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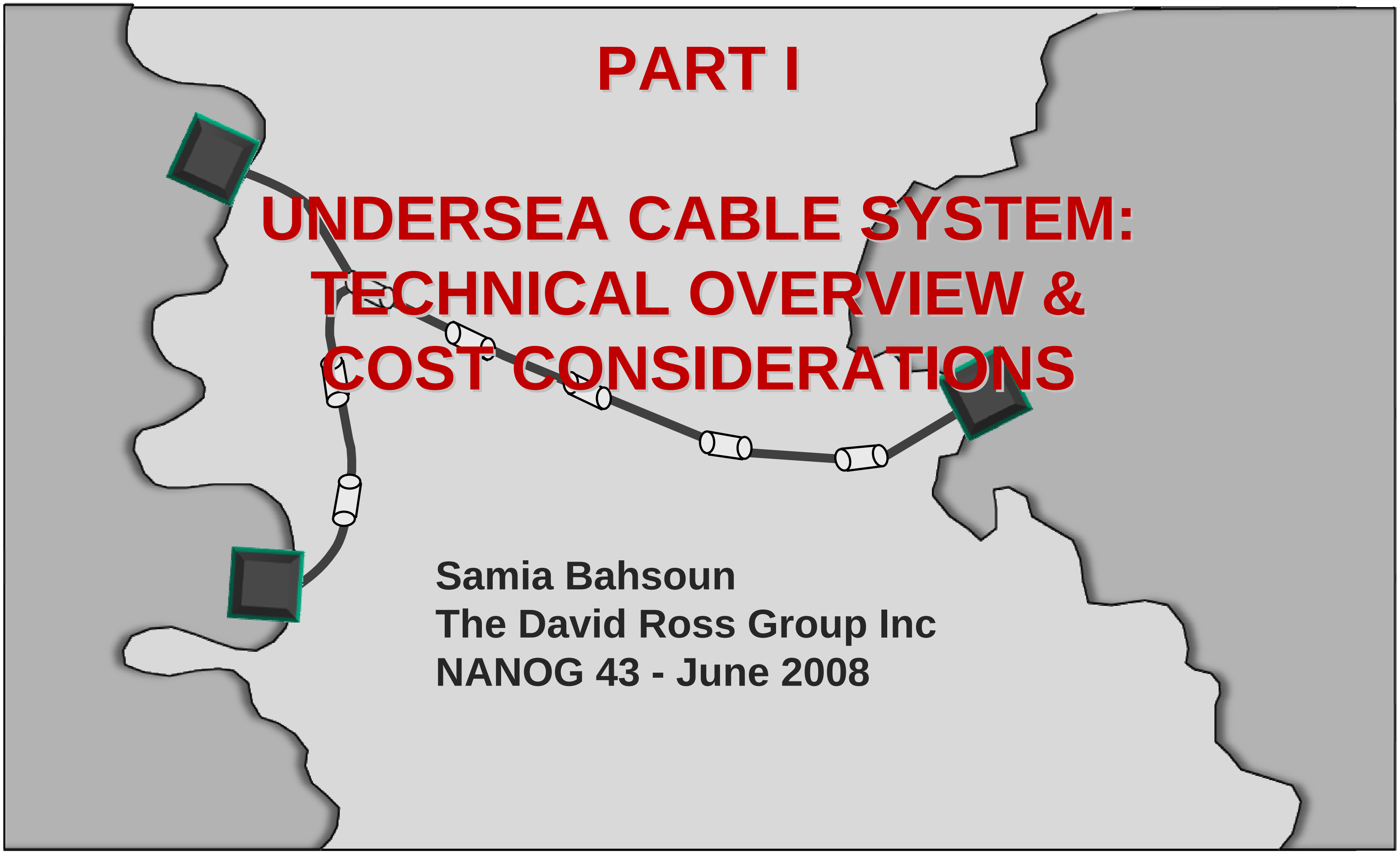
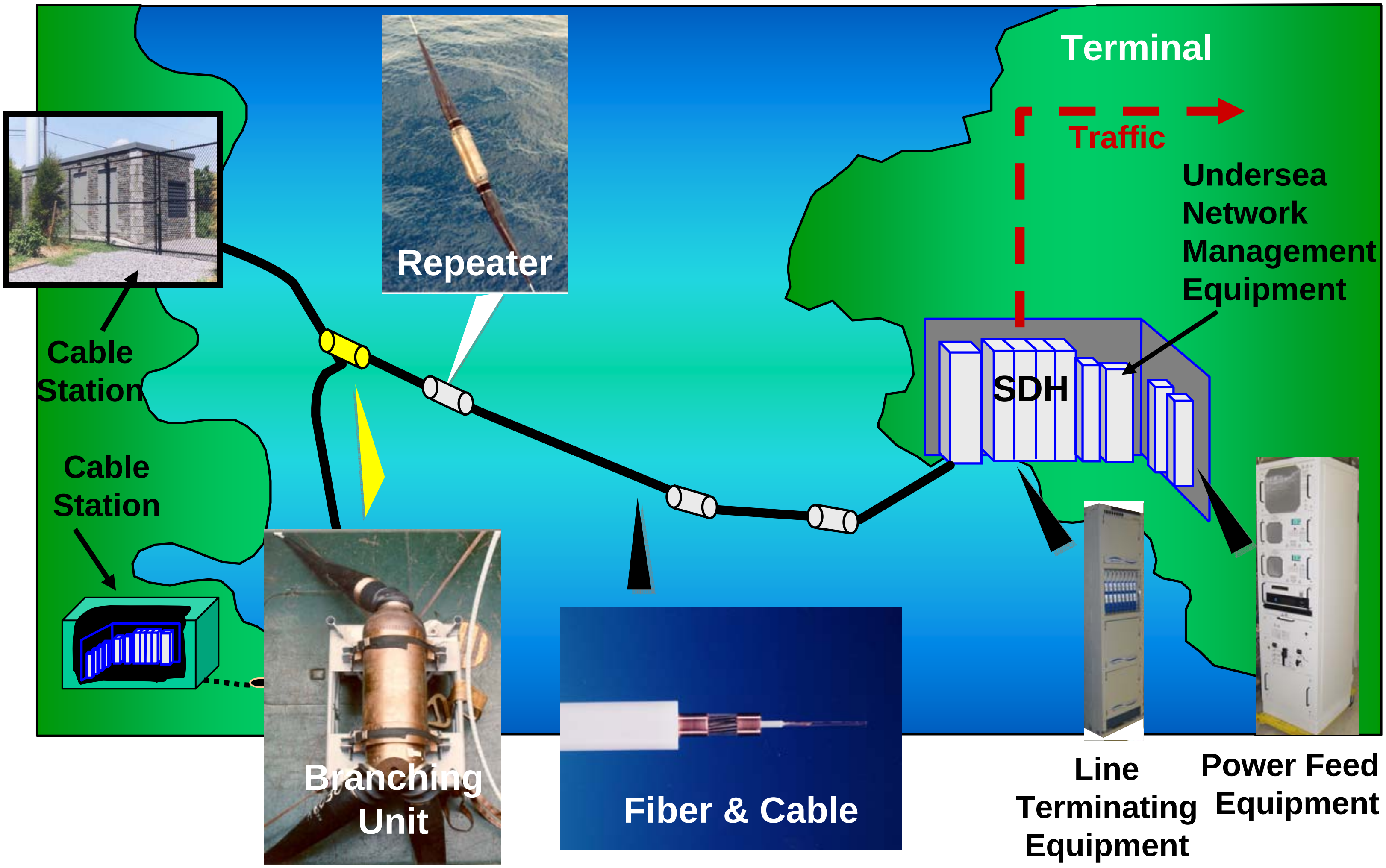
PART I

UNDERSEA CABLE SYSTEM: TECHNICAL OVERVIEW & COST CONSIDERATIONS

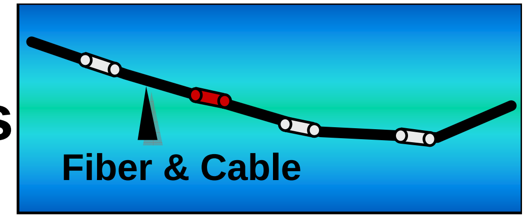


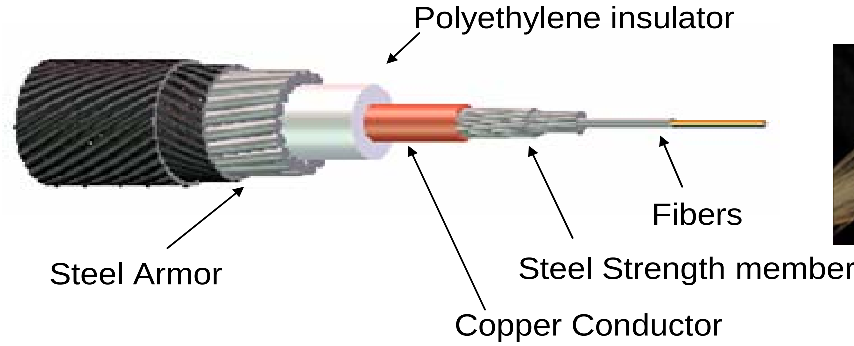
Samia Bahsoun
The David Ross Group Inc
NANOG 43 - June 2008

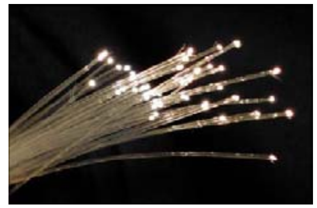
Elements of an Undersea Submarine Cable System

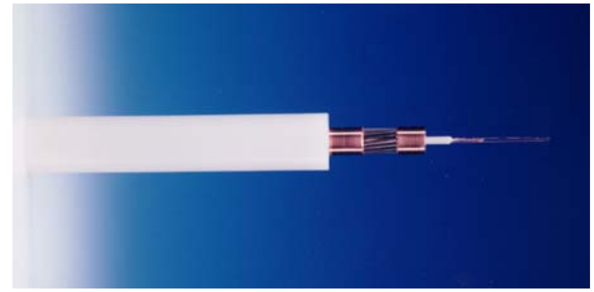


Undersea Cables







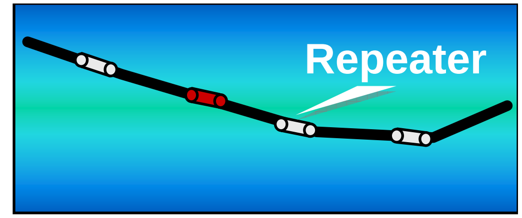


Armored Cable (LWA, SA, DA, etc)

Lightweight Cable: Serves as the core for all armored cables

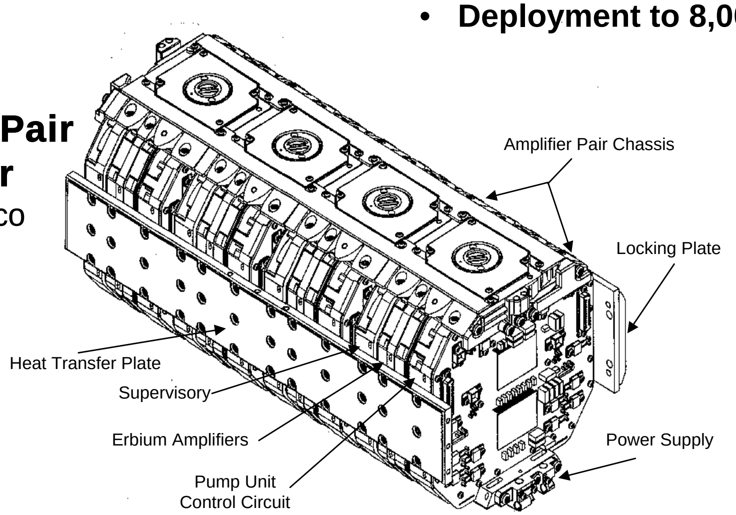
- Contain & protect optical fibers and electrical conductor for 25 years or more in a marine environment.
- Design and construction complies with standard industry safety practices.
- Withstand the stresses and strains (temperature, tension, torsion, pressure, chemical exposure, bending/flexing) associated with deployment, recovery, repair and re-deployment operations with state-of-the-art cable handling equipment.
- Cable types suitable for deep (>1000m) and shallow (<1000m) water use; burial or surface lay.
- Cable power conductor suitable for carrying fault-locating signals.
- Deployment (LW) to 8,000m depth
- Non-threatening to the undersea environment

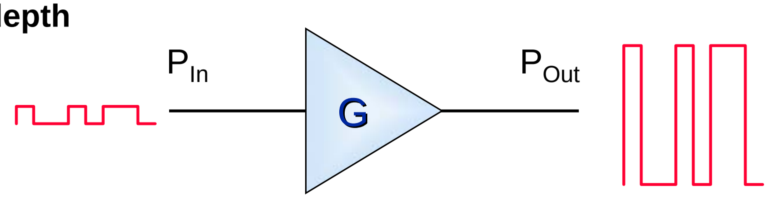
Undersea Repeaters

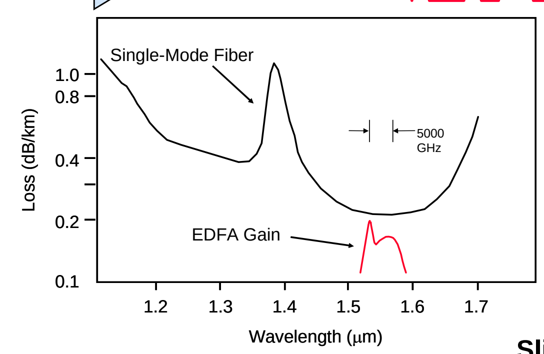


- **Provide periodic optical amplification for each fiber path**
- **Contain one Optical Amplifier Pair per fiber-pair, up to 8 fiber pairs**
- **Designed to withstand typical marine operations, including system laying, burying, recovery, and repair procedures while maintaining its performance and reliability objectives throughout the system's design life.**
- **Qualified to operate at the voltages and currents provided by the Power Feed Equipment (PFE), as required for transoceanic high capacity undersea cable systems (e.g. 12,500v).**
- **Receive electrical power via the cable's copper conductor**
- **Contain loop-back mechanism for line monitoring of each fiber path**
- **Deployment to 8,000m depth**

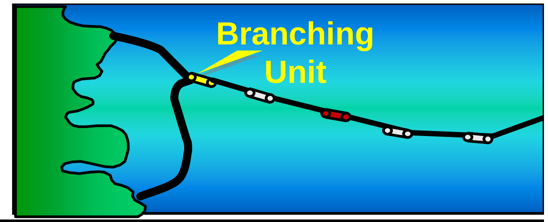
4 Amplifier Pair Repeater
Source - Tyco

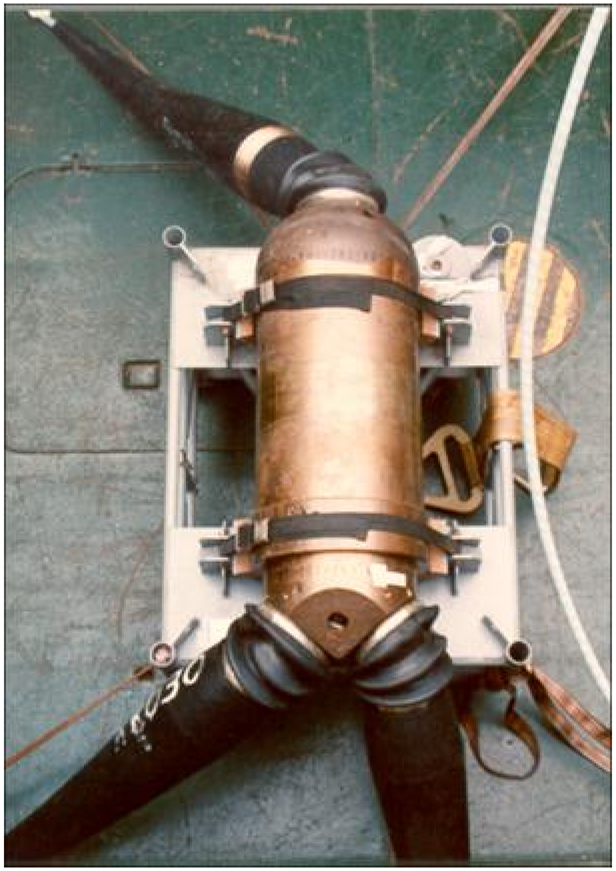




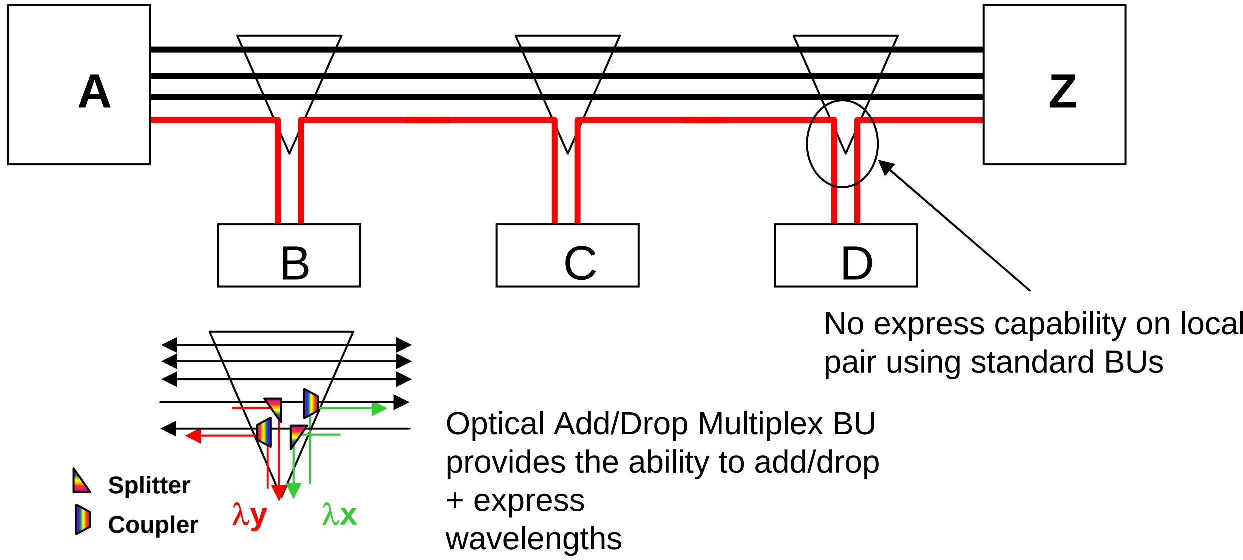


Undersea Branching Units





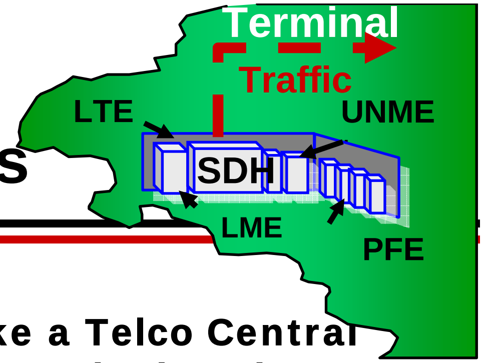
BRANCHING UNIT



Purpose of Branching Units

- Fiber routing between 3 locations
- Maximize the number of express paths for largest bandwidth paths
- Combine the smaller bandwidth-demand generators to as few pair as possible
- Optimize channel count/fiber pair to anticipate express path demand vs local
- Cost to build branches is typically a small incremental amount for the overall project but can be a subsidy for the construction and/or as additional revenue generation for cable owners

Cable Stations



- A typical cable station building is much like a Telco Central Or Gateway Office, except located close to the beach

- With infrastructure (racking, generators, batteries, distribution systems, alarm systems, etc) much like gateways

Structural:
Wind – Category 4 (up to 155 mph) minimum
Earthquake – Seismic Zone 4

Security & Infrastructure:
- Alarm & Security Systems
- Fire/smoke alarms & Fire Suppression
- Remote Monitoring Systems
- A/C, DC Power, Backup Diesel, etc.

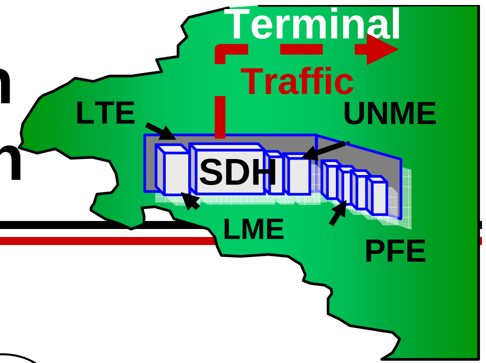
- If beachfront property scarce, or room exists in PoP station can be split into two:

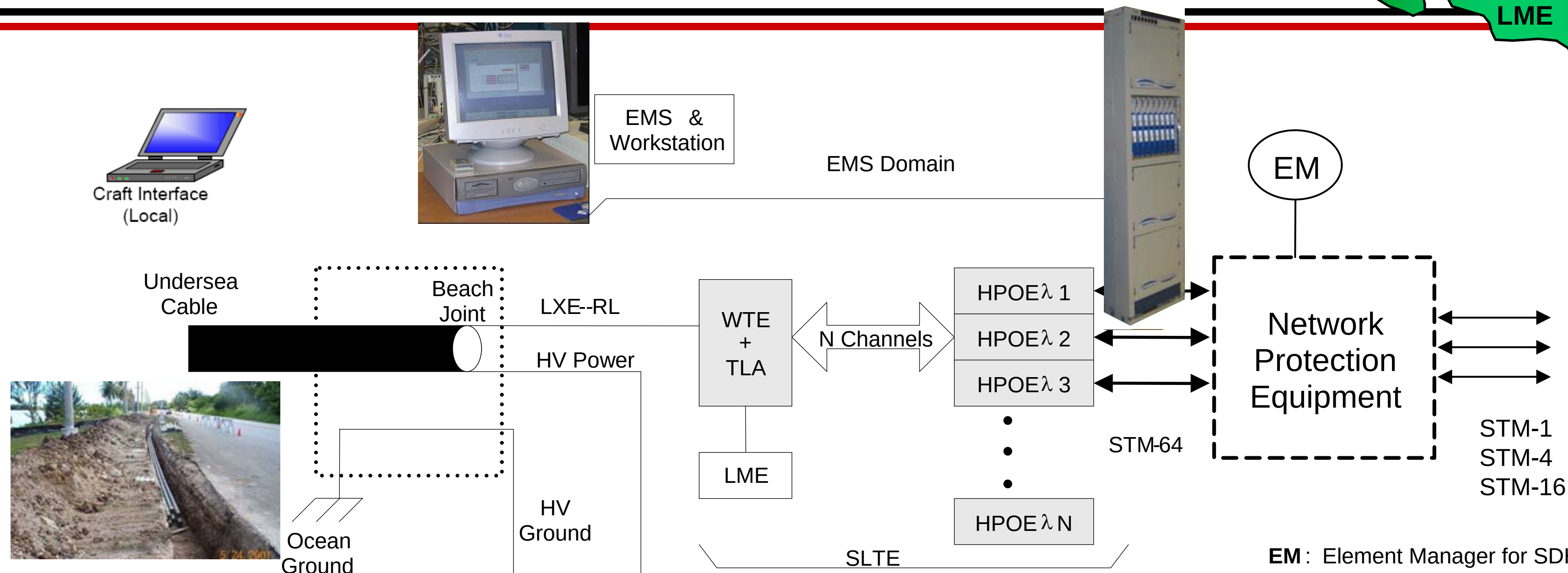
- Container for PFE at beach
- Transmission Gear at Gateway

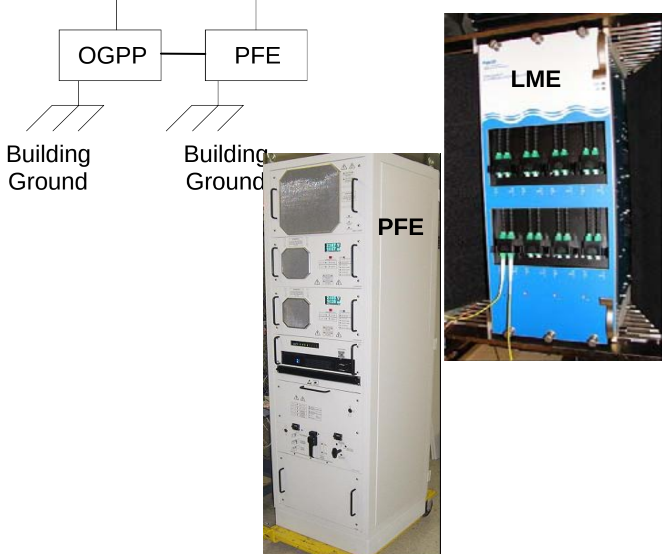
- Costs vary substantially, depending on size (a few million, to several million dollars)

- Associated permitting & construction can often be cause of project delays

Cable Station
Typical Equipment Configuration







EM: Element Manager for SDH

HPOE: High Performance Optical Equipment

HV: High Voltage

LME: Line Monitoring Equipment

OGPP: Ocean Ground Protection Panel

PFE: Power Feed Equipment

LXE-RL: Rodent Lightning

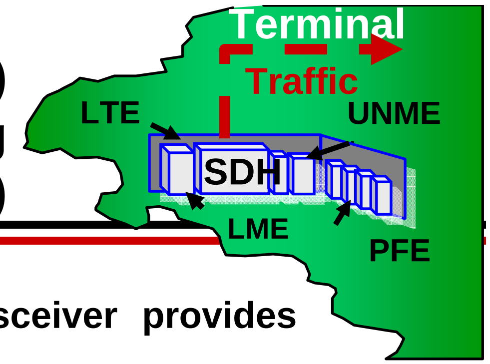
SDH: Synchronous Digital Hierarchy ADM

EMS : Element Management System

TLA: Terminal Line Amplifier

WTE Wavelength Termination Equipment

Line Terminating Equipment (LTE) & Dense Wavelength Division Multiplexing (DWDM)

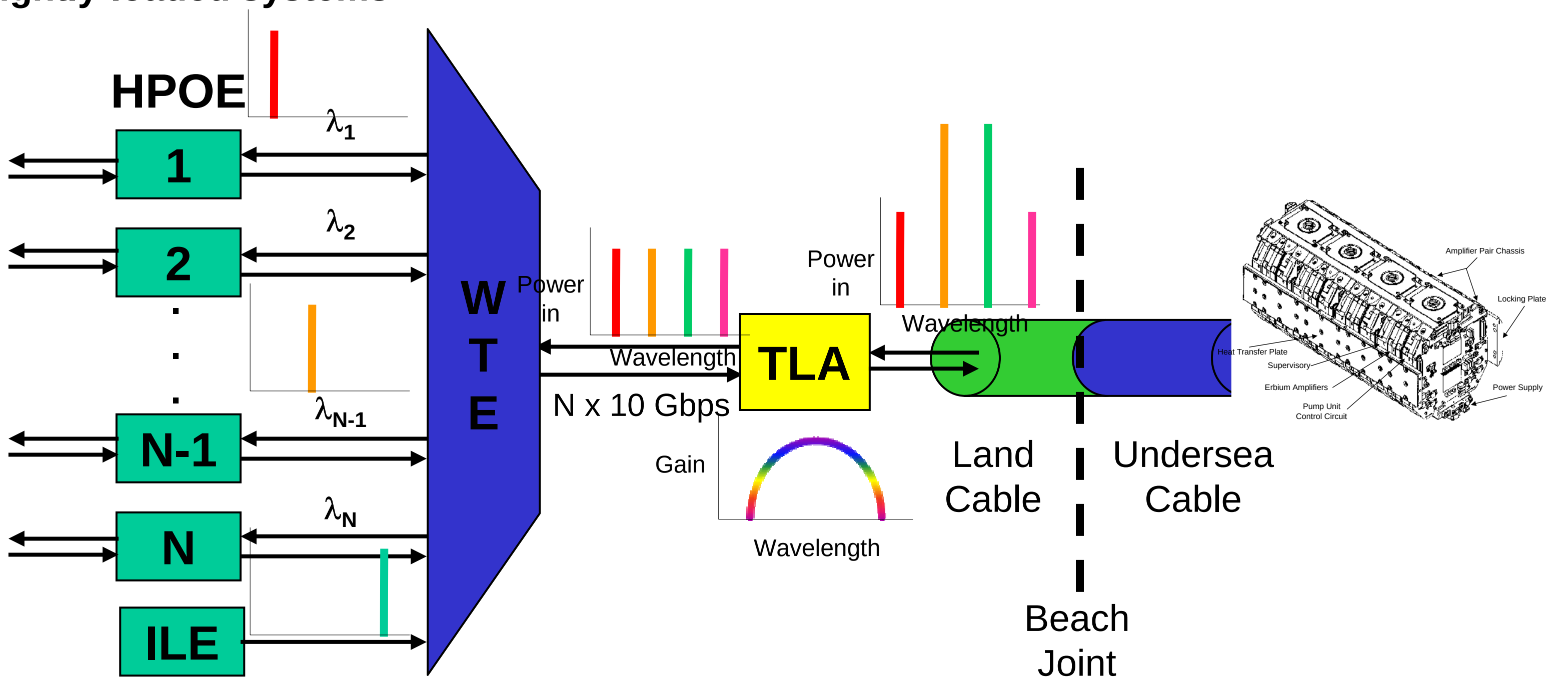


Each High Performance Optical Equipment (HPOE) transceiver provides grooming of the tributary signal at 10 Gbps

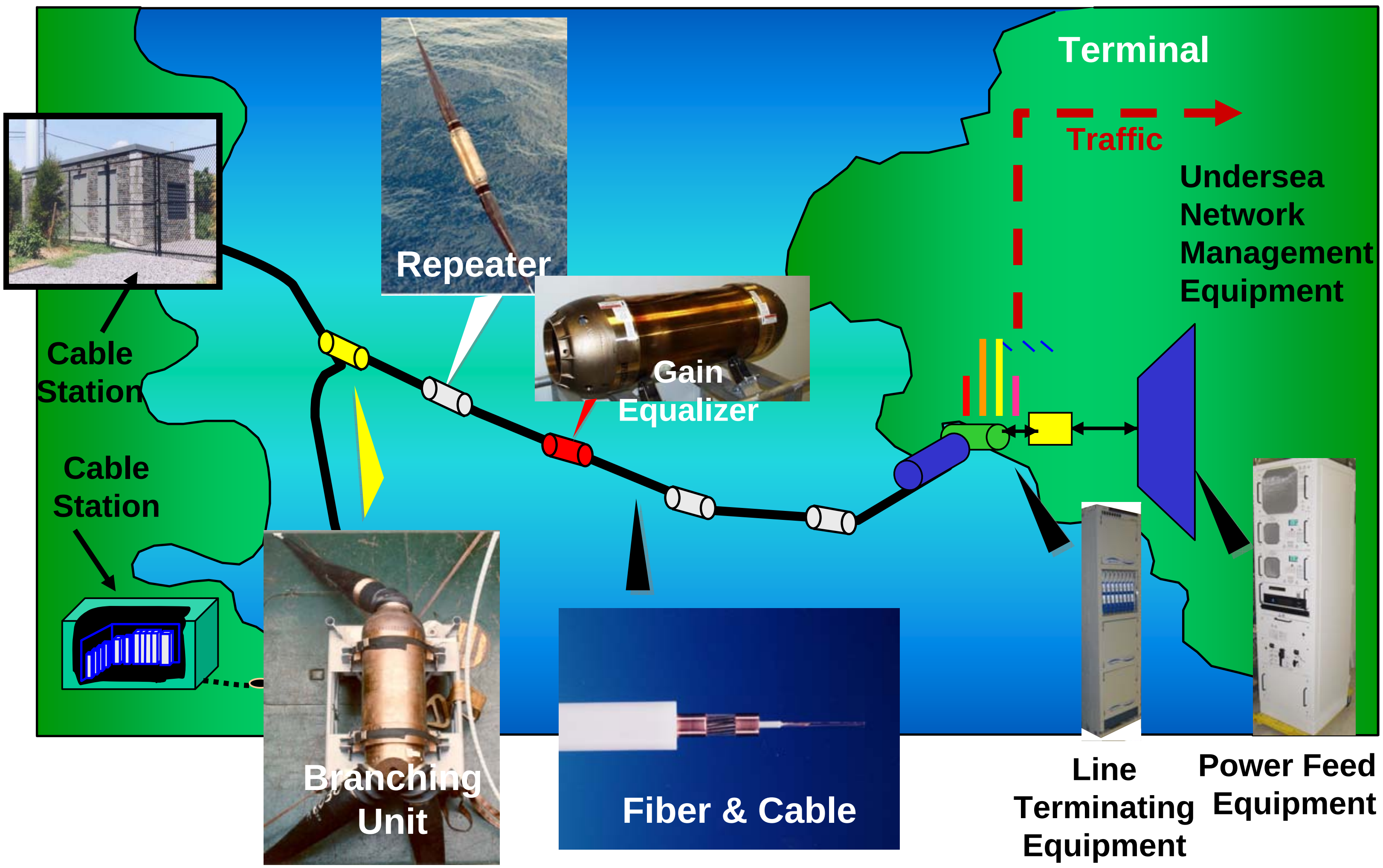
Wavelength Terminating Equipment (WTE) provides the passive Wavelength Division Multiplex/Demultiplex and Dispersion Compensation functions

Terminal Line Amplifiers (TLA) provides optical amplification

Initial Loading Equipment (ILE) provides channel power management for lightly-loaded systems



Elements of an Undersea Submarine Cable System



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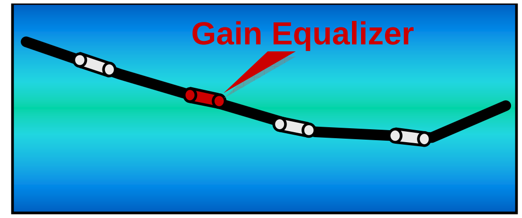
Undersea Gain Equalizers

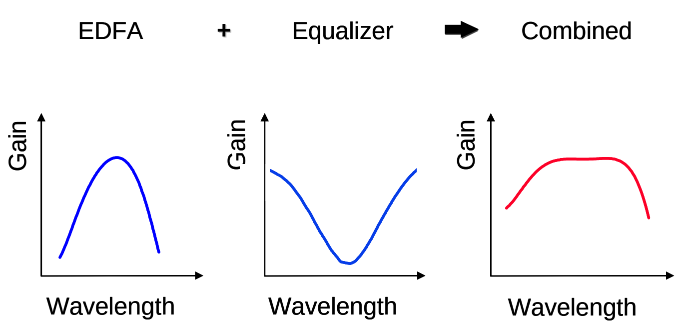


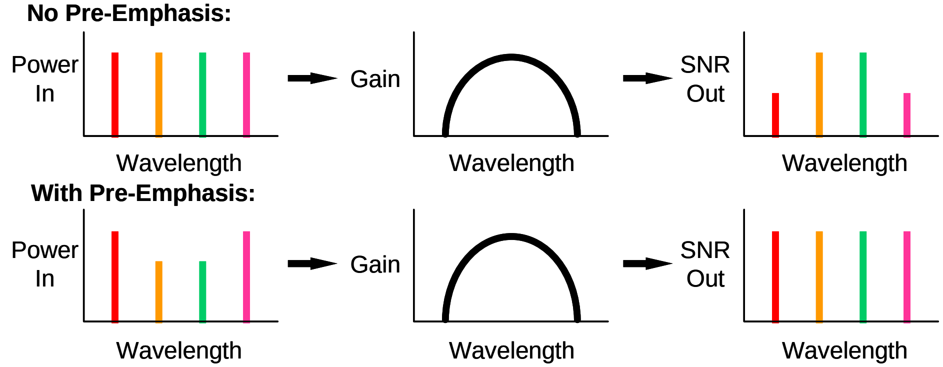
In Dense Wavelength Division Multiplexed (DWDM) systems, the gain and noise of repeaters and the loss of cabled fibers is not constant over all the transmitted wavelengths. Signal quality at the receiver of a Digital Line Section (DLS) will, therefore, be different for each wavelength, unless the system is designed to compensate for these variations in gain, noise, and loss. Thus gain equalization, along with channel pre-emphasis, is needed to assure adequate margin on each and all of the wavelengths.

Gain equalization needed for a particular DLS depends on the number of wavelengths and on the length of that DLS.

Gain Equalizer

<u>Gain equalization techniques:</u>
Gain Flattening Filters (GFFs)
Selectable Gain Equalization Filters (GEFs)
Shape Compensating Units (SCUs)





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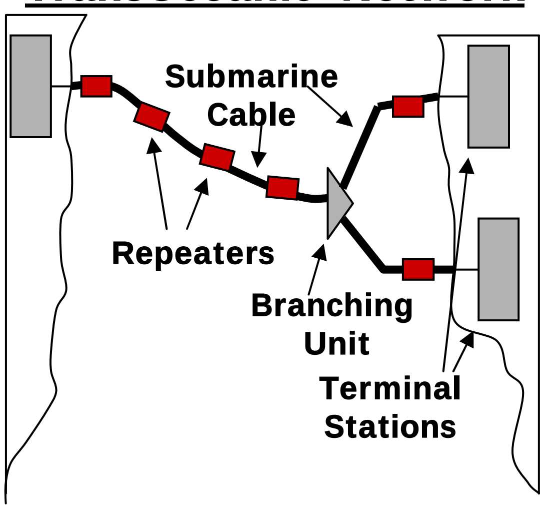
Basic Network Architectures

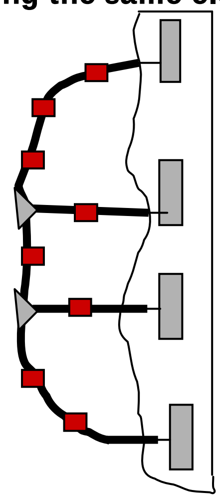
Repeatered Systems

TransOceanic Network



Coastal Network

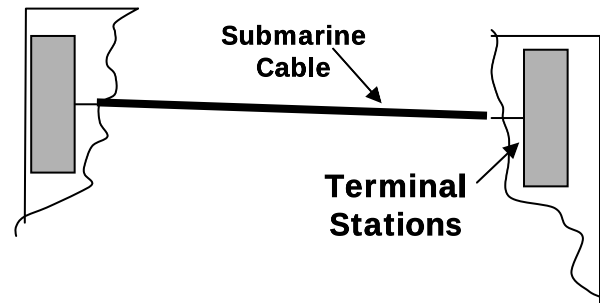
Using the same elements



Comparison	Repeatered	Non-Repeatered
Total Transmission Length	“unlimited”	~400km
Electrical Power	Yes	No
Max. No. Fiber pairs/ cable	8	>12
Branching Unit	Standard	Passive (New)
Maintenance	Complex	“Simple”
Cost	+	-

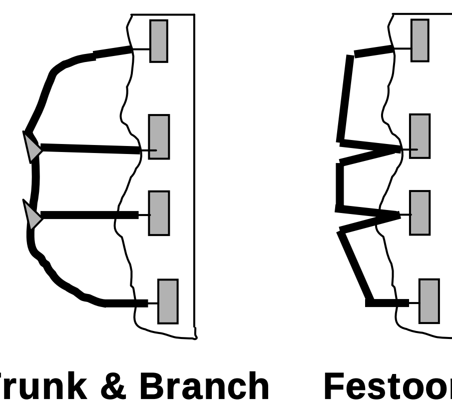
Repeaterless Systems

Inter-island Network



Coastal Networks

Using the same elements



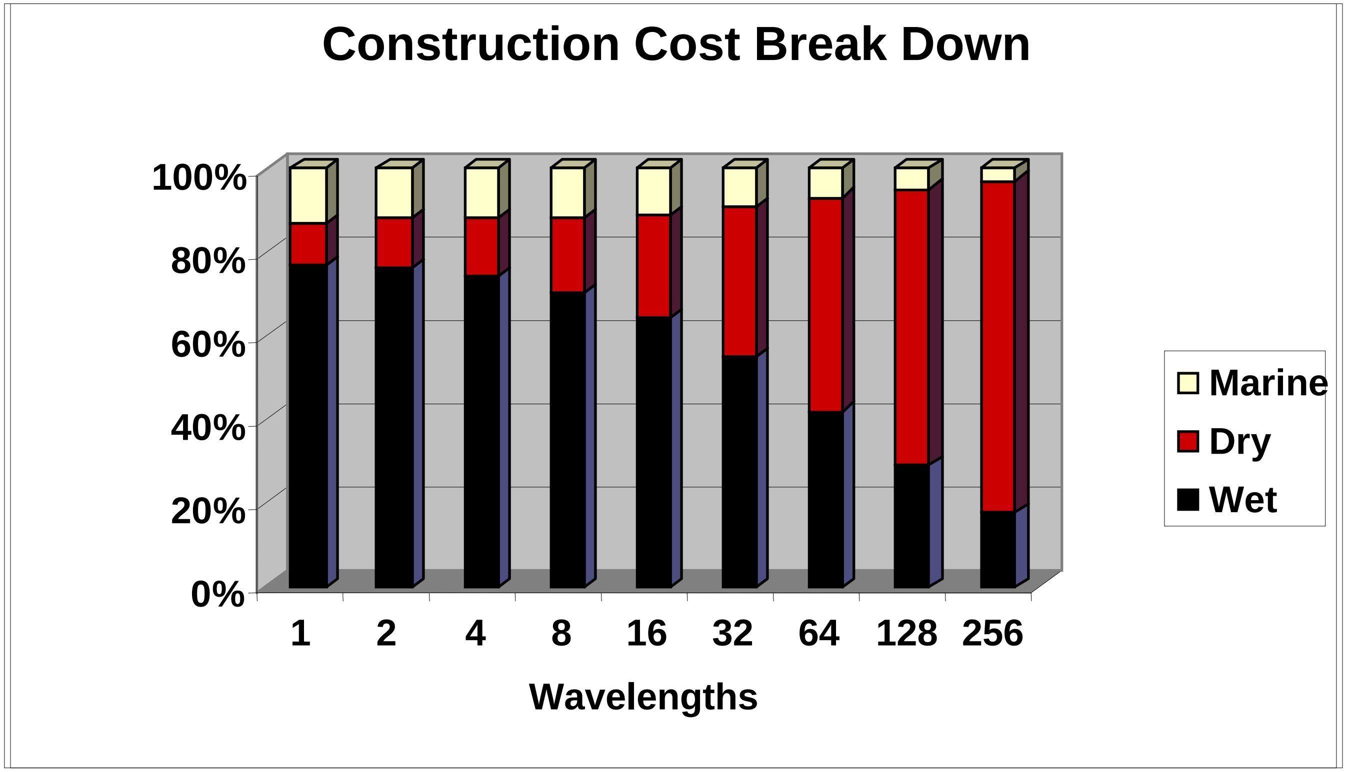
Primary Cost Items In System Construction

- **Network Construction:**
  - Wet Equipment
  - Dry Equipment
  - Installation & Test (Marine & Dry equipment)
  - Project Management, Training, Documentation, Etc
  - Terminal Station Buildings
- **Project Startup Costs:**
  - Licenses & Permits (including environmental)
  - Legal
  - Finance
- **Access Costs:**
  - Backhaul (cable station to service providers)
  - Onward Connectivity (capacity cost to reach global network)
- **Operations & Maintenance Costs:**
  - Marine service (insurance policy)
  - Terminal Station operations costs
  - Equipment service costs (post warranty)

Cost Breakdown for a Hypothetical Transoceanic Ring Network

Hypothetical Transoceanic Ring Network :

- 14,500 Km Length
- SDH Ring
- 3 Landing Points
- 4 Fiber Pair
- 80% Deep Water
- 10 % Buried
- 50 Km Repeater Spacing
- 500 Km Equalizer Spacing
- Various No. of 10 Gb/s Wavelengths



Post-installation Costs: Operations & Administration, Maintenance & Repair, Upgrade costs.

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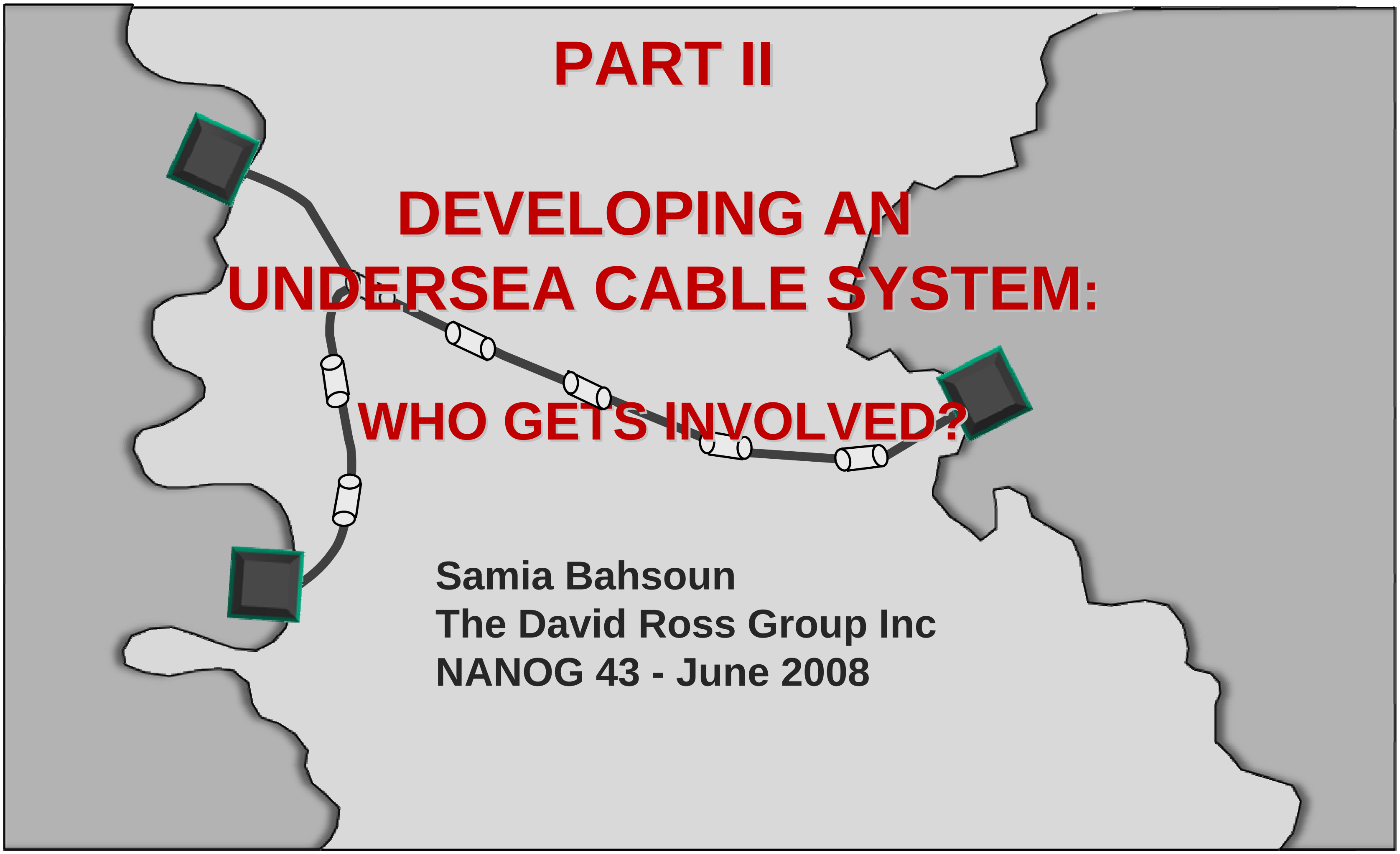
Summary

- **A new undersea cable system typically:**
  - Minimally cost 10's of millions to construct, up to *hundreds of millions* for the very long ones, and at least hundreds of thousands/year to operate & maintain thereafter
  - Take 12-24 months to plan & construct, depending on the length, complexity of finance/regulatory situations, and supply market situation
  - Utilizes well-proven products that perform for decades, and can be purchased from one of several qualified undersea suppliers
  - Can provide huge amounts of transport capacity, starting with very little, and growing over time
  - Provide high-quality transport that typically outperforms satellite quality
- **When planning a new project, key issues that are sometimes overlooked include:**
  - Regulatory issues, and time to get licenses/permits and form agreements with landing parties in other countries
  - The time it takes for financing, and the need to fund initial work with seed capital
  - The cost and importance of access (backhaul & onward connectivity) options
  - The schedule risks of civil construction & environmental permits



PART II

DEVELOPING AN UNDERSEA CABLE SYSTEM:

WHO GETS INVOLVED?

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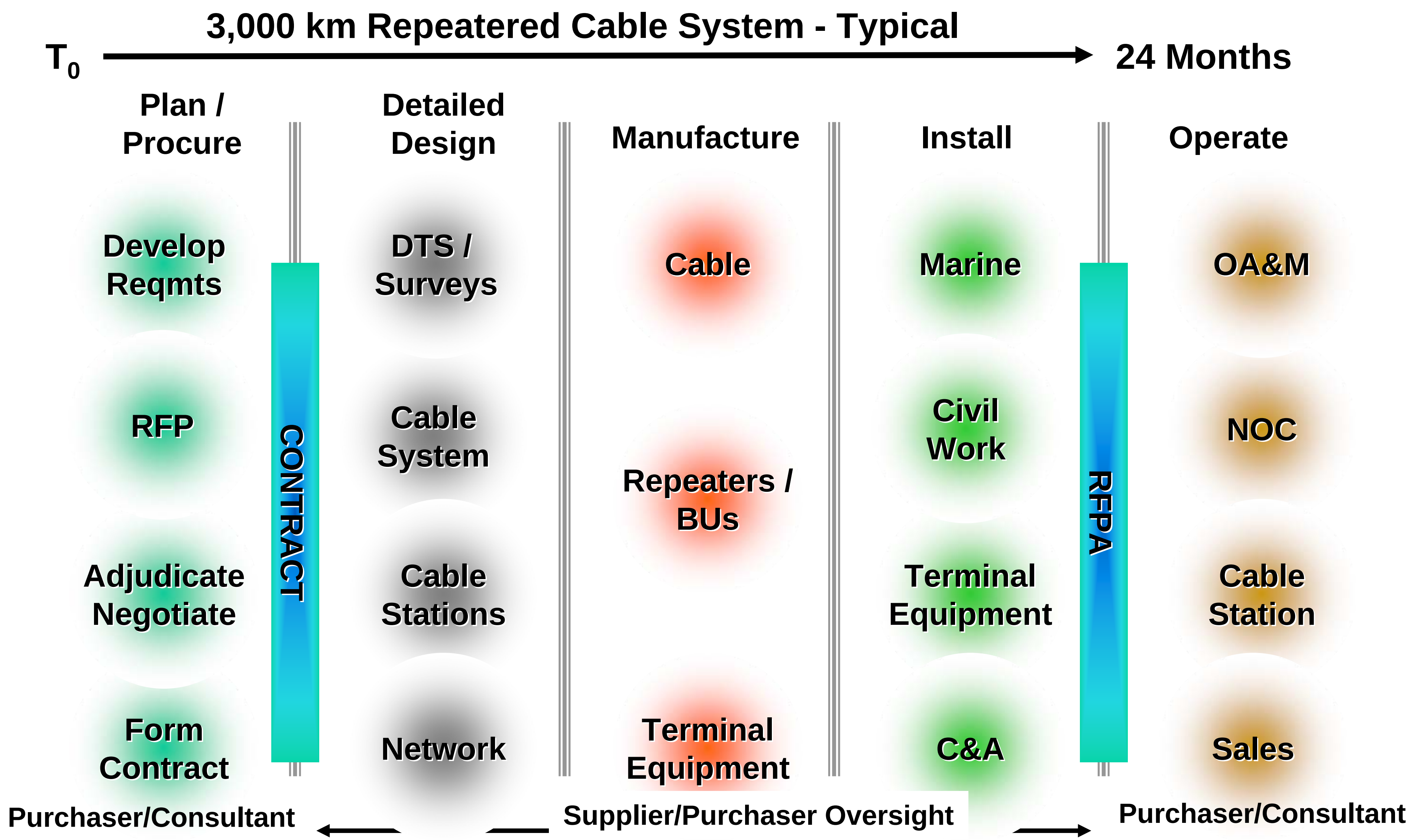
NANOG 43 - June 2008

Activity Sequence for an Undersea Cable System Implementation



Steps in the Development Process

Pre-Contract

- Organize prospective owners – Memorandum of Understanding (MoU)
- Determine connectivity and capacity needs – Demand Forecast
- Estimate Costs - ROM Estimate
- Determine project feasibility – Feasibility Study
- Raise funds – Investor Commitments
- Select a turnkey supplier – DTS, RFP, Proposals, Adjudication, Contract Award, ITP
- Negotiate a purchase agreement - Supply Contract
- Sign ownership agreements (financial close), C&MA, and Supply Contract

Post-Contract

- Survey the undersea route
- Negotiate landing party agreements
- Manufacture and install the system – Land and Sea segments
- Test and Commission
- Begin Commercial Operation

Key Players in Undersea System Development

Player	Role
Telecom Carriers	Users of systems; may also be equity investors or developers
Private Investors	May be developers or passive equity investors
Government Ministries	May define the requirements for a system, may participate in development
Lenders	May provide funds to developers or to carrier users
Regulators	Define rules for development and access to systems within each country
Environmental Agencies	Define environmental guidelines for system deployment in each country
Turnkey Suppliers	Design, manufacture, install, and test systems, may provide maintenance
Maintenance Administration	Provides ships and personnel for marine maintenance
Consultants	Perform studies, may provide assistance in all phases of development
Lawyers	Develop commercial agreements, license and permit applications

Definitions of Key Development Terms

Term	Definition
MOU	Memorandum of Understanding – Defines relationships among developers
Demand Forecast	Projects future demand for capacity on system, typically for at least ten years, assuming certain market growth and competition factors
ROM Estimate	Rough Order-of-Magnitude – an approximation of system cost based on knowledge of route and product prices, using standard estimating practices
Detailed Feasibility Study (DFS)	A demonstration that a system can be economically viable based on projected cash flow given the demand forecast and cost estimate along with projected pricing for capacity in the system
Desktop Study (DTS)	A preliminary layout of the system based on assumptions about landing points and known bathymetric details – includes armoring and burial assumptions
Request for Proposal (RFP)	A formal request for suppliers to propose their detailed solutions for provision of a system, defining the system technical and commercial details as closely as possible
Instruction to Proceed (ITP)	A document authorizing a system supplier to begin work on a system before a formal contract is negotiated, in the interest of timeliness. Requires system developers to commit a fraction of the system cost immediately.
Supply Contract	The formal detailed definition of the suppliers' obligations to manufacture, install, and test the system, and the developers' obligation to pay

Methods of Network Procurement

- Traditional Consortium
- Private Ownership
- Hybrids

Methods of Network Procurement

- **<u>Traditional Carrier Consortium</u>**
  - Joint development by carrier owners who share the facility
  - Dates to first undersea telecom cables of 1950s
  - Originally developed for pre-liberalization, one- carrier- per- country conditions
  - Adaptations for current conditions keep this a viable model worldwide
  - Financed by carriers from operating revenues
  - Philosophy: cooperate on facilities, compete on services
  - United Nations – style arrangement
  - Requires unanimous or majority agreement
  - Detailed Request for Quotations
  - Rigid competitive bidding
  - Lengthy Q&A, "Best & final offer" process
  - Carriers own capacity in proportion to investment
  - IRU sales by individual owners
  - Capacity Pricing: Determined by consortium

Methods of Network Procurement

- **<u>Private Networks</u>**
  - Development by private investors who sell capacity to carriers and enterprises, otherwise known as carriers' carriers
  - Flourished in the late 1990s telecom boom
  - Well suited to a liberalized, competitive market
  - Model has been applied worldwide in large and small markets
  - Philosophy: compete on facilities
  - Very informal Request for Quotations
  - Competitive offers and/or direct contract award
  - Entrepreneurs own network
  - Suppliers may share in ownership
  - IRU sales or capacity lease strategy, published pricing
  - Deals for volume purchasers
  - Sales through agents
  - Capacity Pricing: Determined by market conditions

Methods of Network Procurement

- **Hybrid Networks**
  - Development by a mix of carriers, enterprises, investors, and government
  - Primarily a 21st century development
  - Well suited to niche and developing markets with special needs
  - Philosophy: compete on facilities and services
  - Informal Request for Quotations
  - Competitive offers and/or direct contract award
  - Entrepreneurs and carriers own network
  - Suppliers may share in ownership
  - IRU sales or capacity lease strategy, published pricing
  - Deals for volume purchasers
  - Sales through agents
  - Capacity Pricing: May be consortium-like for owners, or determined by market conditions