Open Undersea Cables

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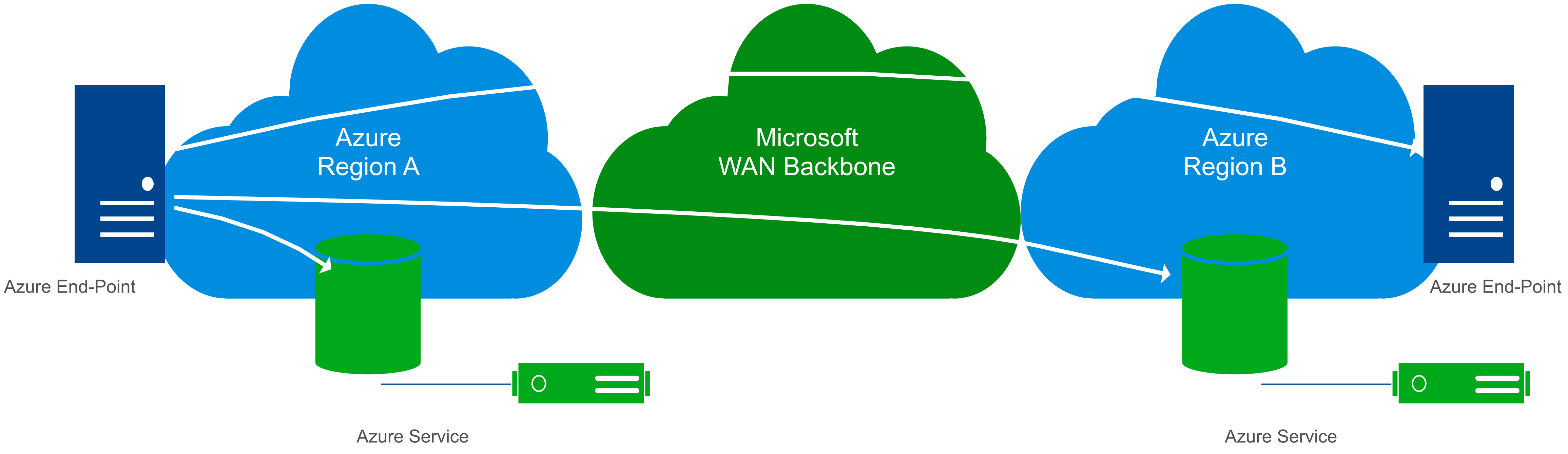
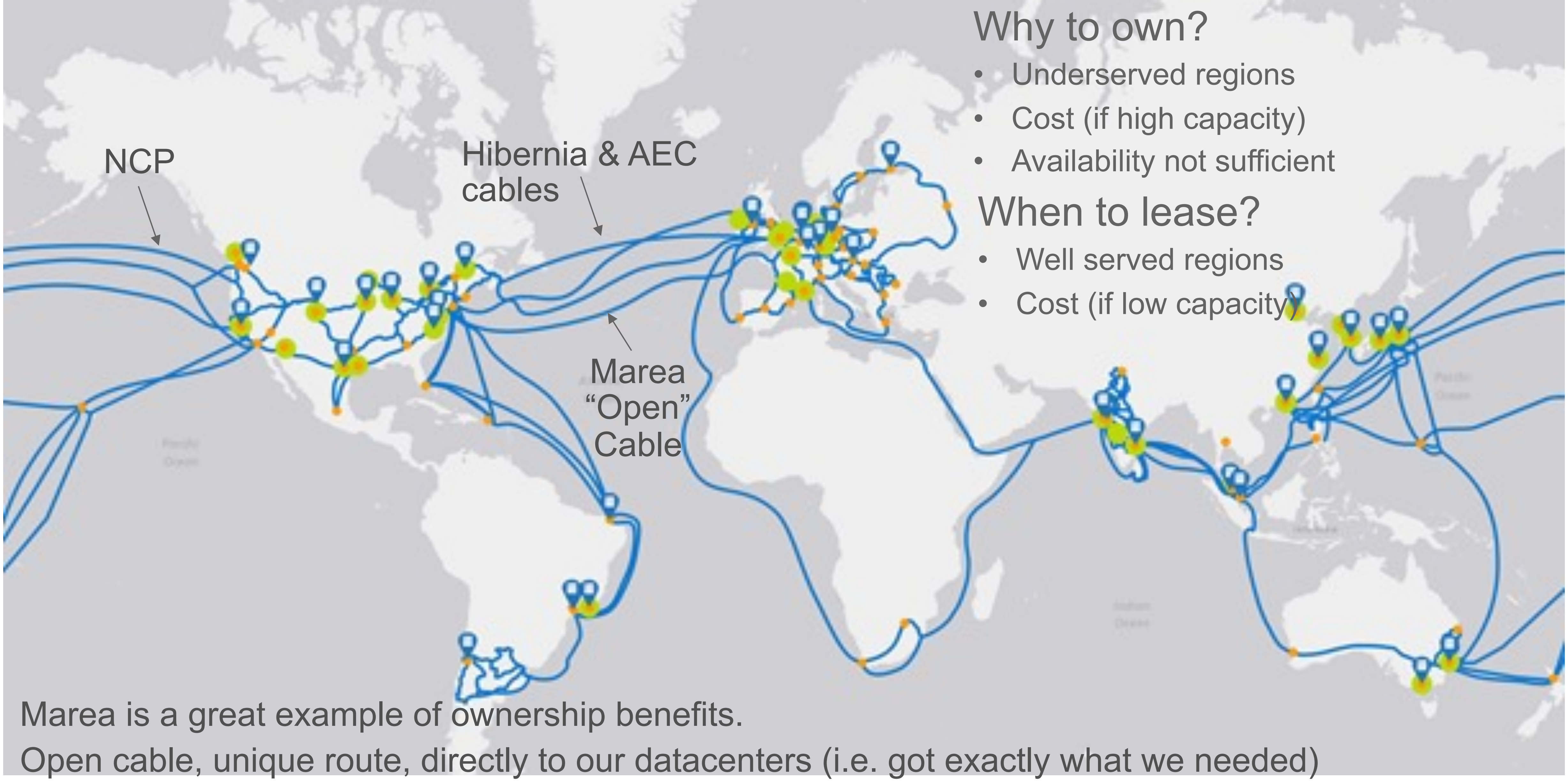
Microsoft Network. Not the Internet!

- Services traverse the Microsoft WAN
- **WAN experiencing exponential 'organic' growth as cloud adoption accelerates**
- Trans-oceanic capacity needs a creative solution



Undersea Cables in the Azure Network



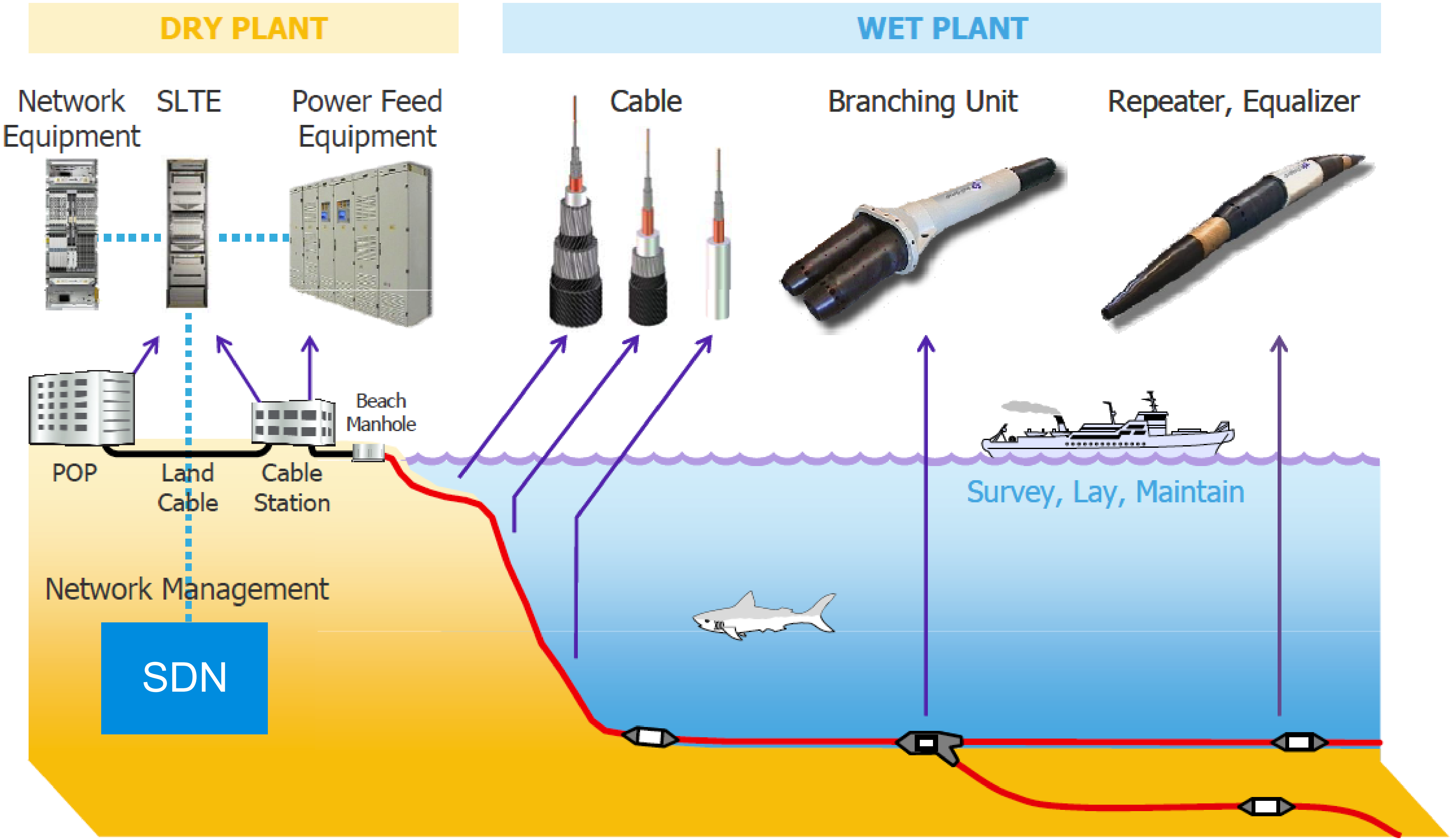
Why to own?

- Underserved regions
- Cost (if high capacity)
- Availability not sufficient

When to lease?

- Well served regions
- Cost (if low capacity)

Marea is a great example of ownership benefits.
Open cable, unique route, directly to our datacenters (i.e. got exactly what we needed)

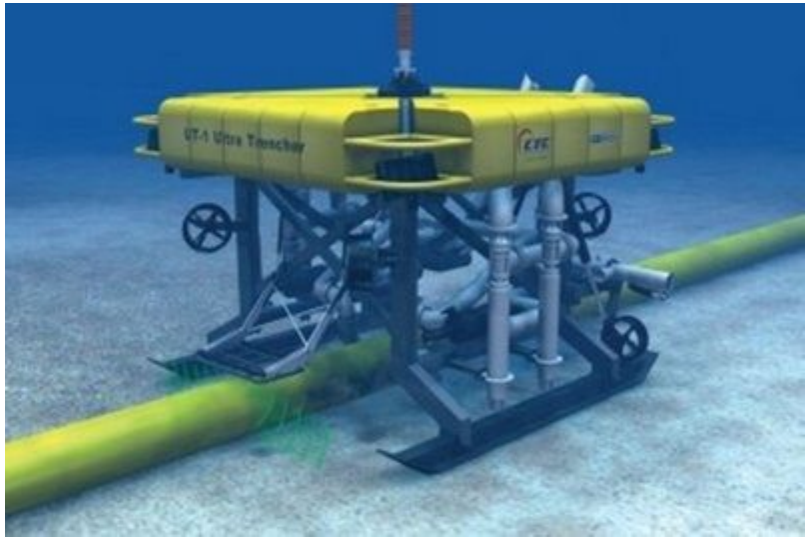

DRY PLANT
WET PLANT
Network Equipment
SLTE
Power Feed Equipment
Cable
Branching Unit
Repeater, Equalizer
Beach Manhole
POP
Land Cable
Cable Station
Survey, Lay, Maintain
Network Management
SDN

Cable Landing Station

Backup generators
(almost as big as landing station)

Shore Burial

Undersea Plow

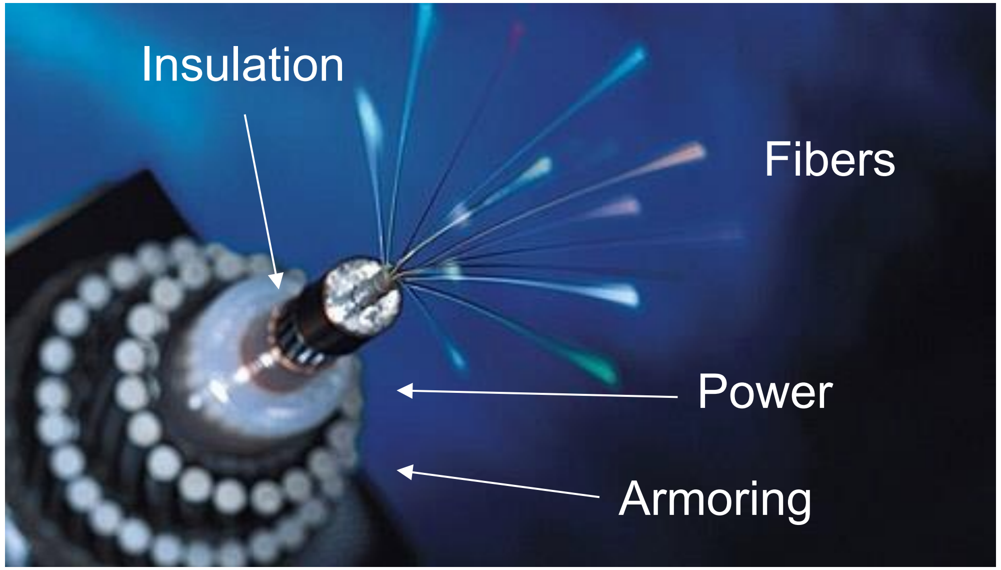


Cable and Powering

- Shore powering with PFE and ‘virtual’ ground

  +7 kV < ------------ 0 kV -------------- > -7 kV

  [14kV total voltage across thousands of km]



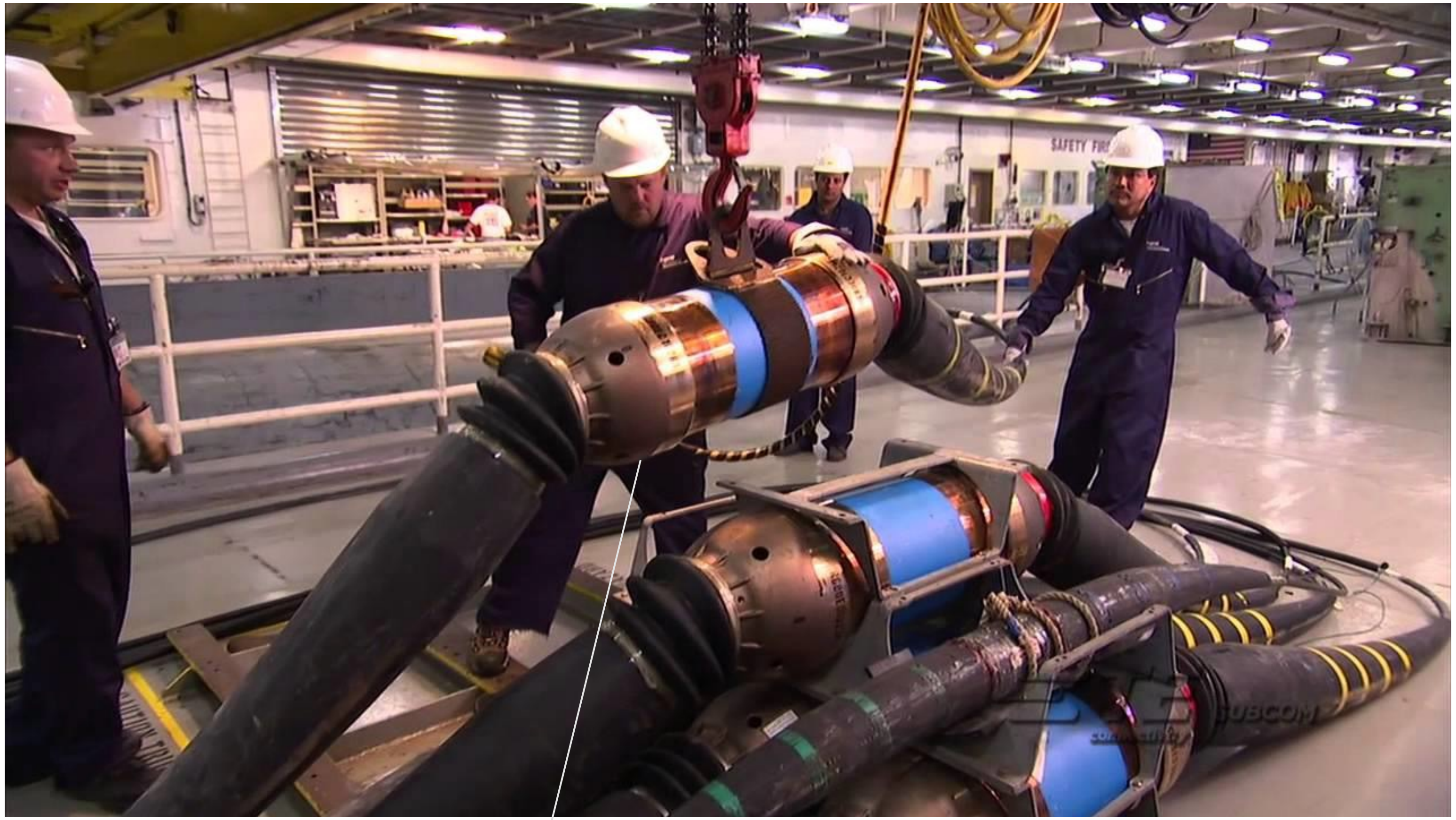
- Shunt faults and single end feeding

  +12 kV < --------------------- 0 kV --- > -2 kV

  - Cable fault ‘leaks’ current into sea (which grounds cable). PFE changes virtual ground and keeps cable running!

Repeaters

- 25 year lifetime at bottom of Ocean
  - Depth up-to 8000m (Japan trench)
- Repeaters every 60km – 100km (over 200 repeaters across the pacific!)
- … we get to put our name on the repeaters
- $$$



8 FP EDFA repeater

Reliability

- Cables get cut!
- It takes weeks to fix them
- **Each cable is less-than 99.9% available**
  - High MTTR of deep water work.
- Need **3-or-more diverse routes between regions to achieve 5-9's**

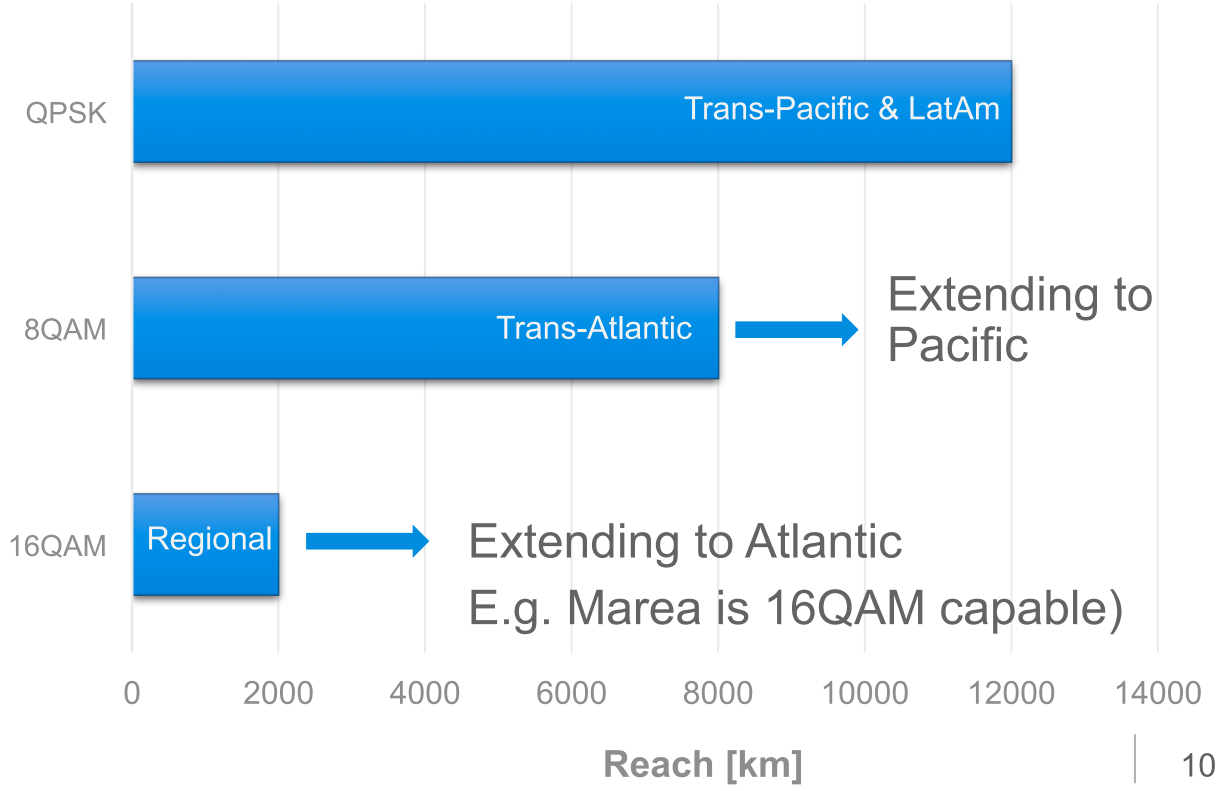
Problem Statement

SLTE

- Transponders and power management for cable
- Use latest technology to get the most out of the cable.
- Cycle SLTE every ~5 years as technology advances (cable has 25 year lifetime).
  - Cycle multiple SLTE over life of Cable.

Modulation	Capacity (today's view 2017)
QPSK	12 Tb/s [~30Gbaud @ 37.5 GHz spacing]
8QAM	18 Tb/s [~30Gbaud @ 37.5 GHz spacing]
16QAM	24 Tb/s [~30Gbaud @ 37.5 GHz spacing]

Next Gen < 1 year away!



Options for SLTE + Cable

Closed Systems

Turnkey end-to-end solution

Upside: Easy

Downside: locked into 1 vendor, limited to their equipment

Over 25 year lifetime, generally not a good idea.

Upgradeable Systems

Initial build is Turnkey

Subsequent upgrades are open to other dry plant suppliers

Upside: Potential for better capacity at lower cost per bit

Downside: Long upgrade cycles. Lack of data on wetplant requires field trials and rolling lab

Open Cable Systems

OLS like attributes

Any third party solution for day one deployment

Open, programable hardware

- Vendor agnostic API (REST)
- Simple CLI
- UDP based alert/alarm

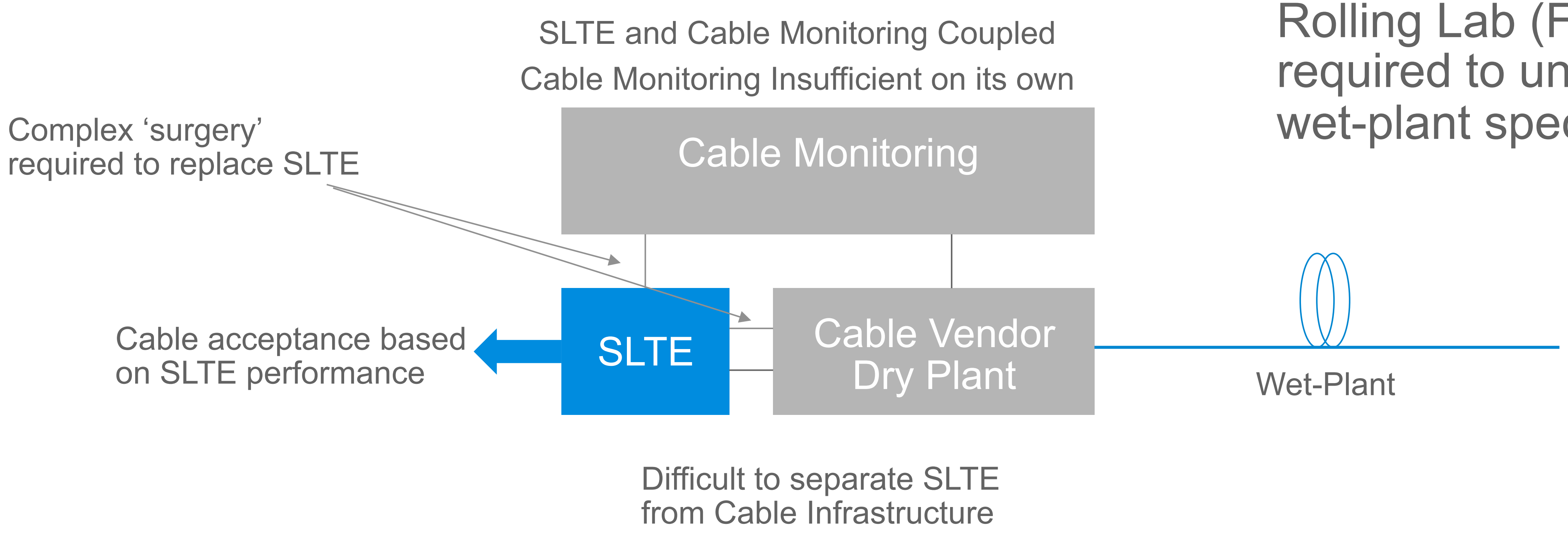
Upside: Best upgrade costs. Fast upgrade cycle. Flexible over 25 years.

Downside: Most up-front work

Upgradable System Concept

Offers SLTE / Cable disaggregation, but…

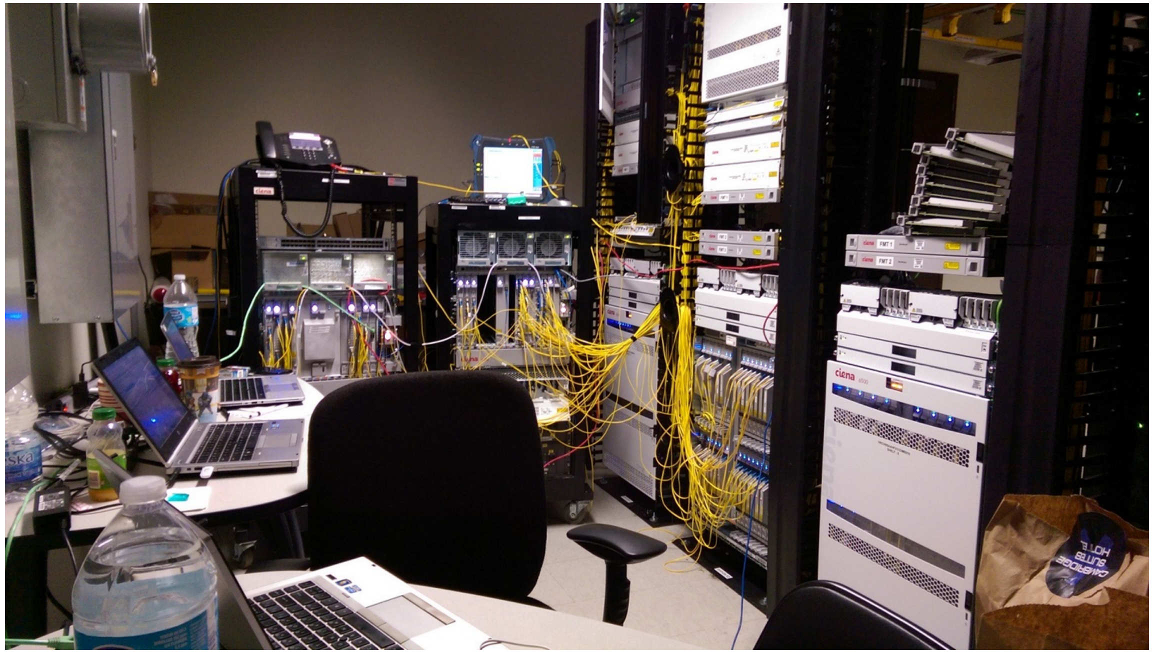
Rolling Lab (Field Trial) required to understand wet-plant specifications



Upgradable System – Upgrade Cycle

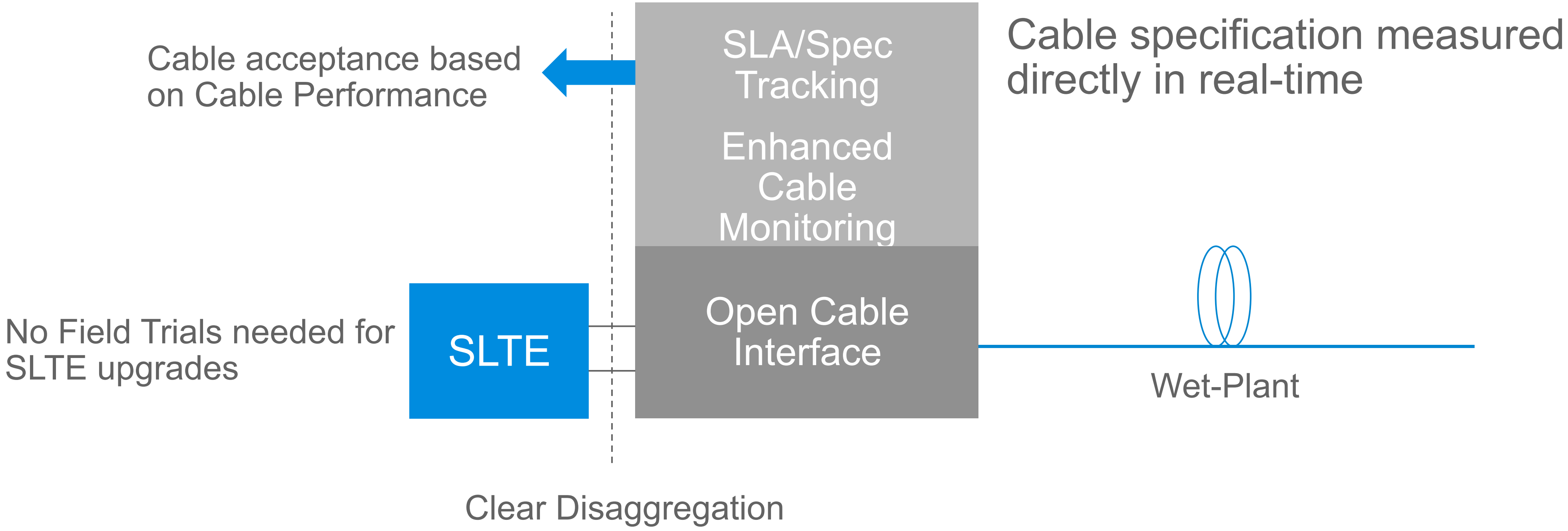
2 months of planning + rolling lab +
6 people, 2 weeks, 16 hour days onsite.

Needed to measure wet-plant specifications. Original turnkey system data abstracted behind dry-plant



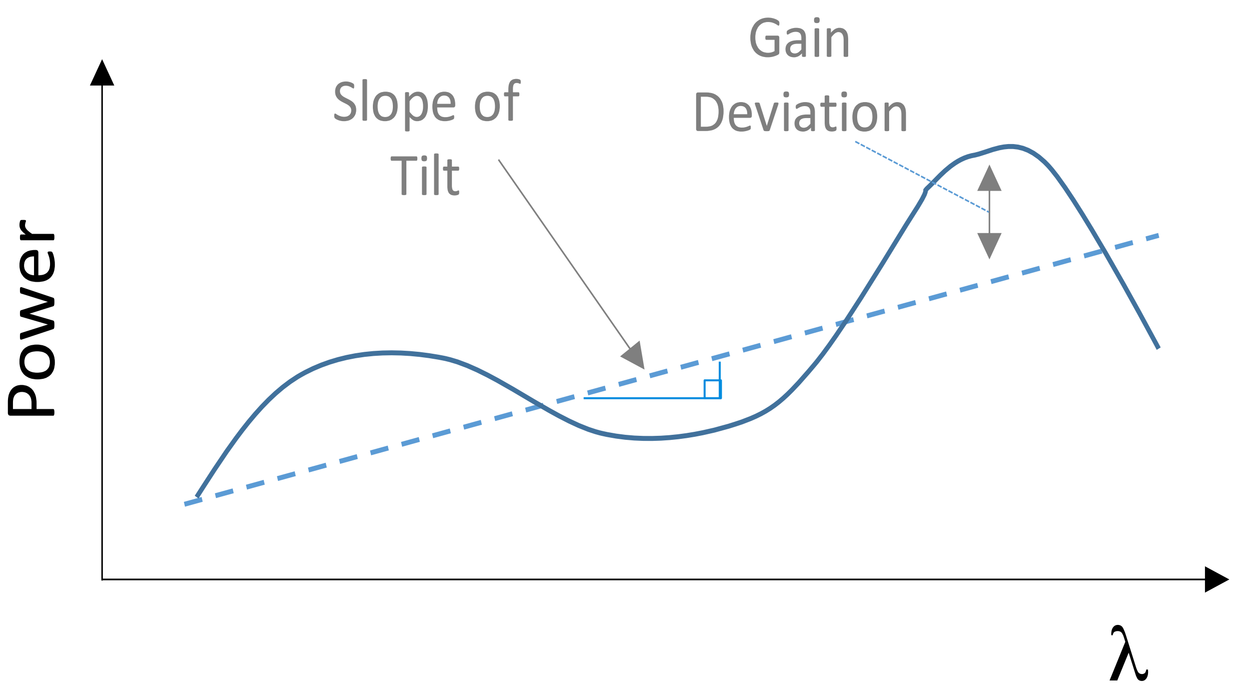
Open Undersea Cable

- Designed specifically to be disaggregated and vendor agnostic
- Includes sufficient open hardware to monitor an maintain the cable separate from the terminal equipment
- Integrate seamlessly with Terrestrial Open Line System



Specification Table

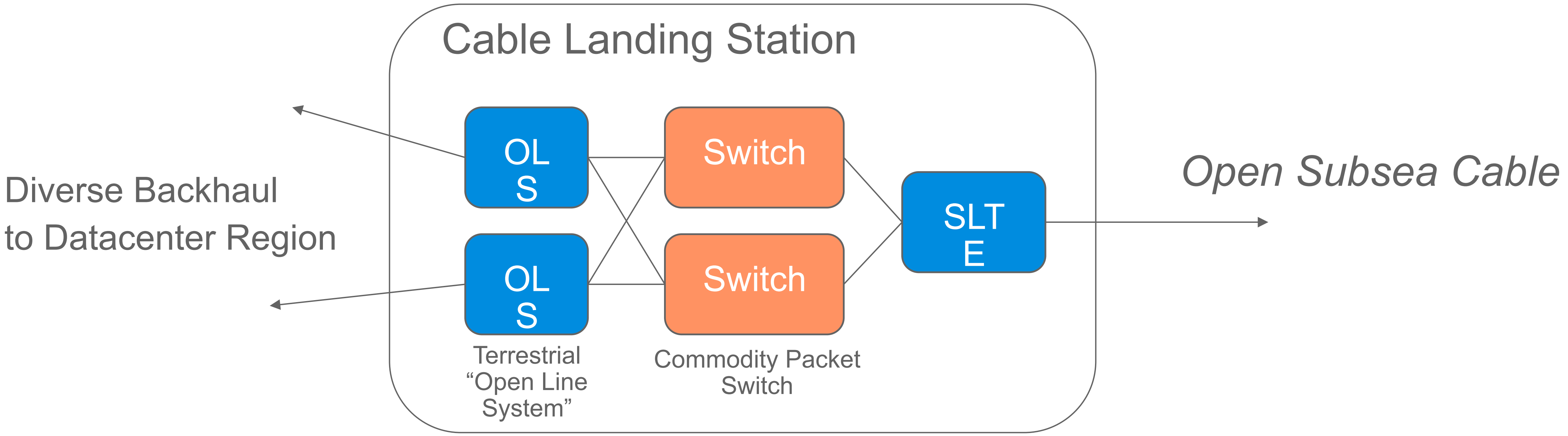
- Performance Acceptance and lifetime SLA monitoring defined on line system characteristics
  - Most notably OSNR, Power, Tilt, Gain Deviation



Name	*Example Cable*	
Segment	*Example Segment*	
Landing Sites	A	B
Length	x,xxx	km
Quantity of Channels at Full Loading		carriers
	Start-of-Life [SOL]	
	Average	**Worst Case**
1. System Specification		
1.1 Power [dBm/carrier] at full loading		
1.2 Slope of Tilt [dB/THz]		
1.3 Gain Deviation from tilt [dB]		
1.4 Equalized OSNR [dB/0.1nm] across the Passband at full loading		
1.5 Span Length [km]		
1.6 Span Loss [dB]		
1.7 Passband Start/Stop [THz]		
1.8 Average DGD across the Passband [ps]		
1.9 mean PDL [dB]		
1.10 Total accumulated Chromatic Dispersion [ps/nm] at 1550nm		
2. Repeater Specification		
2.1 Repeater Total Output Power [dBm]		
2.2 Average Repeater Noise Figure across Passband[dB]		
2.3 In-band monitoring channel(s) [THz]		
2.4 In-band monitoring channel width [GHz]		
3. Fiber Specification		
3.1 Fiber Effective Area [um^2]		
3.2 Fiber Chromatic Dispersion [ps/nm/km]		
3.3 Fiber Attenuation [dB/km]		
3.4 Fiber Dispersion Slope [ps/nm^2/km]		

End-to-End Design, “Packet switched CLS”

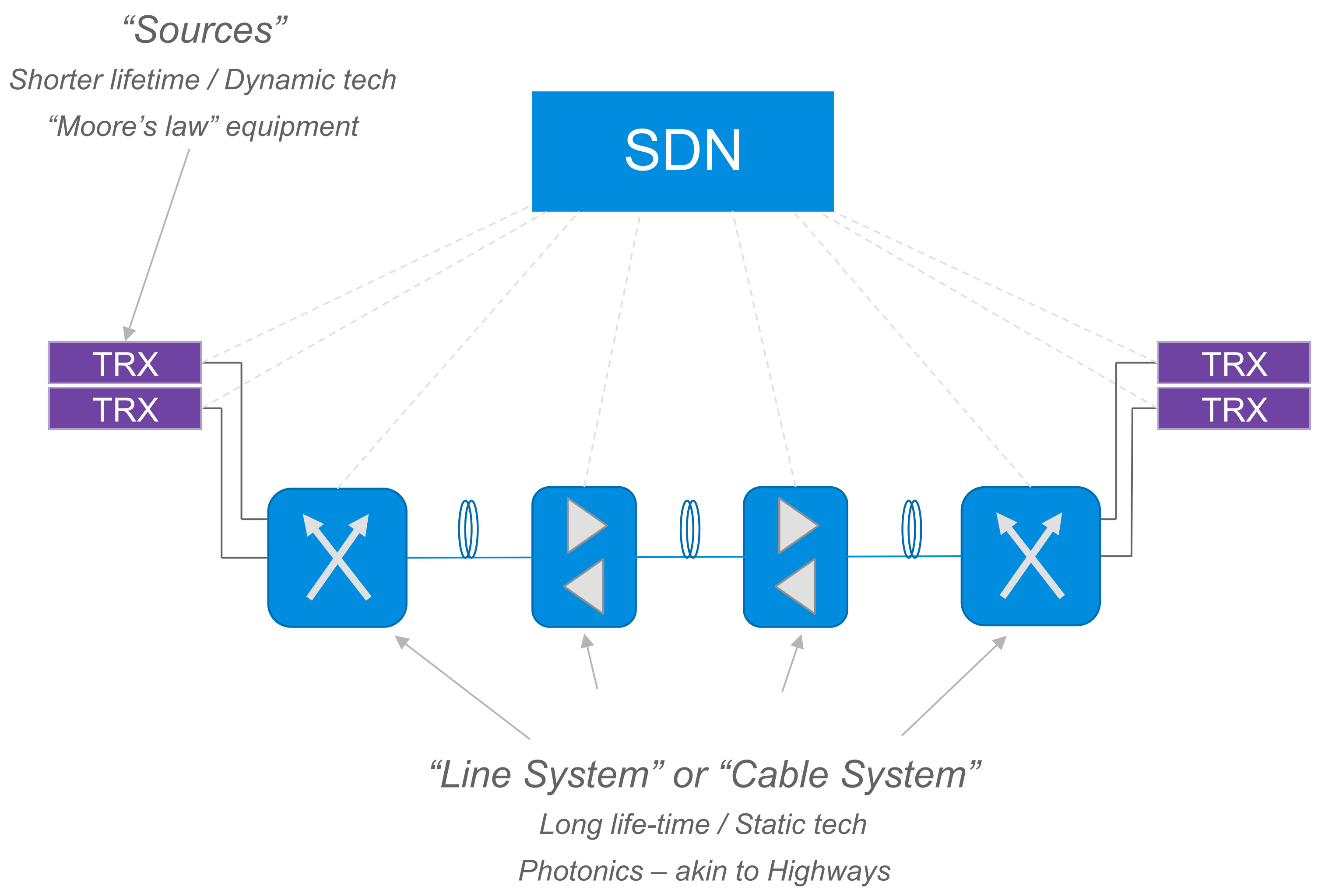
- “POP-to-POP” lowers SLTE cost, but is bad for availability and spectral efficiency.
- Landing stations are excellent locations for packet switching



Alignment with Terrestrial Open Line Systems

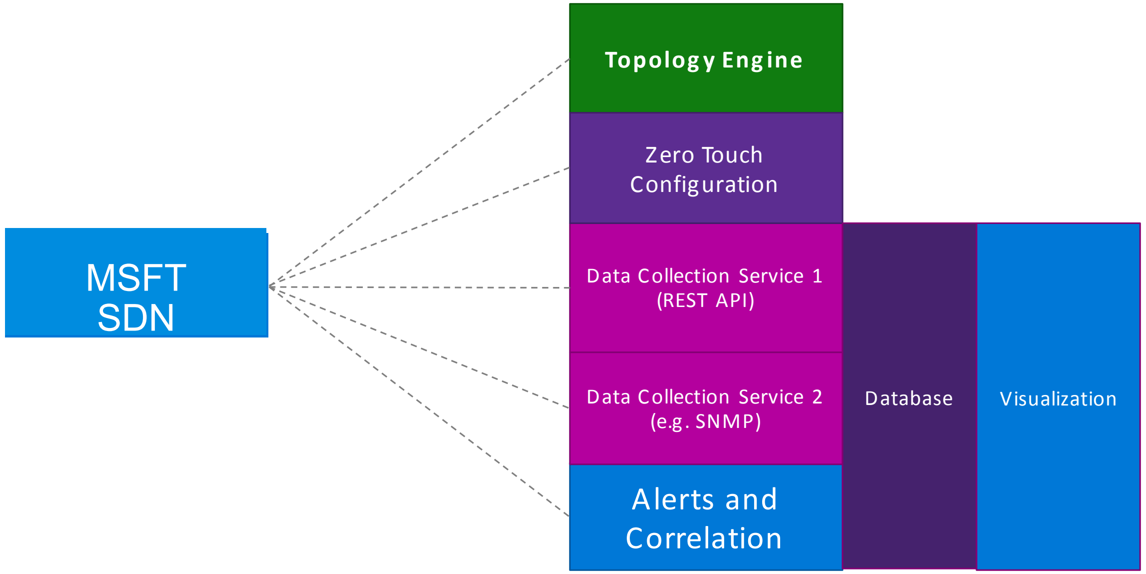
The Open Cable aligns with our Terrestrial Strategy

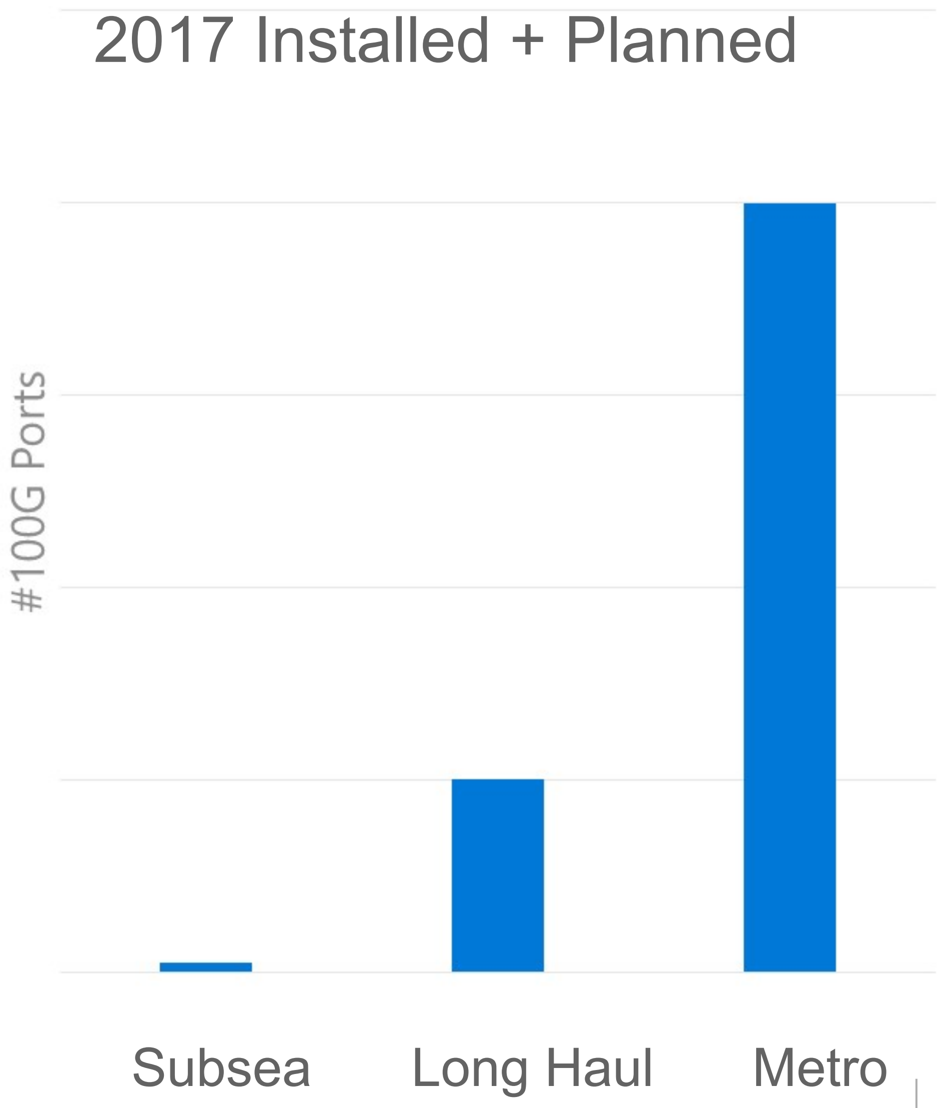
- OSNR based acceptance
- Direct nodal control
- Disaggregated Line and Sources



Port Allocation in Cloud Network

- SDN Tooling built and optimized for majority use-cases
- Subsea ports are extremely important, but operations, control, and management need to align with majority use cases.
  - No NMS, REST APIs, OpenConfig, etc..





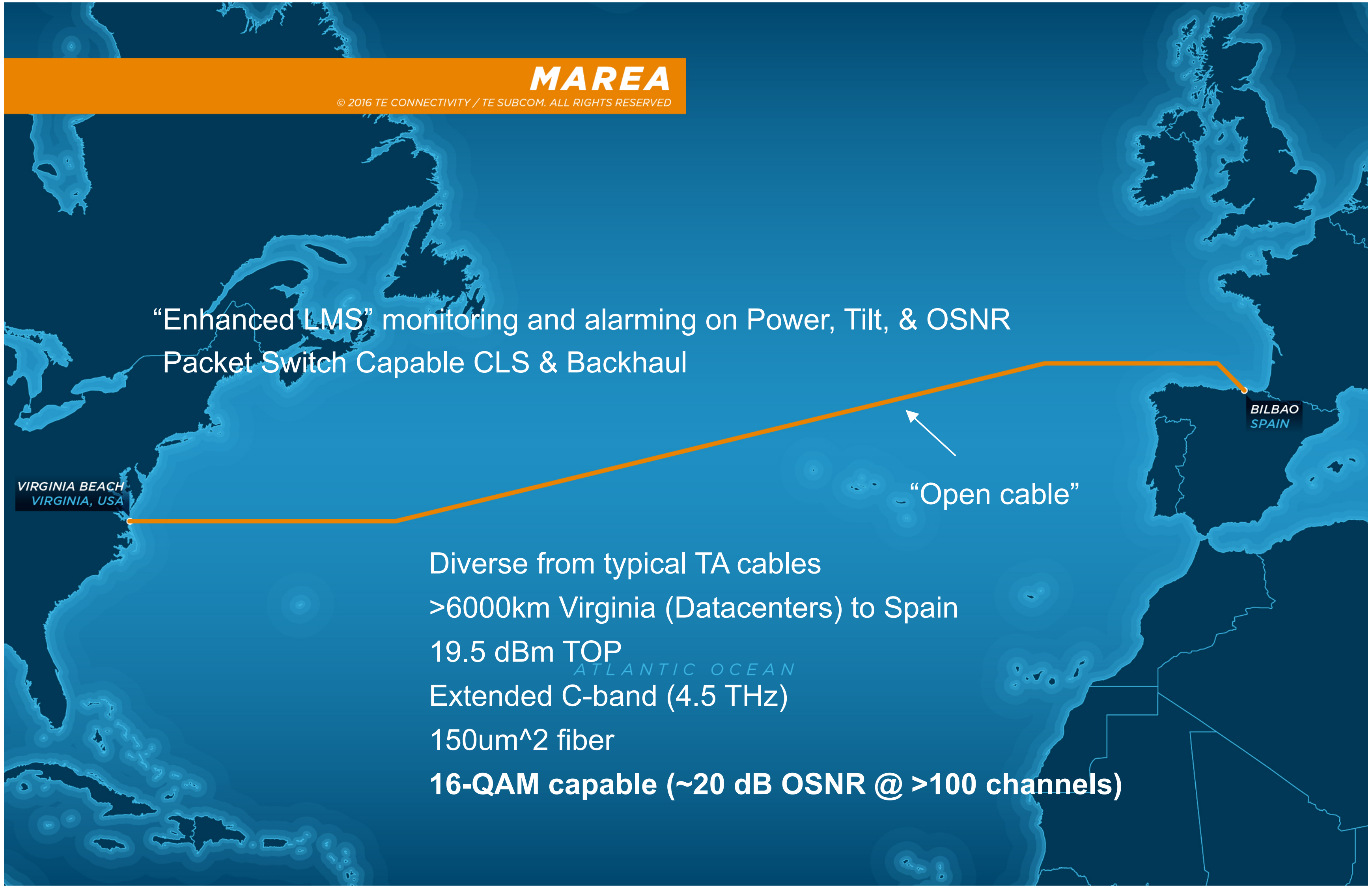
Marea Cable

Our first completely open cable acceptance.

- Previous cables were designed closed and converted to open.

Cable acceptance separate from SLTE acceptance

- Cable will be accepted on OSNR, tilt, core size, CD, etc..
- Enhanced line monitoring separate from SLTE



Thank you!

Microsoft