armored Cable

- Armored cable
  - Used in shallower water where hazards from abrasion, fishing activity or anchors warrant
  - Comes in several varieties
    - SPA, for light abrasion or “fishbite” protection
    - LWA, for harsher abrasion
    - SA, for light marine activity
    - DA, for heavier marine activity
    - Rock armor, for the most challenging environments
  - Specified jointly by supplier, installer, and purchaser
  - Armor is costly, takes more time to produce, load, lay
  - Result: systems in difficult environments cost much more

Undersea Plant- Repeaters

- Repeater
  - Performance designed to match needs of system
  - Two sizes presently available
    - 1 to 4 fiber pair
    - 5 to 8 fiber pair
  - One optical amplifier per fiber
  - Costs strongly dependent on number of fiber pair
  - Cost also dependent on performance
  - Spacing (between repeaters) set for system performance / cost, and typically 50-80km
  - Shorter spacing generally yields higher ultimate capacity
  - In long (many thousand km) systems, often largest single component network cost

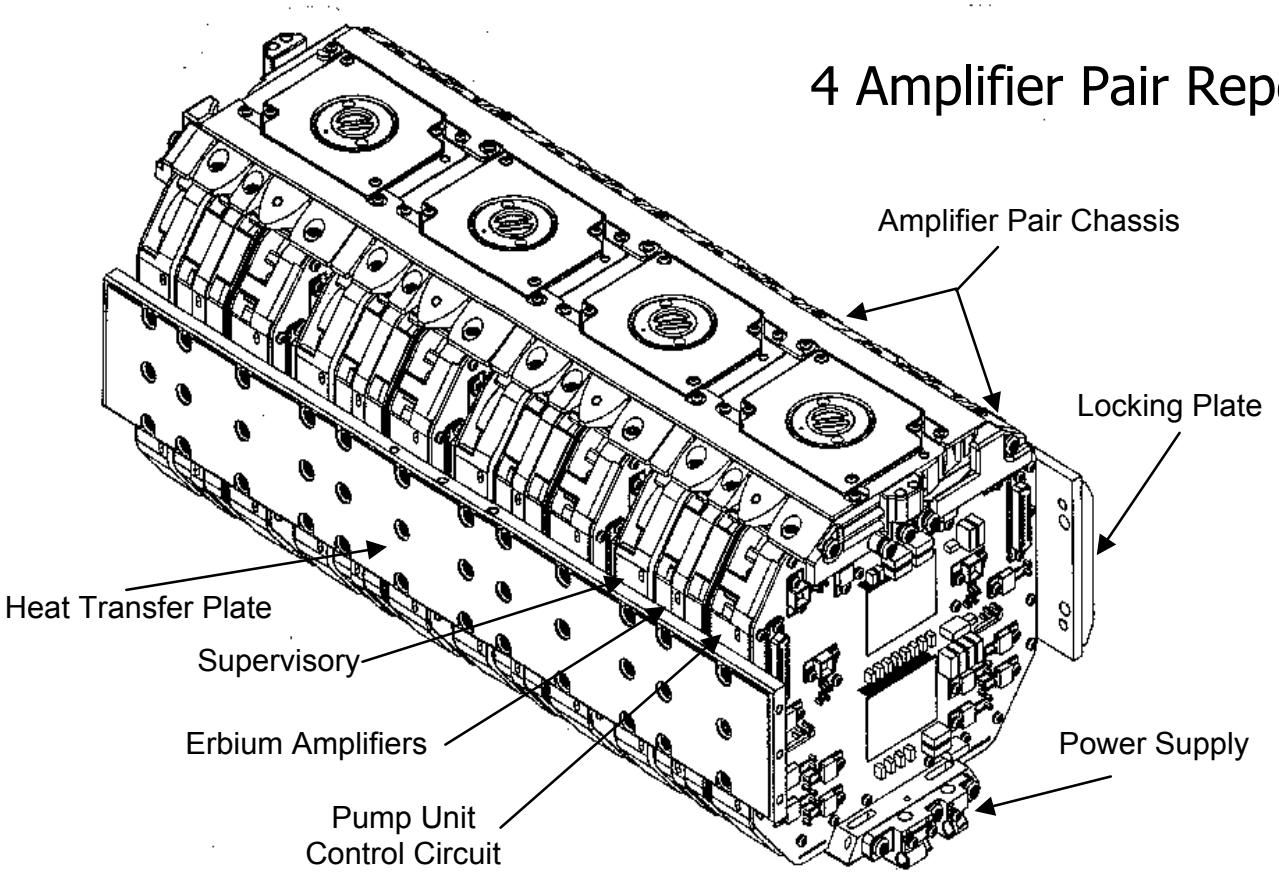
Undersea Plant – Repeater



Source - NEC

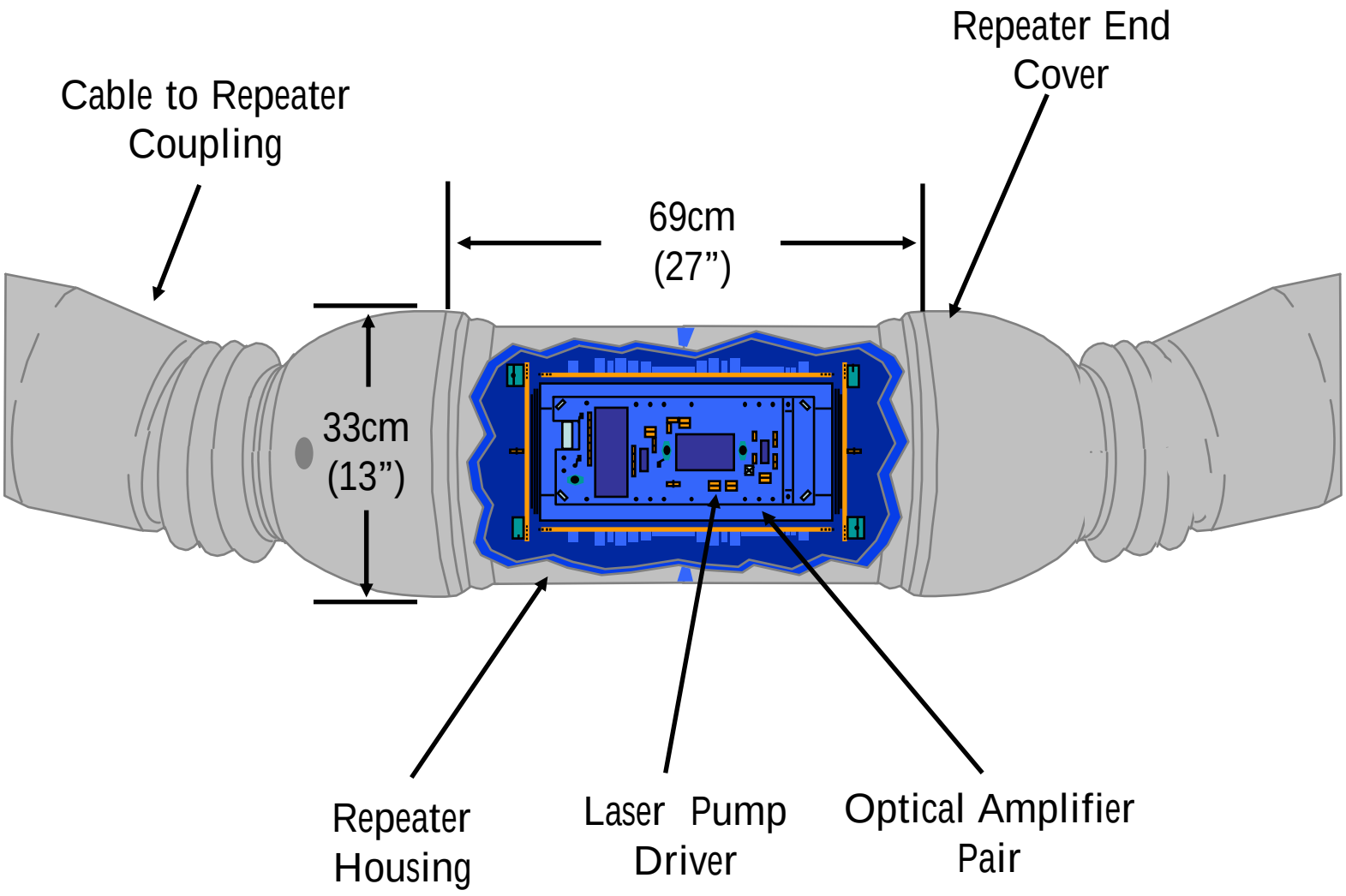
Undersea Plant – Repeater

4 Amplifier Pair Repeater



Source – Tycom

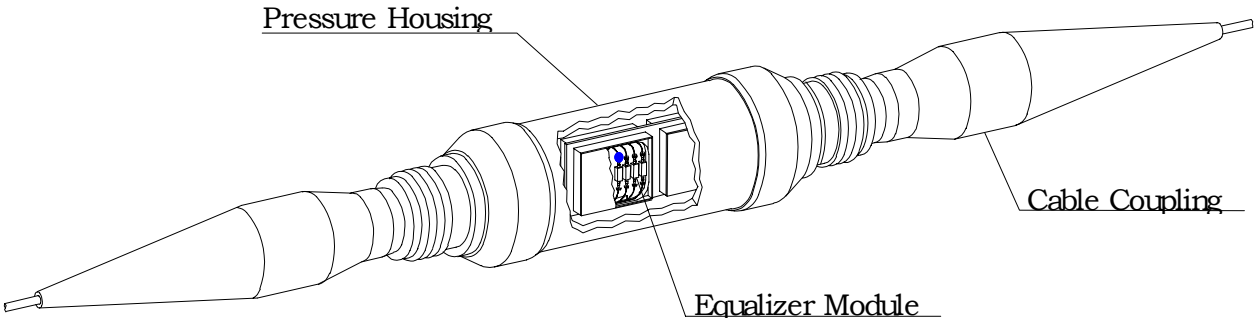
TSSL Repeater < 2000



Undersea Plant

- Equalizer
  - Performance designed to match needs of system
  - Inserted at periodic intervals as needed
  - One equalizer per fiber
  - Cost strongly dependent on number of fiber pair
  - Higher capacity systems generally require more exotic equalization

Undersea Plant – Equalizer

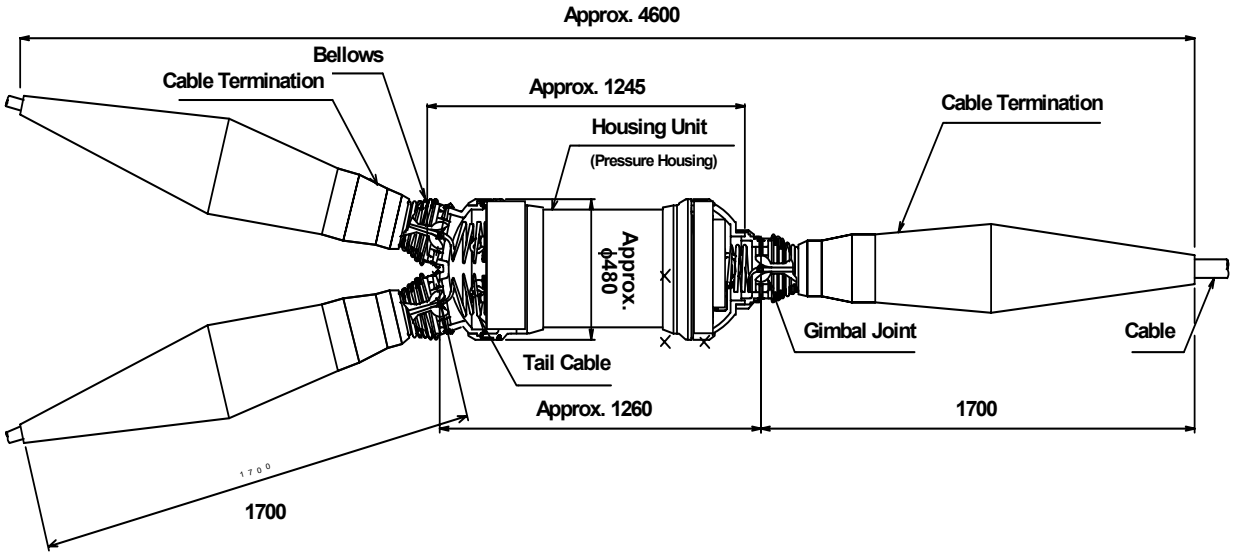


Source - NEC

Undersea Plant

- Branching Unit
  - All currently produced are three-terminal
  - One or more fiber pair may be branched
  - Fiber connections or powering may be switchable from a shore terminal or NOC for restoration or security
  - Wavelength branching (Optical Undersea Add-Drop Mutiplexing) has been done on a limited basis
  - Cost is strongly dependent on degree of complexity and number of fiber pair

Undersea Plant – Branching Unit



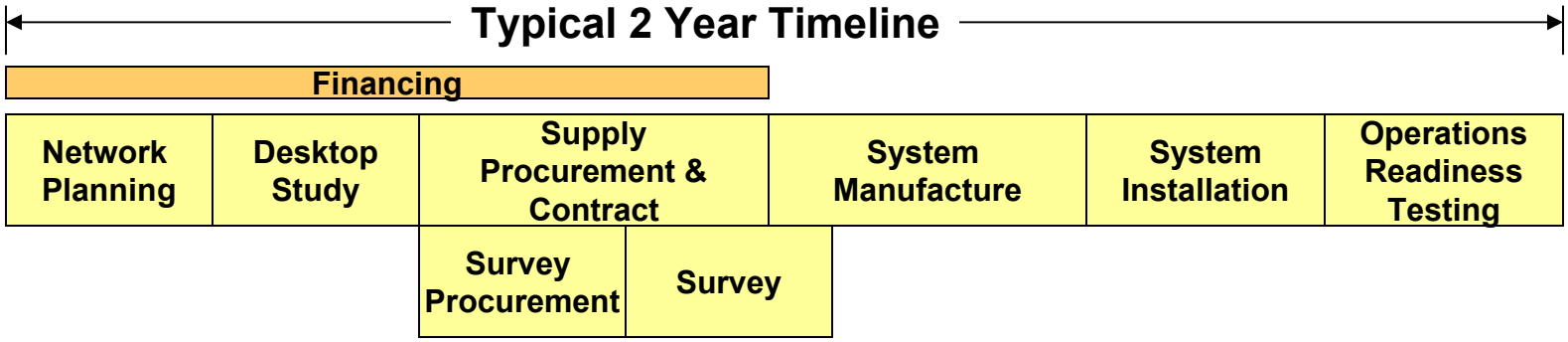
Source - NEC

Undersea Plant

- Marine Installation
  - Uses specially designed cable-laying vessels and tools
  - Costs strongly dependent on
    - Water depth
    - Types of cable and protection employed
    - Bottom characteristics
    - Burial depth required
    - Number of shore landings and branching units
    - Number of cable and pipeline crossings
    - Distance of lay from cable factory
    - Weather

Deployment Timeline – Economies to Be Achieved

Traditional Procurement Cycle



Source – The David Ross Group
http://www.davidrossgroup.com

Primary Network Construction Elements

- Wet Plant
- Dry Plant
- Terminal Stations & Backhaul
- Marine Work
- Network Operations Center

Network Construction Cost & Payment Schedule

- Typical Network Costs (1998-2001): $30-40K/km, plus stations
- Today's Discounted Network Costs, with Market Oversupply: $20K/km, plus stations
- Work Typically Begins with secure finance, followed by secure supply contract
  - 5-10% down payment
  - Periodic milestone-based progress payments during construction period, cumulating to 75-85% before service begins
  - Additional 10-15% at start of service
  - Last 5-10% at final acceptance months thereafter
- Work might begin earlier via an ITP **IF** purchaser guarantees payment for all supplier expenses prior to secure contract

Today's oversupply market offers huge discounts for purchasers, but minimal opportunities for vendor finance

Costs After the Initial Installation

- Operation and Administration
- Maintenance and Repair
- Network Upgrades

Costs After the Initial Installation

- Operation and Administration
  - In consortium and domestic systems, operation handled by experts landing-party carriers.
  - In private systems, operation provided by carriers' carriers or outsourced to suppliers.
  - Involves staff at cable stations and the Network Operations Center (if any).
  - Functions involve provisioning, troubleshooting, monitoring performance, and billing.
  - For domestic undersea networks, processes can readily be integrated with similar processes for other land & satellite-based elements of the carrier's complete network

Costs After the Initial Installation

- Maintenance and Repair
  - Dry maintenance and repair handled by operations staff and suppliers.
  - Wet maintenance and repair handled by Cable Maintenance Authorities under Cable Maintenance Agreements.
  - CMAs employ ships, spares, and skilled personnel on standby to do repairs on any cable within the agreement.
  - CMAs are specific to geographic regions, e.g. Atlantic, Pacific and Indian Ocean, etc.
  - Costs of CMAs typically depend on length of system and number of landings, as drivers of expected number of repairs.
  - Per-network costs are greatly dependent on the number of networks covered in the CMA sharing its expense.
  - Wet maintenance costs have dropped dramatically from 2001-2003 as a consequence of an excess of cable ships, but remain millions (US$) annually

Costs After the Initial Installation

- Network Upgrades
  - Network upgrades to increase capacity by adding wavelengths are planned and contracted (price-capped) at the time of the initial system construction.
  - Typically, but not always, the same supplier installs and upgrades the network
  - Terminal stations must be sized for the ultimate capacity of the system, often requiring tens of thousands of square feet.
  - In high-capacity WDM systems, upgrading to the ultimate design capacity may take many years, and will often cost more than the initial undersea system installation.
  - Since technology and prices change over time, purchasers often obtain better prices (than originally contracted) at the time they are needed

Life-Cycle Costs