APAC Subsea Cable Systems

Impact to IP Backbone Design

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NANOG52 – Denver, CO

Richard Kahn

Director, Technical Services

PACNET

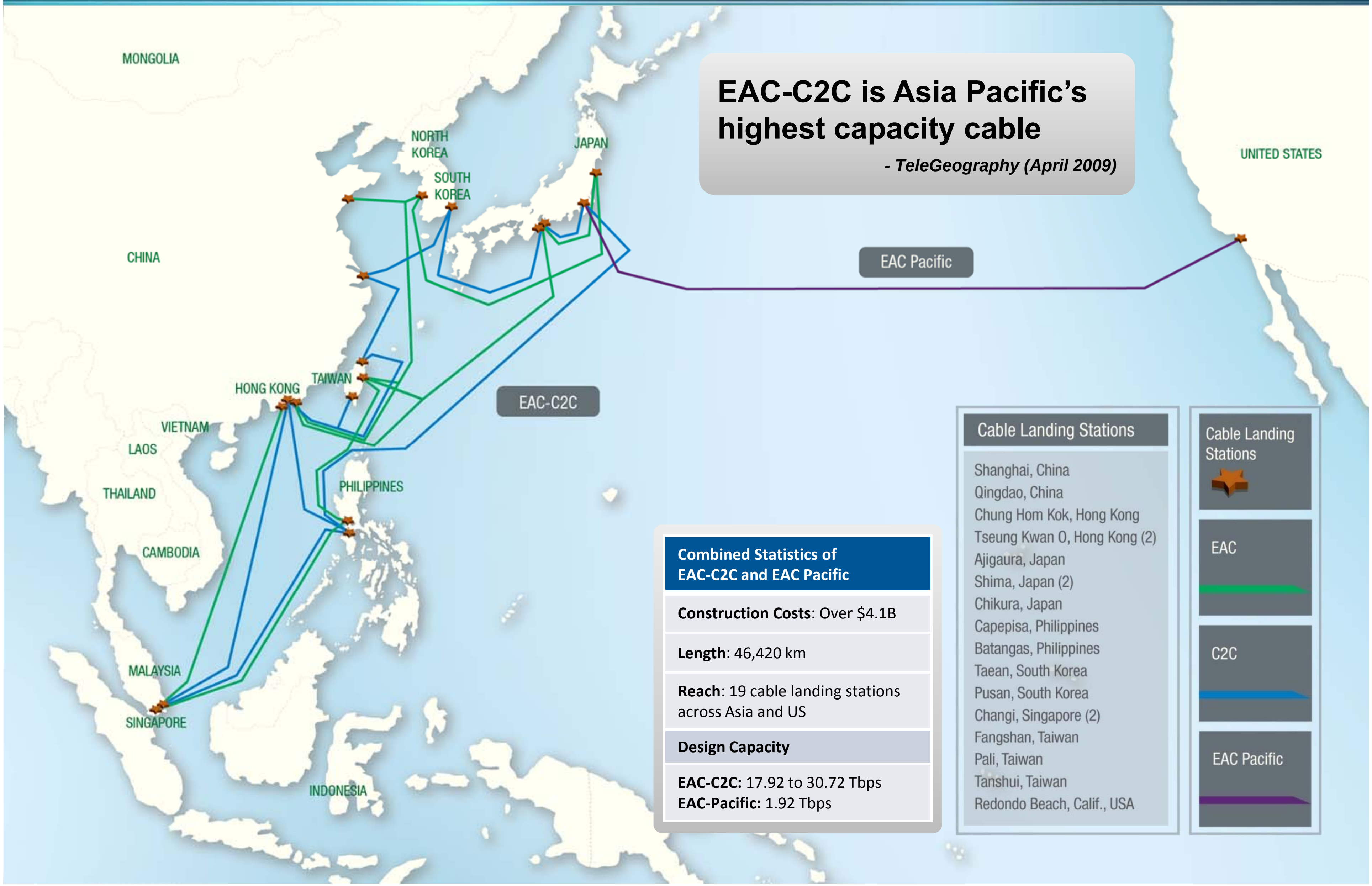
Agenda

- Who is PACNET?
  - History and Company Snapshot
- Subsea System Components
  - Breakdown of cable components
  - Various cable types and construction
    - Deployment strategies
- Subsea Operations and Repair
  - Types of faults
  - Indentifying fault locations
  - Repair process and timelines
- Outage Factors
  - Natural Disasters
    - Typhoons
    - Seismic Activity
      - Useful Tools
  - External Aggression
    - Shipping and Fishing Vessels
    - Piracy and Espionage

Agenda continued

- Restoration, Repair, and Potential Mitigation
  - Restoration constraints
  - Factors affecting repair timelines
    - Does the type of outage affect the repair process?
  - Potential mitigation of subsea faults
    - Planning and risk projection
    - Guard Boats
- Design Factors for IP Backbones reliant on Subsea Systems
  - Geographical limitations
  - Regulatory constraints
  - Historical analysis and planning
  - Approach to increase trunking efficiencies
    - Collapsing the Cable Station and POP
      - Shifting SLTE to the City Center
      - Moving the POP into the Cable Landing Station
        - » Maintaining carrier neutrality
        - » Accessibility to diverse systems and routes
    - Route fault tolerance
      - Optical protection versus linear
      - Optical Mesh

Who is PACNET?



EAC-C2C is Asia Pacific's highest capacity cable

- TeleGeography (April 2009)

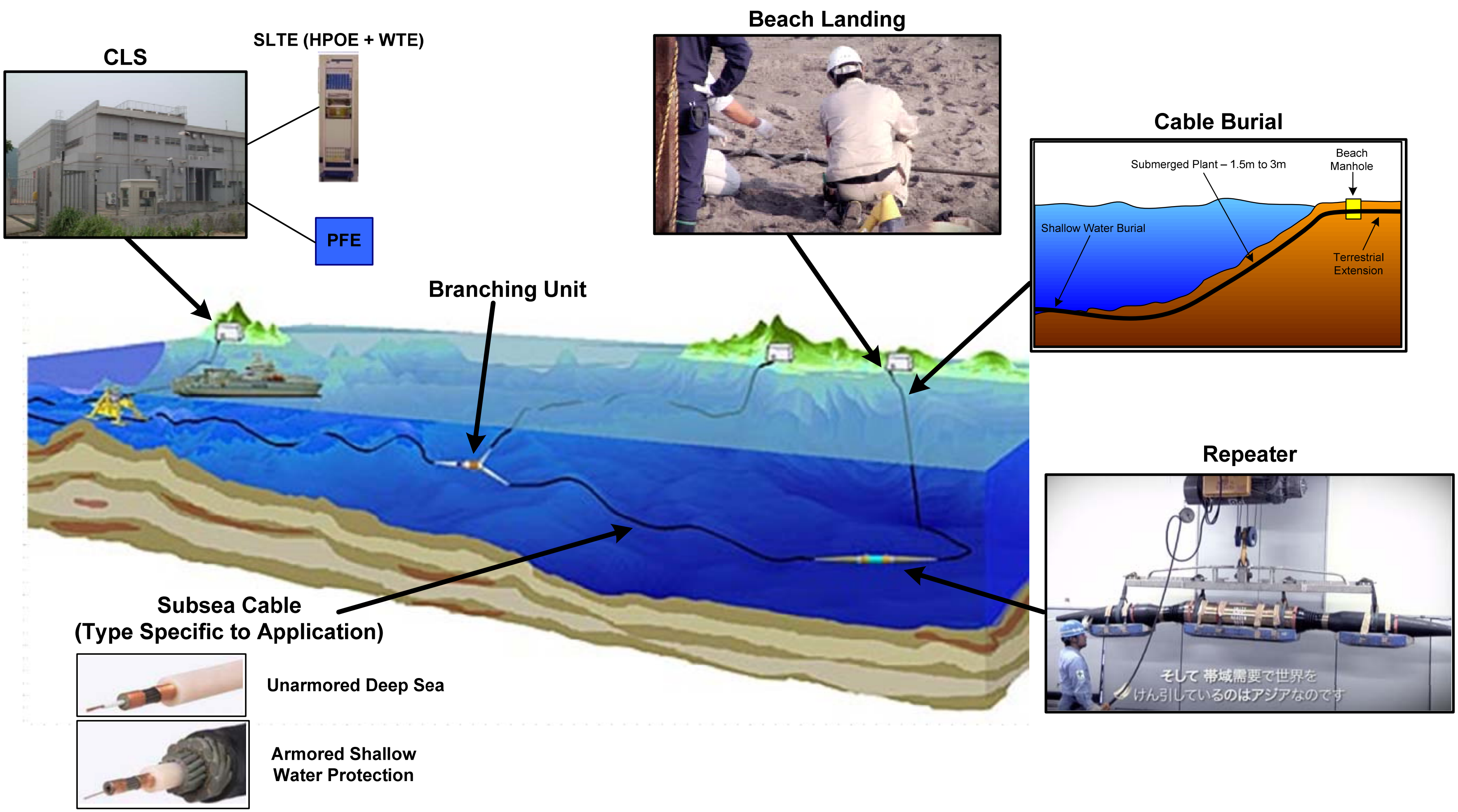
Combined Statistics of EAC-C2C and EAC Pacific
Construction Costs: Over $4.1B
Length: 46,420 km
Reach: 19 cable landing stations across Asia and US
Design Capacity
EAC-C2C: 17.92 to 30.72 Tbps **EAC-Pacific:** 1.92 Tbps

Cable Landing Stations

- Shanghai, China
- Qingdao, China
- Chung Hom Kok, Hong Kong
- Tseung Kwan O, Hong Kong (2)
- Ajigaura, Japan
- Shima, Japan (2)
- Chikura, Japan
- Capepisa, Philippines
- Batangas, Philippines
- Taean, South Korea
- Pusan, South Korea
- Changi, Singapore (2)
- Fangshan, Taiwan
- Pali, Taiwan
- Tanshui, Taiwan
- Redondo Beach, Calif., USA

Subsea Cable Components (High Level)

- Breakdown of cable components



Subsea Repeaters – Making +10K km spans possible

Tyco SL Repeater

- A proven & qualified product successfully deployed in undersea systems worldwide since the early 1980s
- Same External Pressure Housing Hardware
- Modular Internal Hardware

Tyco SL Repeater being deployed as it leaves the ship and before it breaks the water surface

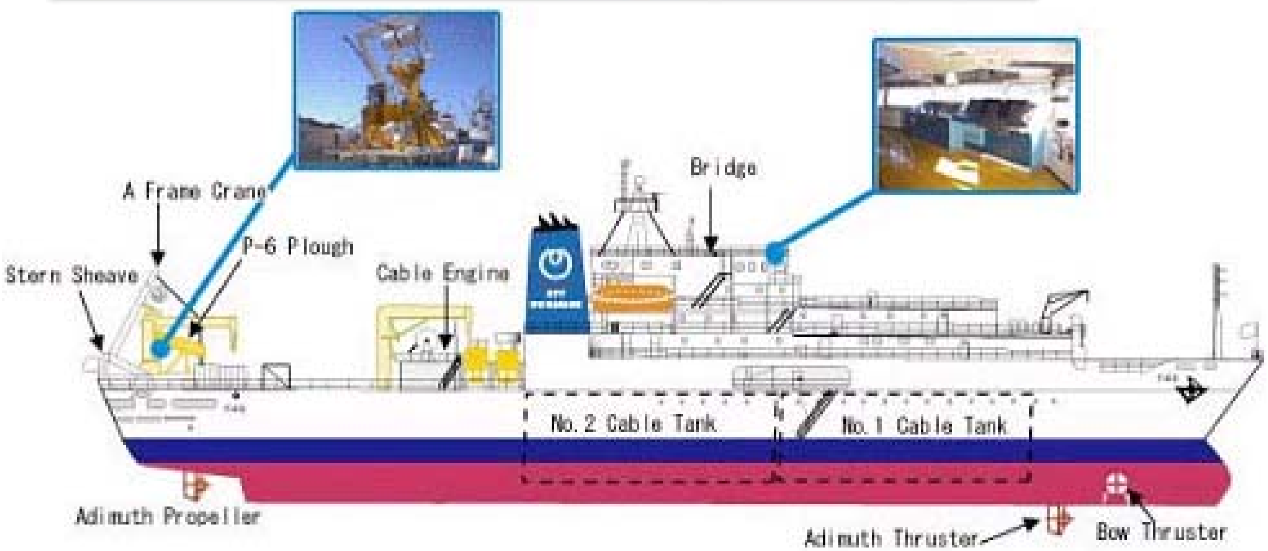
- **Repeaters**
  - Be-Cu Repeater housing
  - Can accommodate up to 16 fibers
  - Modular Internal network for all amplification and equalization needs

Courtesy of TE SubCom

Submarine Cable Deployment/Repair Equipment

Cable Ship

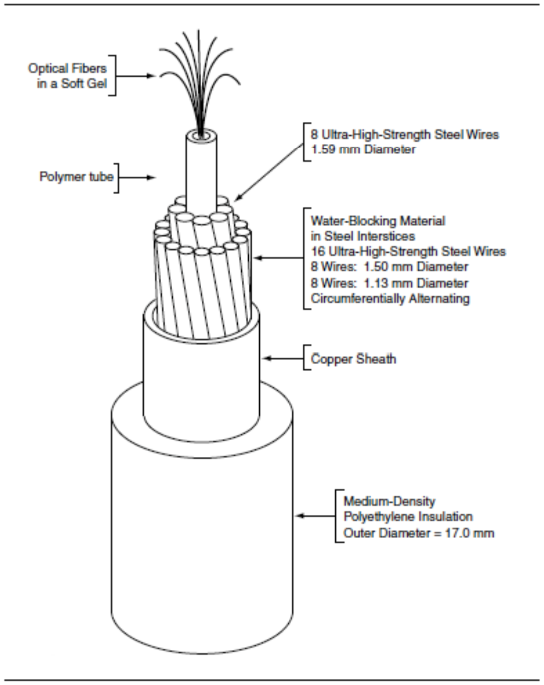
Plough

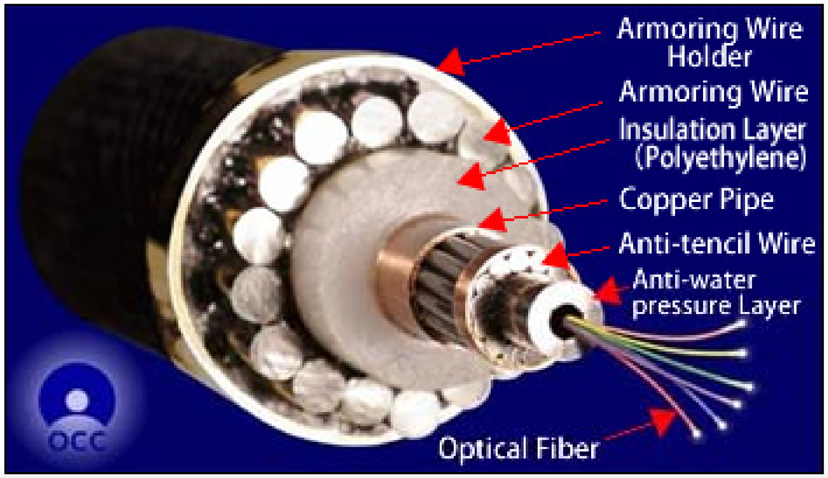


ROV

Subsea Cable Construction

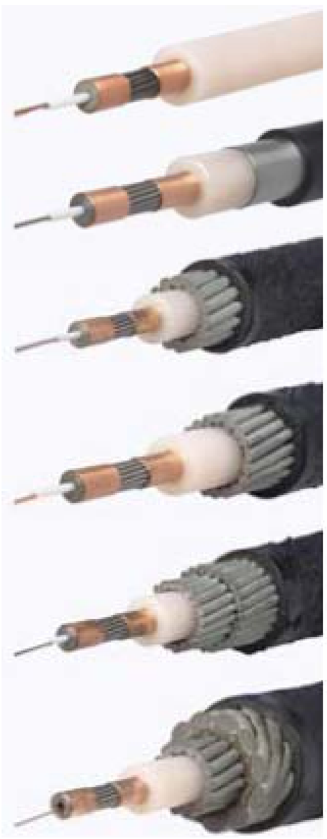
- Baseline Lightweight Cable Construction
  - Unit Fiber Structure (UFS) tube containing optical fibers
    - Provides a soft medium for fiber support, typically with excellent, water, chemical, and wear resistant properties such as PBT
    - May include a high viscosity gel to aid in water ingress protection during a cable break
  - Ultra–high-strength steel wire support around the core
    - Provides cable strength and tensile stiffness
    - Limits cable and fiber elongation during handling
    - Isolates and protects the UFS by forming a pressure vessel
    - May be coated further with a hydrophobic water-blocking compound, typically resistant to extreme temperature variations, to aid in water ingress protection
  - Seam-welded copper sheath formed around anti-tensile wire
    - Main power conduit for PFE
    - Improves handling
    - Facilitates cable monitoring and maintenance
  - Medium-density polyethylene jacket surrounding the copper sheath
    - Provides high-voltage insulation from natural ground potential of the sea
    - Resists abrasion and corrosion
    - Protects against oceanic hydrogen sulfide concentrations





Courtesy of TE SubCom and OCC

Subsea Cable Types and Usage



Lightweight (LW)

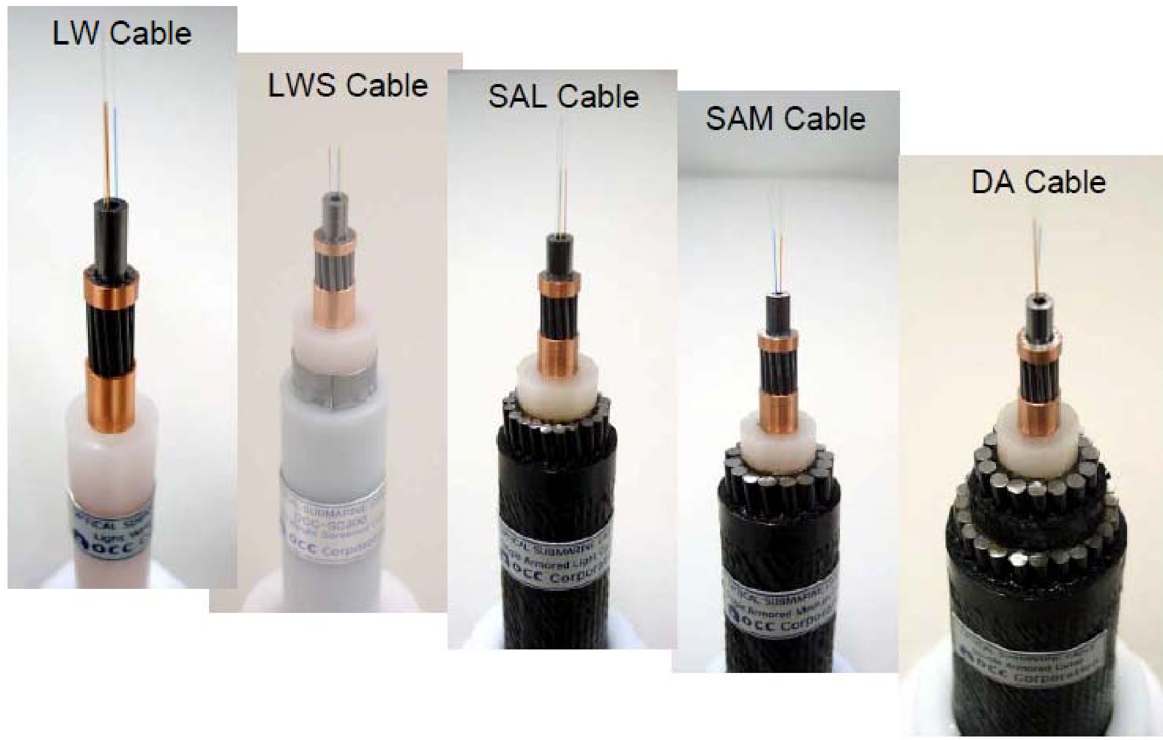
Special Application (SPA)

Light-Wire Armor

Single Armor

Double Armor (DA)

Rock Armor (RA)



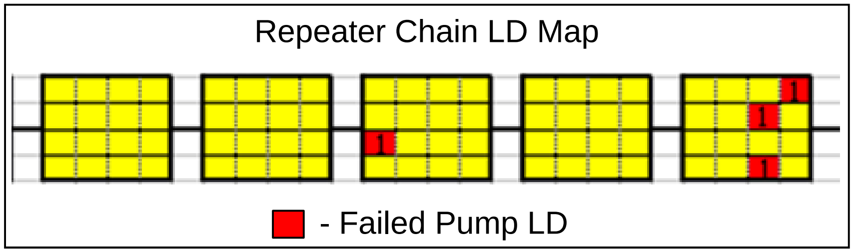
Courtesy of TE SubCom

Cable Fault Types

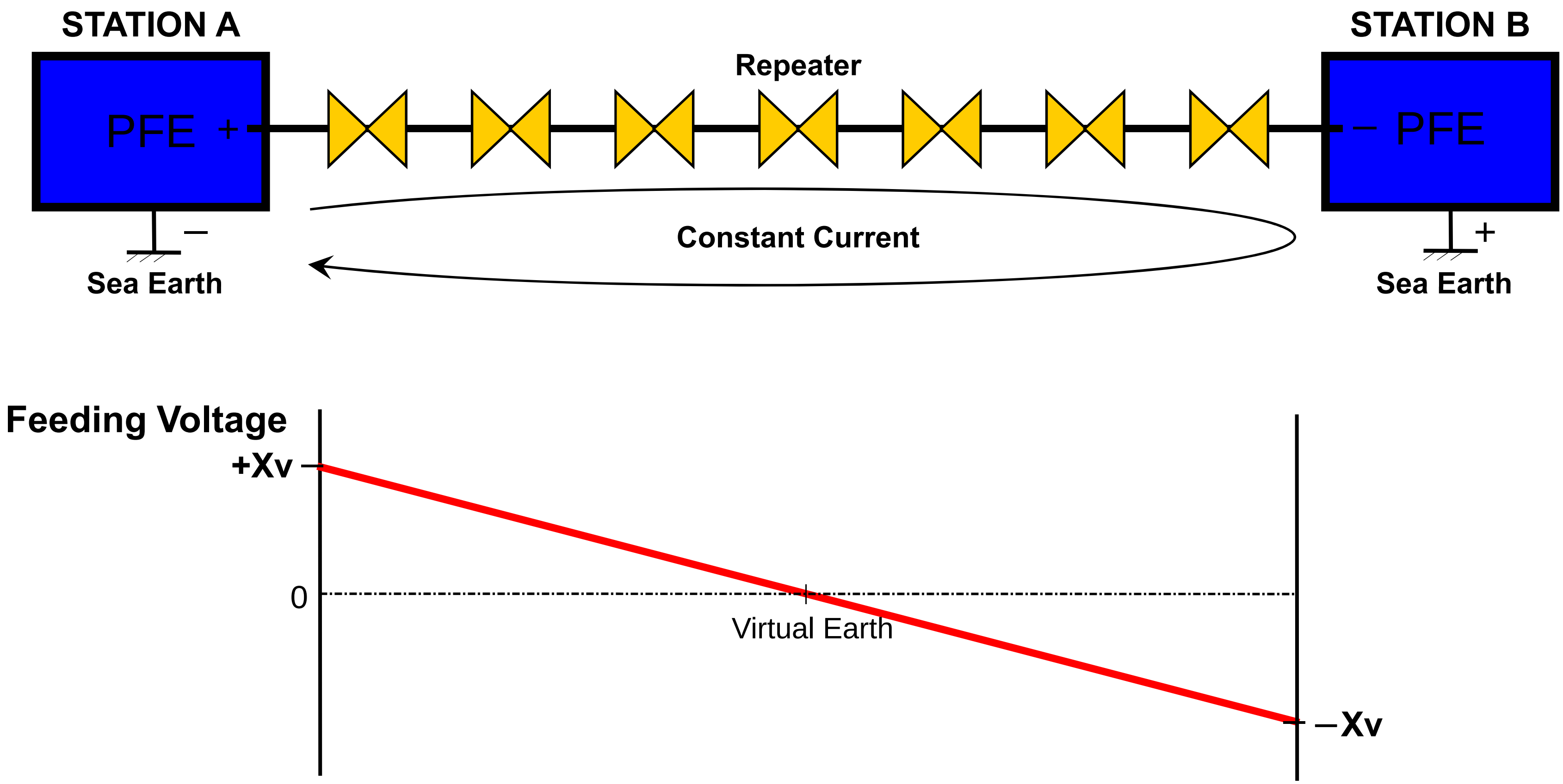
- Shunt Fault
  - Exposed power cable
    - Fiber pairs intact
    - Reconfiguration of PFE to maintain service

- Cable Cut
  - Complete cut of physical cable and fiber pairs

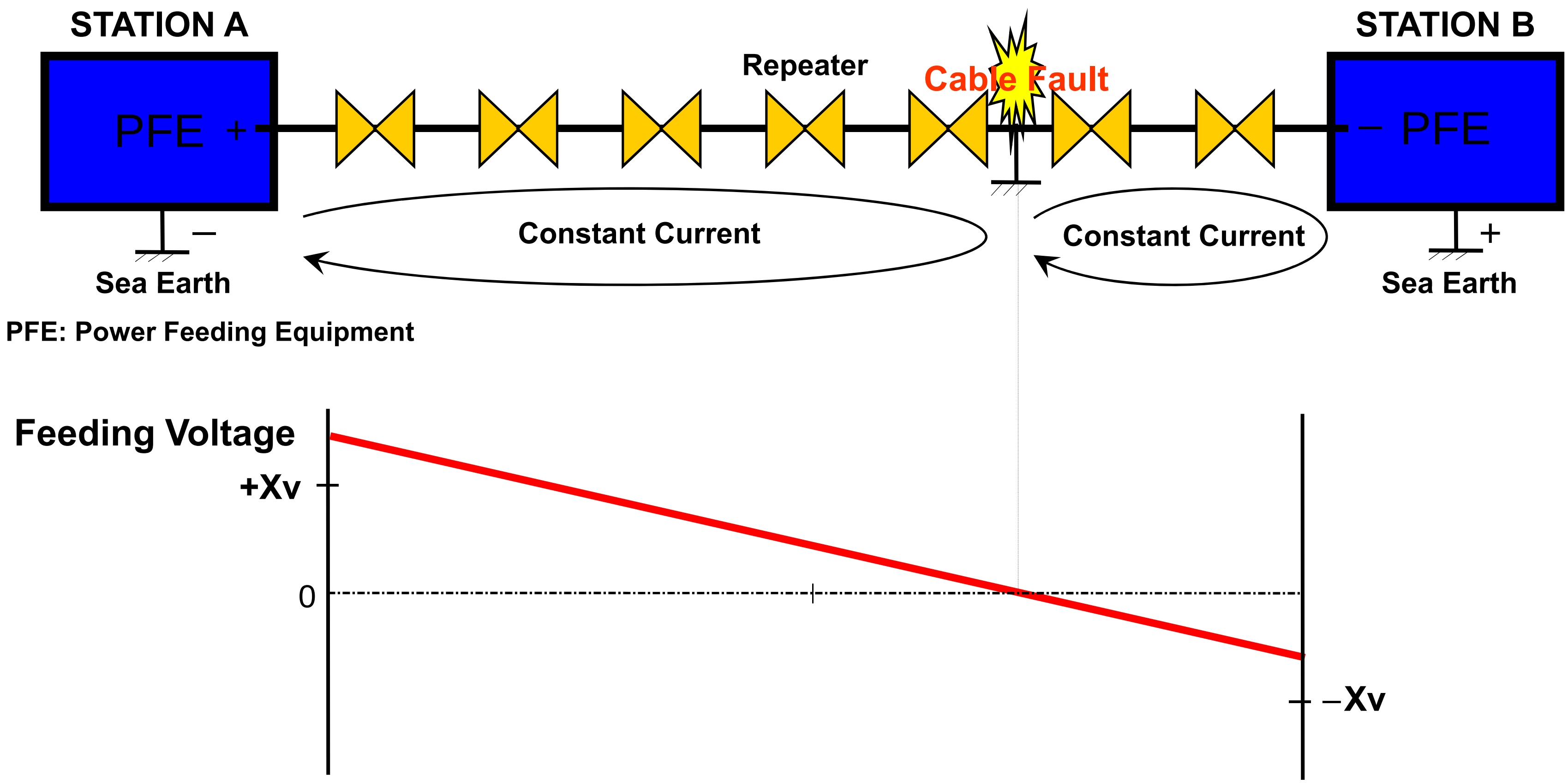
- Repeater Servicing
  - Pump LD Failures



Power Feeding - Normal



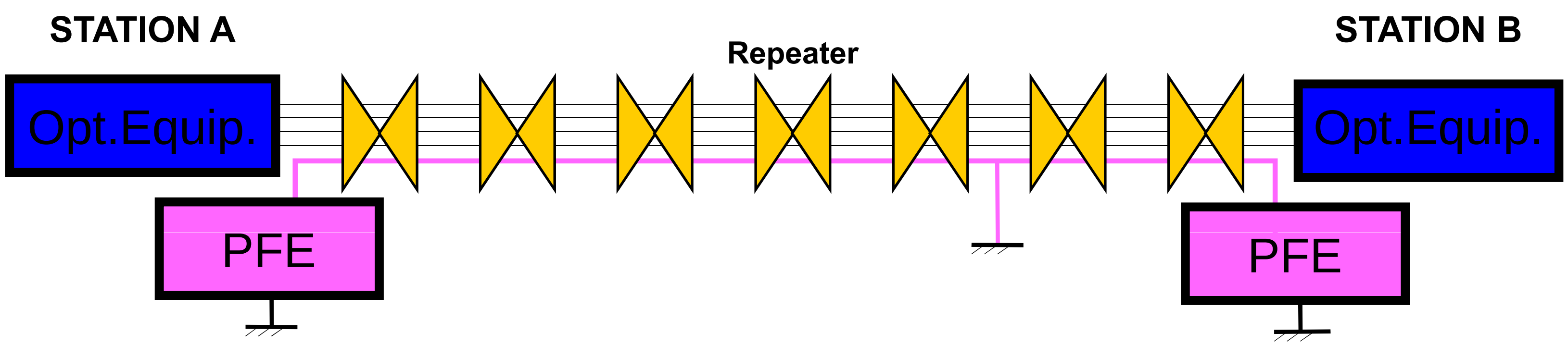
Power Feeding – Cable Cut



Fault Location – Shunt Fault

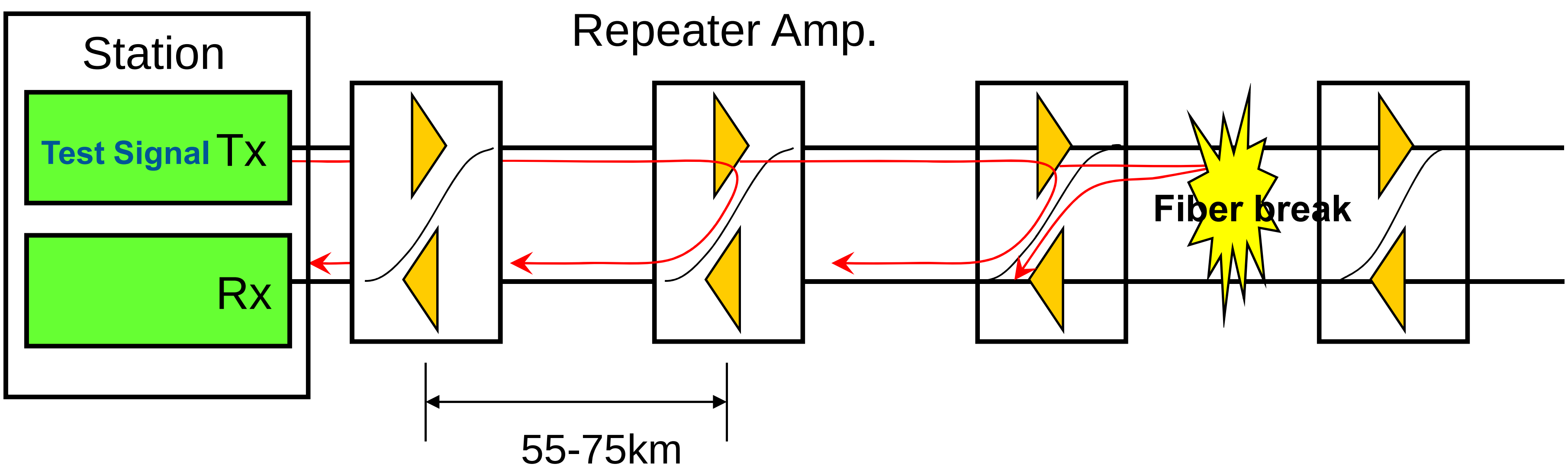
1. Shunt Fault

   DC current into the ocean → **Voltage measurement**

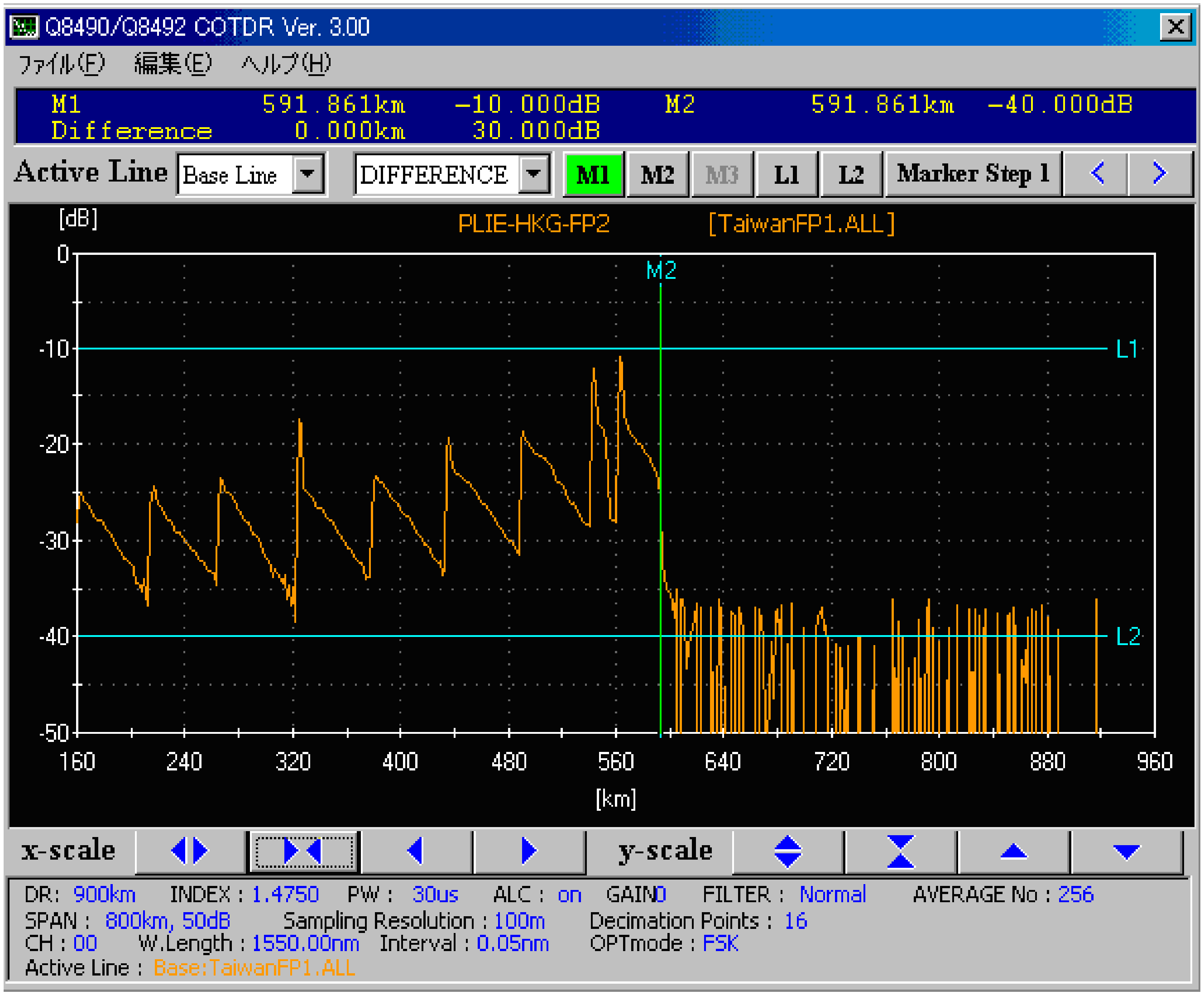


Fault Location – Cable Cut

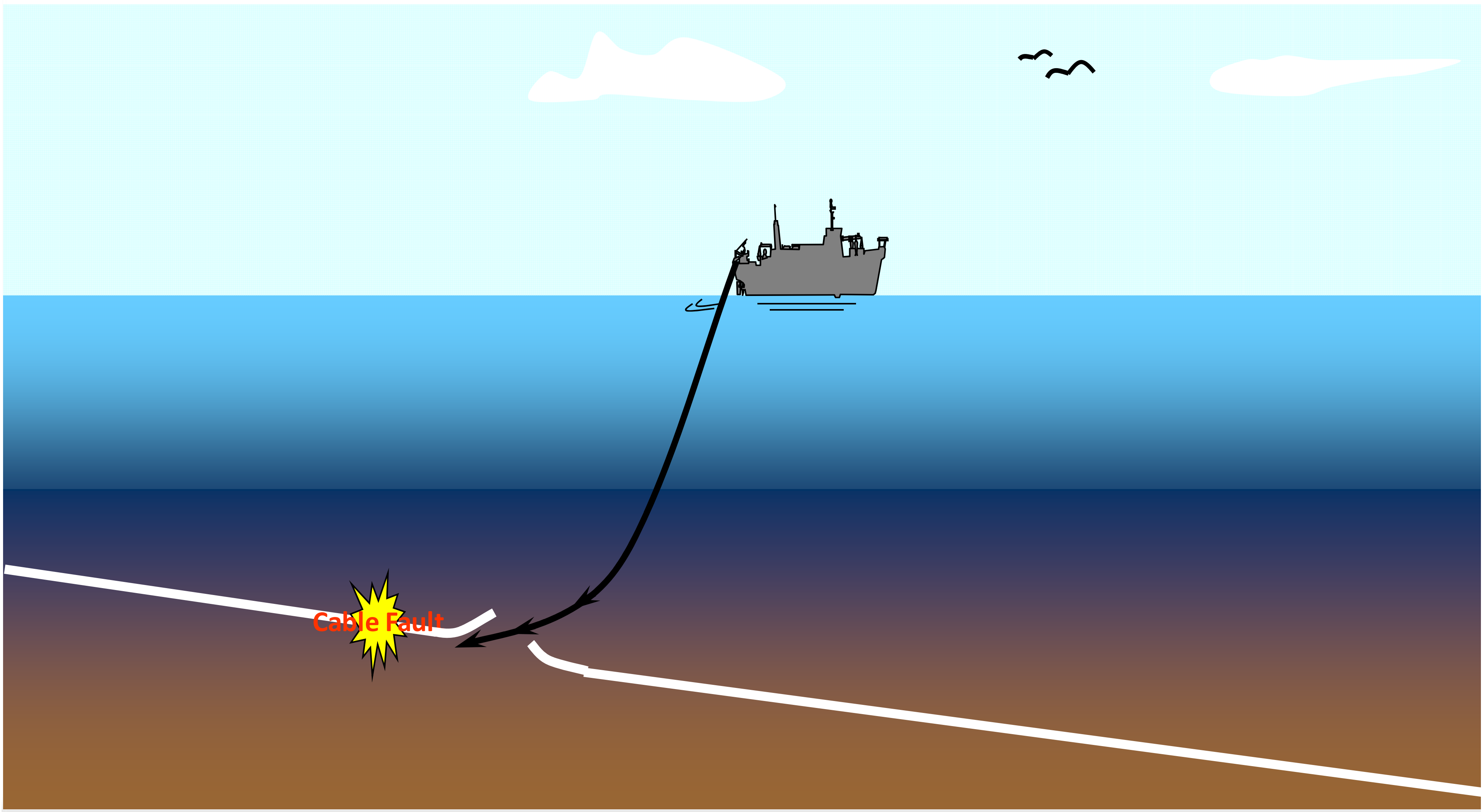
1. Cable cut
   (1) Fiber Break → **Optical measurement**
   (2) DC current into the ocean → **Voltage measurement**



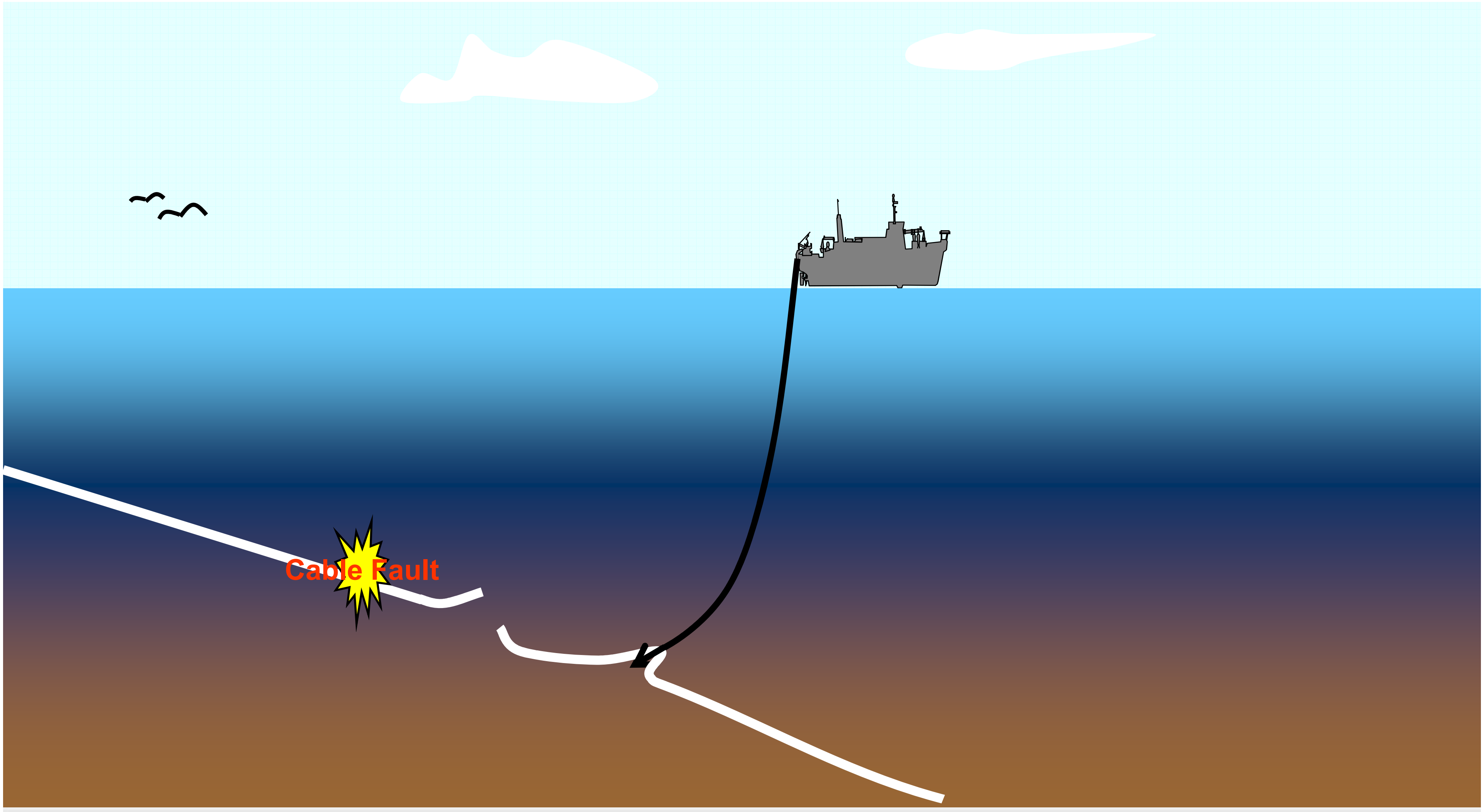
COTDR (Coherent Optical Time Domain Reflectance)



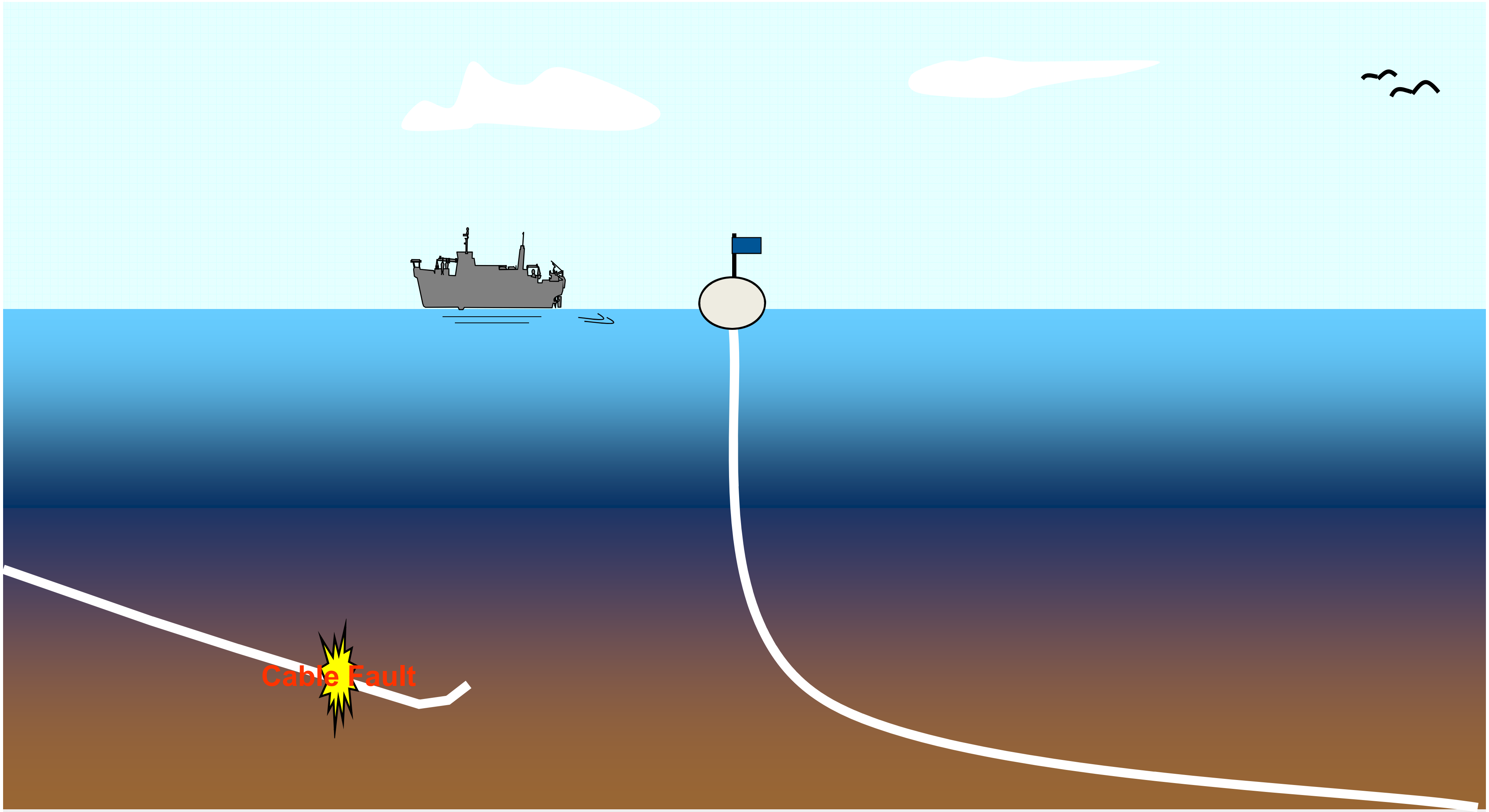
Cutting Drive



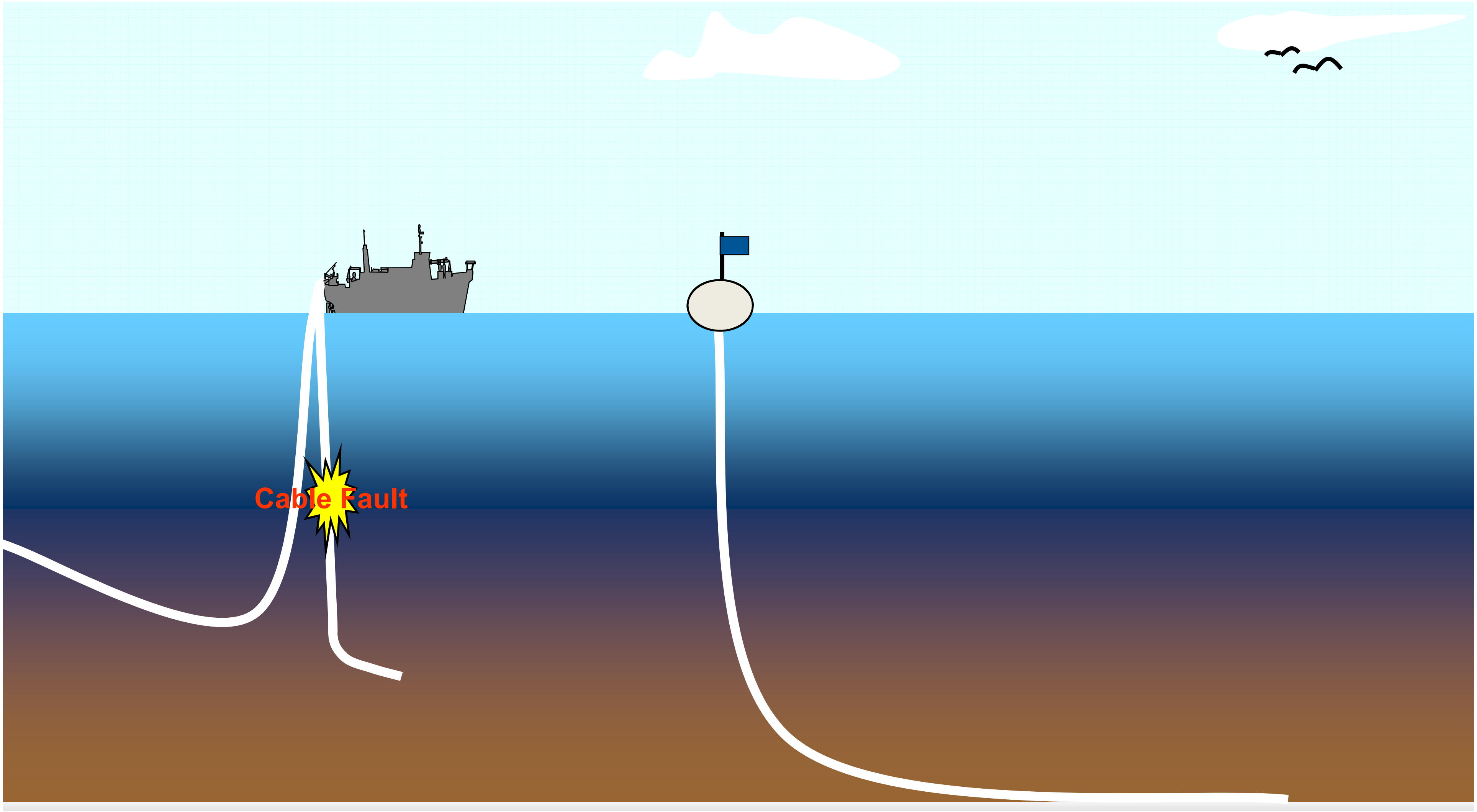
Holding Drive - 1



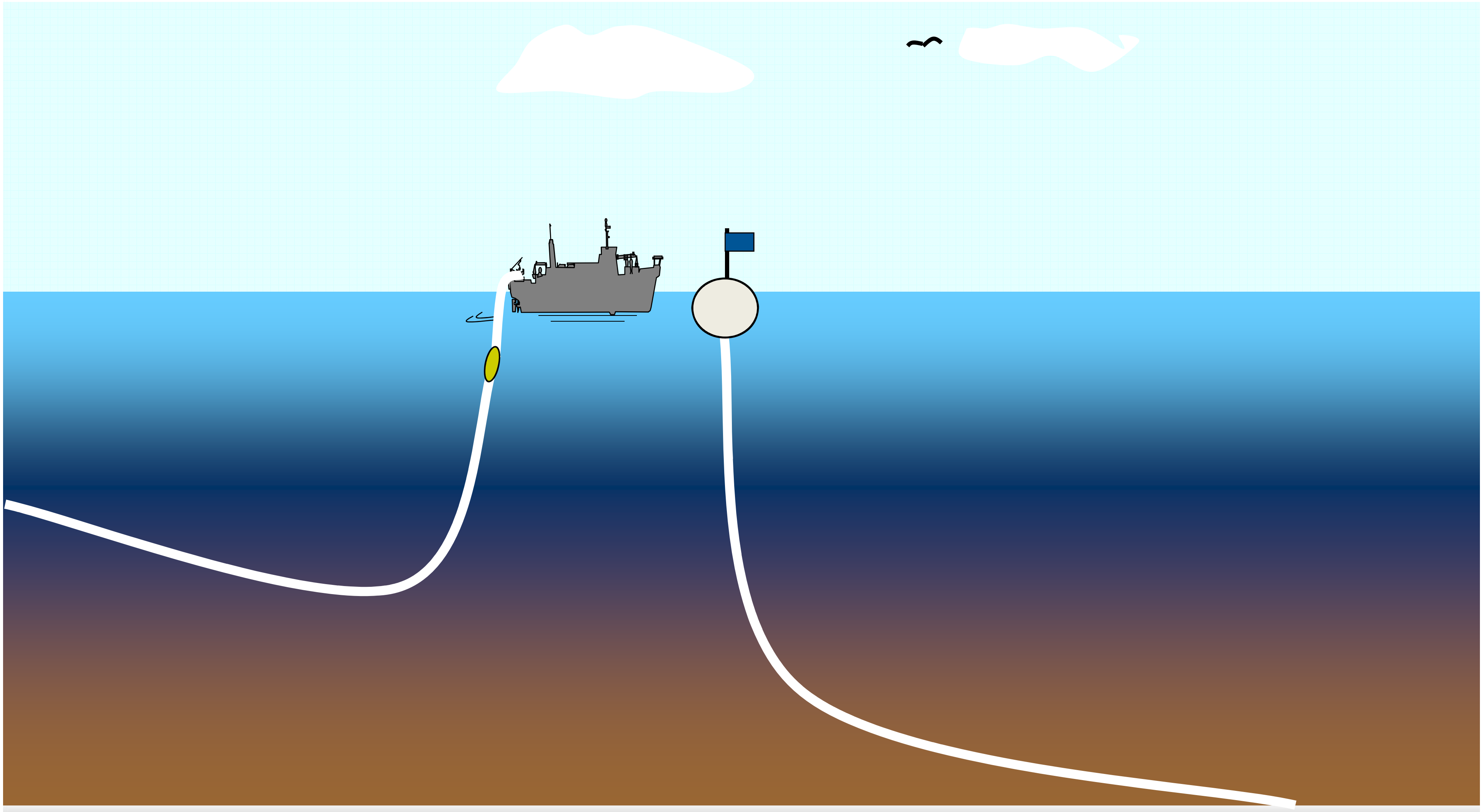
Buoying



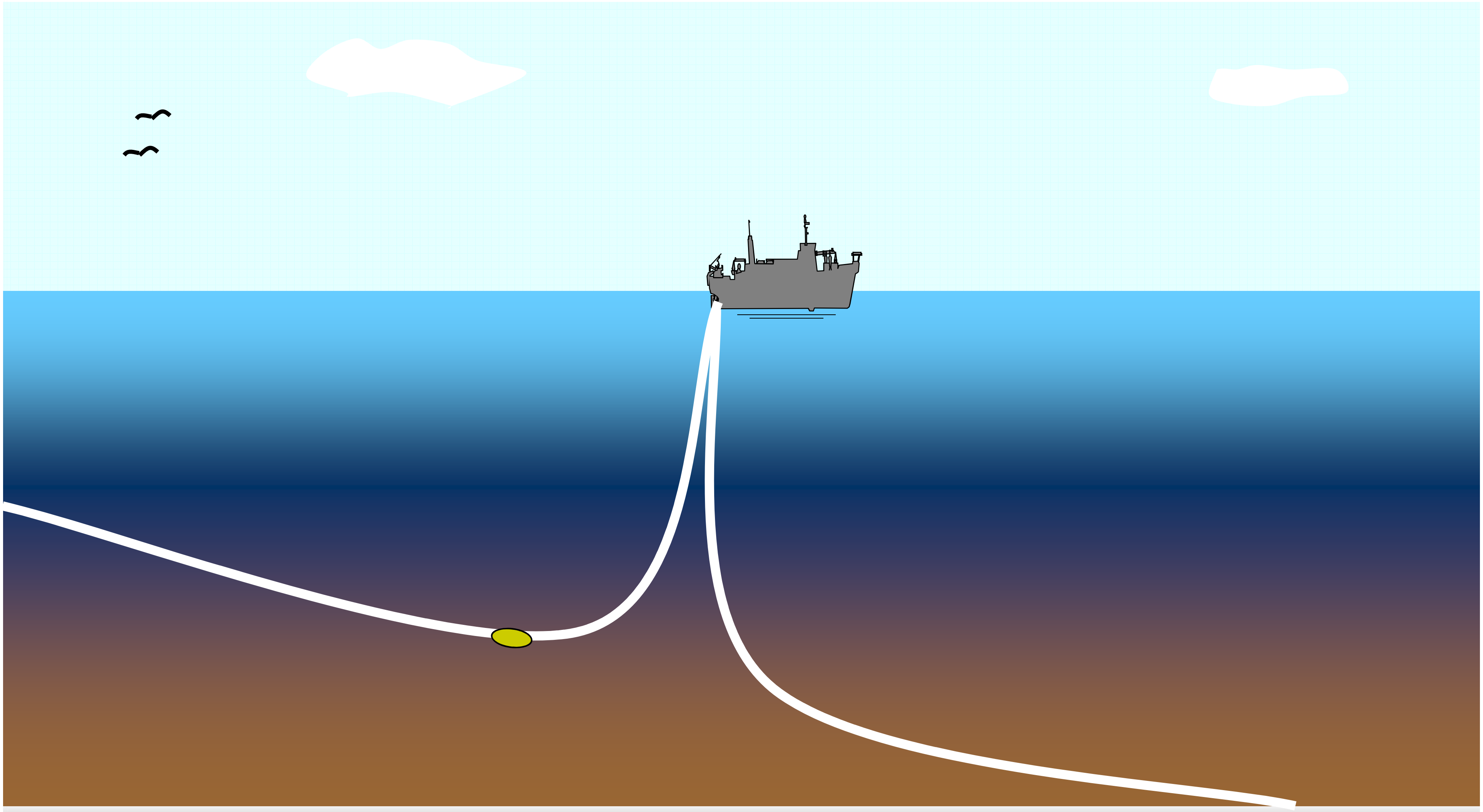
Holding Drive - 2



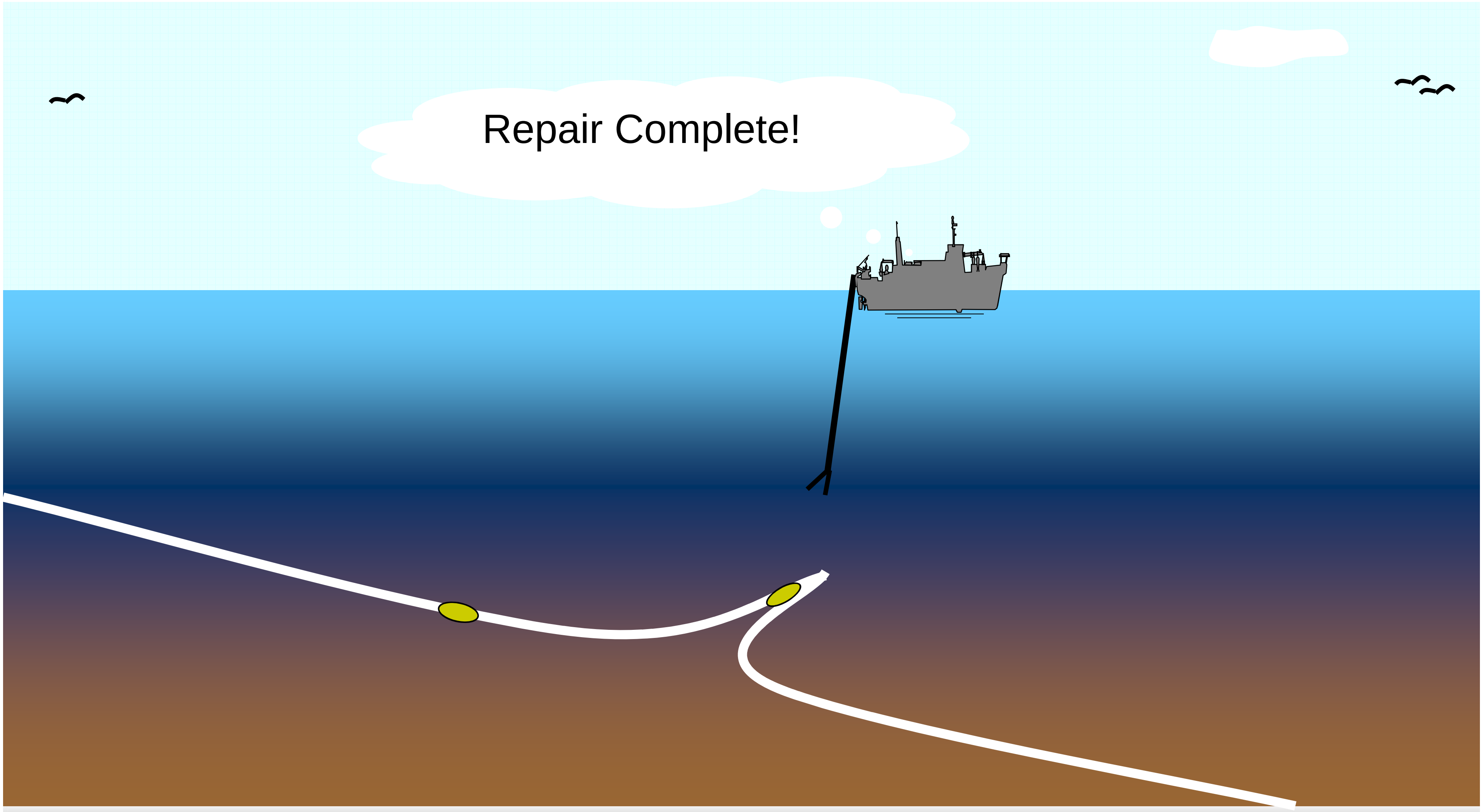
First Splice and Laying



Final Splice



Final Bight Release



Repair Timelines

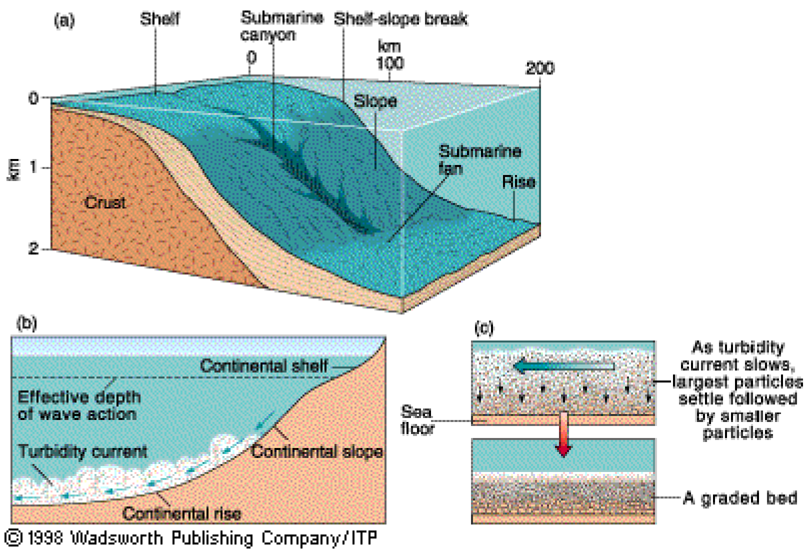
- Repair timelines and sequence
  - Day 1
    - Mobilization and loading
  - Day 2
    - Transit to cable grounds
    - PFE Reconfiguration of affected and adjacent segments
  - Day 3
    - Preparation and Route Survey
    - Fault Localization
    - Cable cutting drive (if required)
    - Holding drive #1
  - Day 4
    - Setting Buoy
  - Day 5
    - Holding drive #2

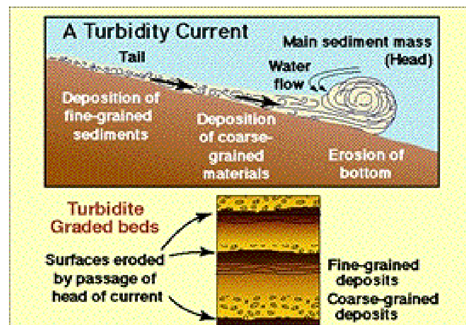
Repair Timelines continued

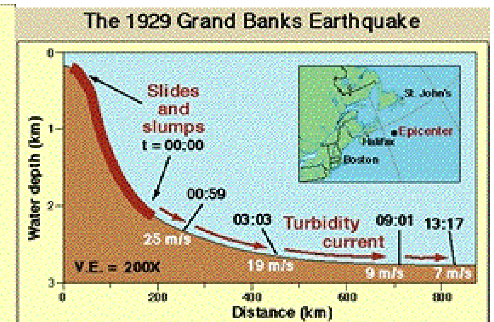
- Repair timelines and sequence
  - Day 6
    - Initial splice
  - Day 7
    - Spare cable laying
  - Day 8
    - Final splice
  - Day 9
    - Final Bight Release Operation
    - PFE Reconfiguration of affected and adjacent segments
  - Day 10
    - Traffic Normalization
- Additional delay factors include
  - Permit application processes
  - Environmental factors (weather, seismic activity, etc)
  - Cable Ship availability and proximity
  - Additional repairs (repeaters, multiple cuts, extended damage)
  - Shallow water retrieval and burial

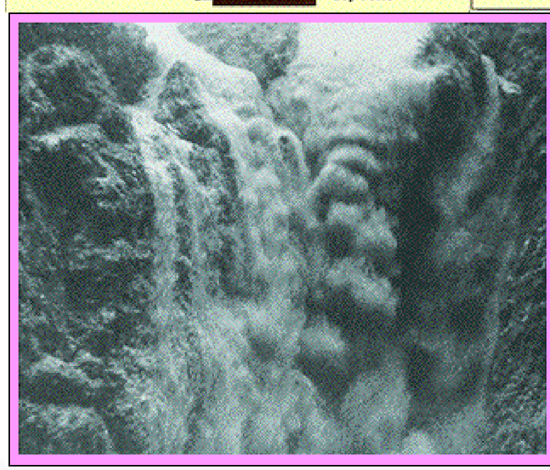
Outage Factors

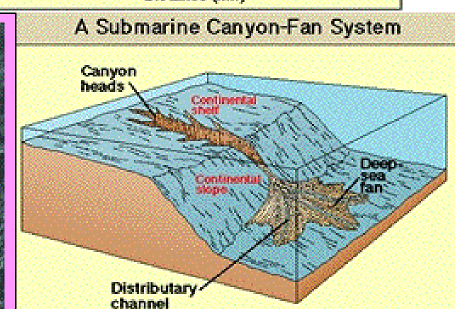
- Natural Disasters
  - Seismic Activity
    - Resulting Turbidity Currents and Undersea Landslides from the earthquake are the predominate cause of cable damage
    - Flows can reach very high rates of speed depending on continental / canyon slope and density of sedimentary material







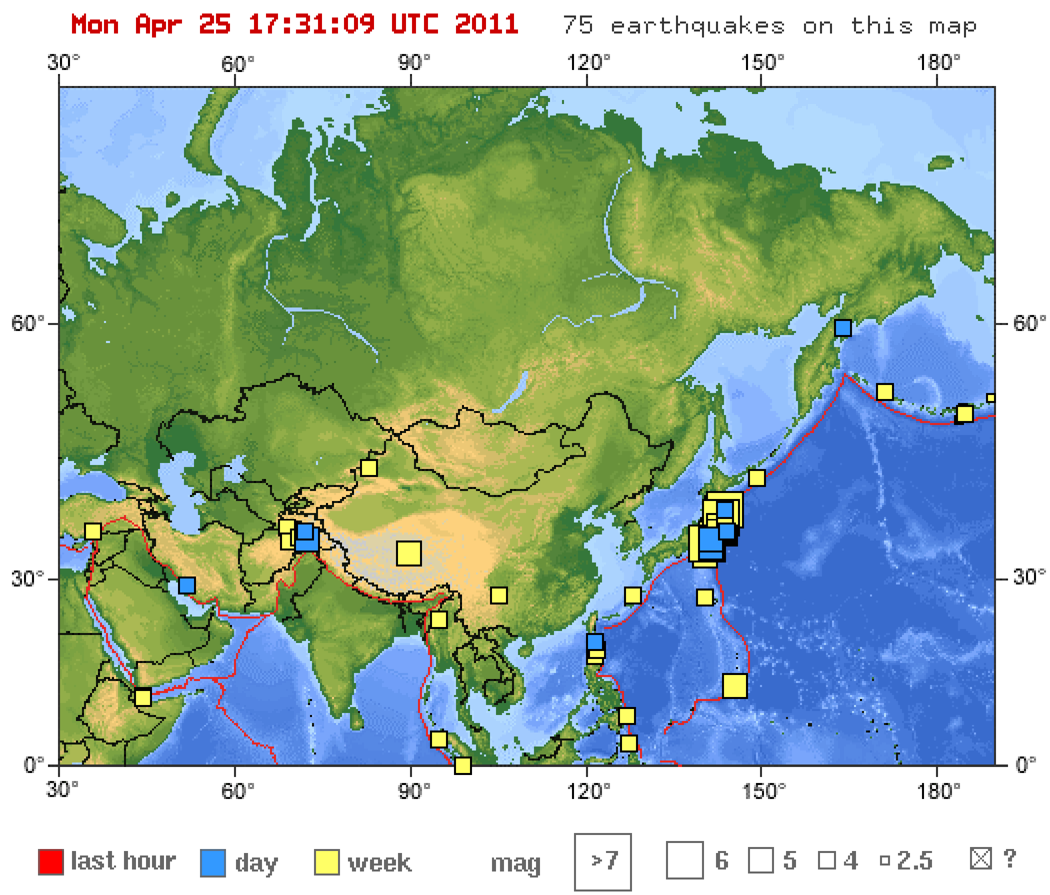




Images courtesy of WMU Dept. of Geosciences

Useful Tools - USGS

- Indentifying seismically active areas of the Pacific Plate and Historical Analysis
- http://earthquake.usgs.gov/



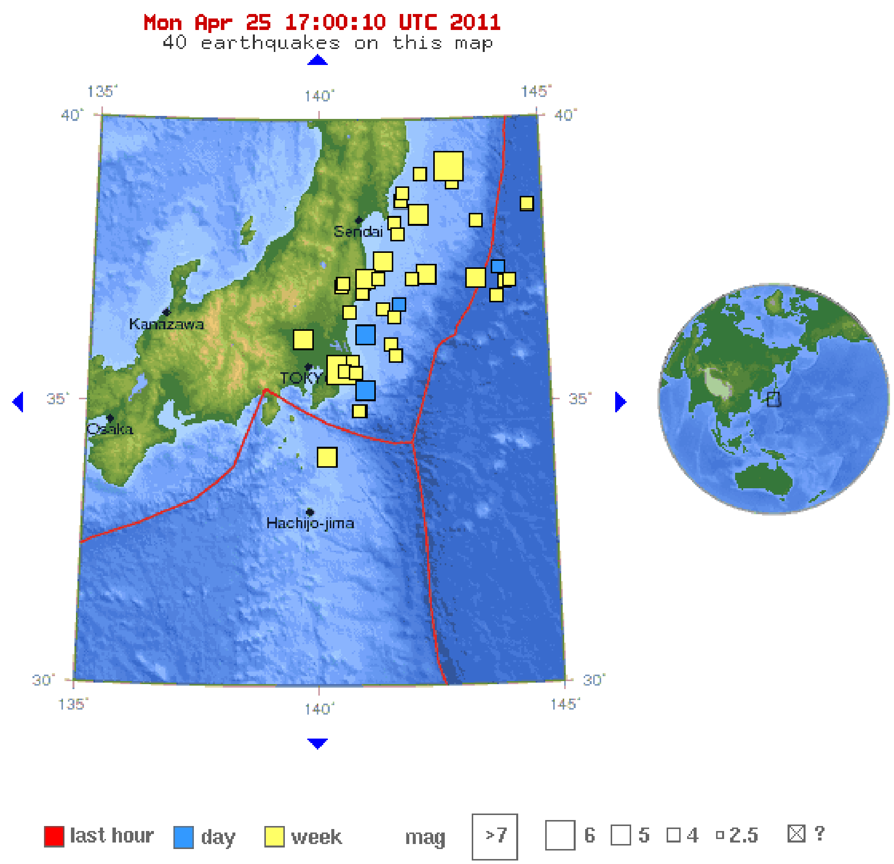
Useful Tools - USGS

10-degree Map Centered at 35°N,140°E

Earthquake Details

This event has been reviewed by a seismologist.

Magnitude	9.0
Date-Time	**Friday, March 11, 2011 at 05:46:23 UTC** Friday, March 11, 2011 at 02:46:23 PM at epicenter Time of Earthquake in other Time Zones
Location	38.322°N, 142.369°E
Depth	32 km (19.9 miles) set by location program
Region	NEAR THE EAST COAST OF HONSHU, JAPAN
Distances	129 km (80 miles) E of **Sendai, Honshu, Japan** 177 km (109 miles) E of **Yamagata, Honshu, Japan** 177 km (109 miles) ENE of **Fukushima, Honshu, Japan** 373 km (231 miles) NE of **TOKYO, Japan**
Location Uncertainty	horizontal +/- 13.5 km (8.4 miles); depth fixed by location program
Parameters	NST=350, Nph=351, Dmin=416.3 km, Rmss=1.46 sec, Gp= 29°, M-type=centroid moment magnitude (Mw), Version=A
Source	USGS NEIC (WDCS-D)
Event ID	usc0001xgp



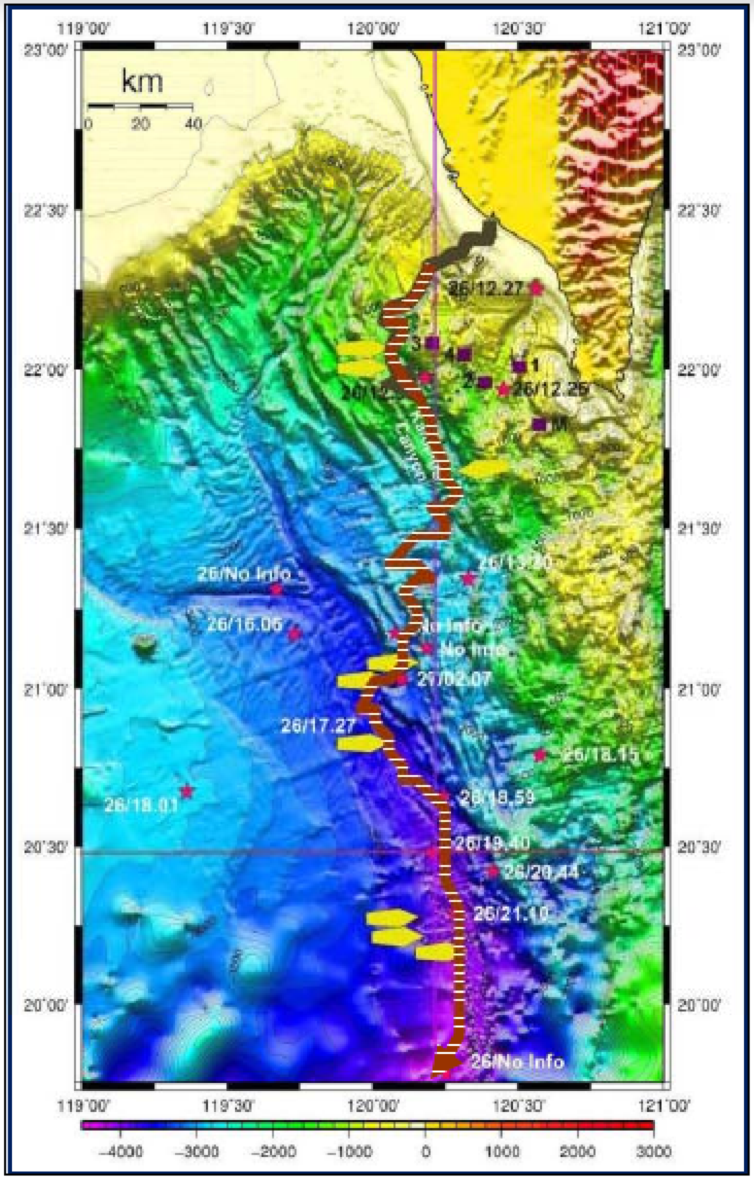
Outage Factors

- Natural Disasters
  - Typhoons
    - Example: Morakot in August 2009
    - Resulting Storm Surge and extreme river discharge triggered turbidity currents in the Kaoping Canyon that caused significant cable damage downstream all the way to the Manila Trench

Images courtesy of Reuters and AFP

Outage Factors

- Turbidity Currents from Typhoon Morakot occurred in 2 separate flows
  - First flow triggered 2 cable events during peak flood from initial river discharge
  - Second flow was triggered 3 days later from sedimentary build-up along the Kaoping canyon resulting in additional cable events
  - Faults to 8 separate cable systems were recorded



Courtesy of www.iscpc.org

Outage Factors

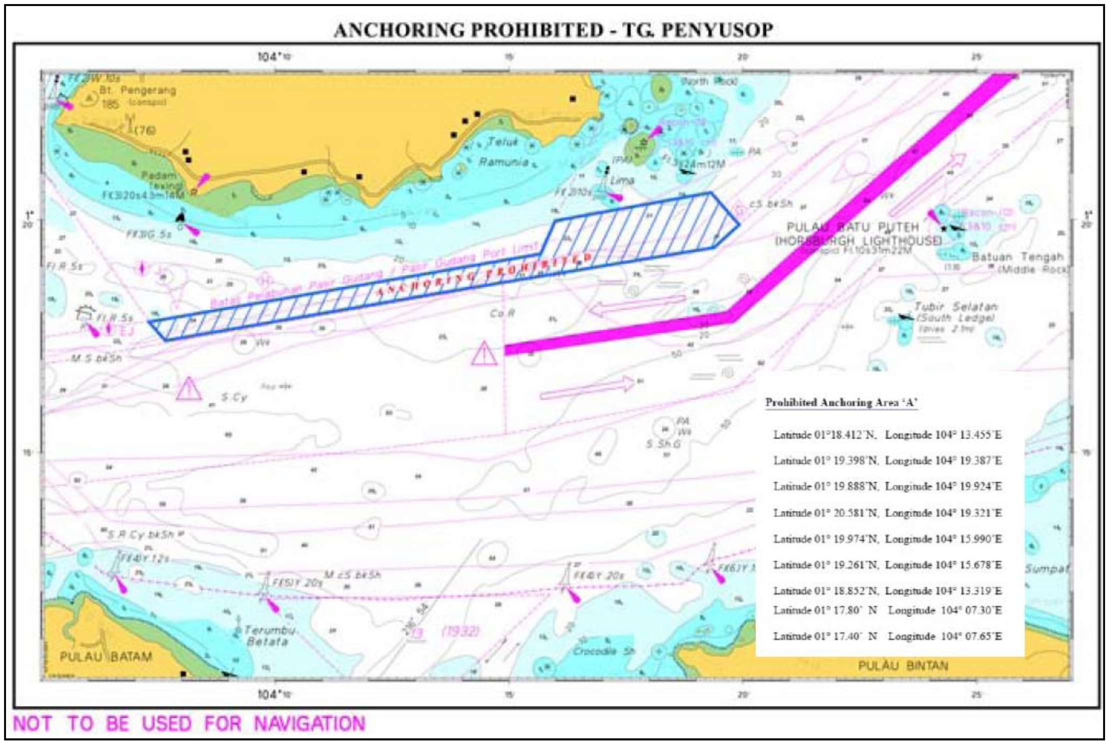
- External Aggression
  - Shipping and Fishing Vessels
    - Anchor drops and drags
    - Bottom Trawling based fishing
    - Dynamite/Explosives based fishing
  - Piracy and Espionage
    - Reclamation of cable assets
    - Increased market value of quality copper materials presents issues on theft of cable segments
      - Typically opportunistic incidents
      - Some instances of targeted malicious intent

Restoration and Repair Constraints

- Restoration constraints
  - Weather and high seas can delay repair activities
  - Unique environmental factors such as radiation exposure (Japan Fukushima Plant)
- Factors affecting repair timelines
  - Does the type of outage affect the repair process?
    - Shunt fault repairs involving additional cutting drives
    - Repeater maintenance and supply chain
    - Shallow water retrieval and equipment availability
    - Adverse seabed conditions
      - Low visibility and muddy landing points
      - Rocky outcroppings and ledges
    - Fast currents and dangerous diver conditions

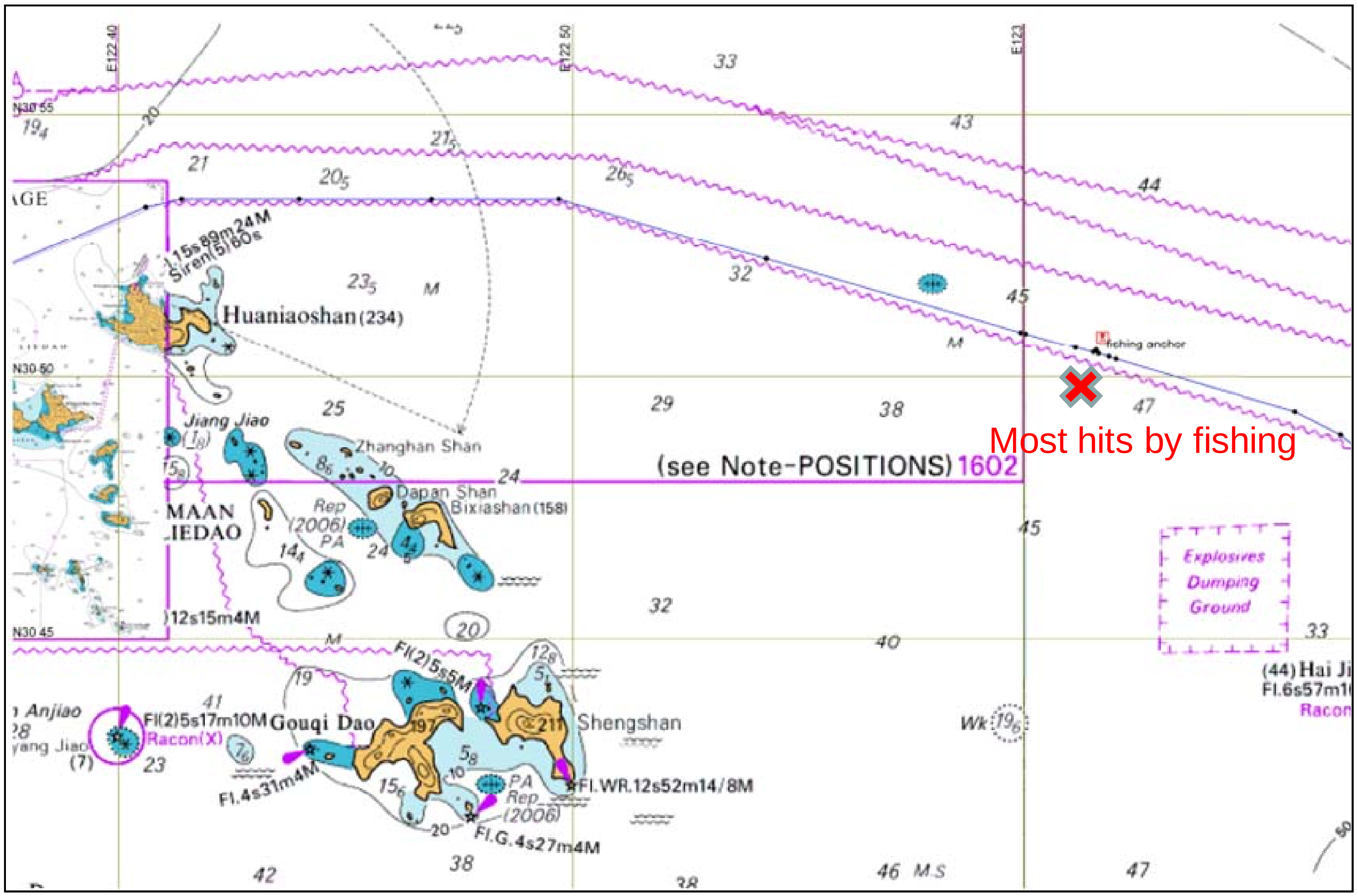
Mitigation of faults?

- Planning and risk projection
  - Route analysis during DTS phase of design
  - Understanding fault events, proximity, and probability
    - Historical factors determining Seismic susceptibility, shipping lanes, fishing frequency and type (bottom vs. mid-water trawling)



Use of Guard Boats to protect high incident sites

- Guard Boats
  - Typically not effective for long term protection due to cost

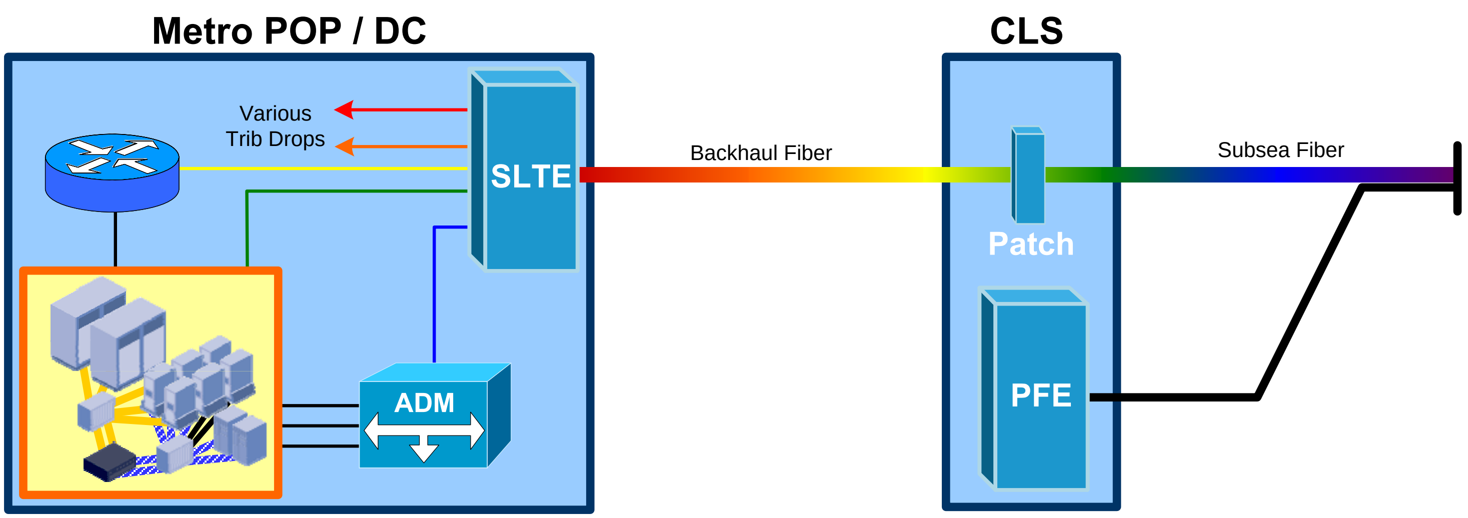


Design Factors for IP Backbones

- Geographical
  - Limitations on subsea routes
    - Cable depth and shortest path tend to drive deployments
      - Luzon Strait
    - Bypassing seismic regions are not realistic for certain routes
- Regulatory constraints
  - Termination rights, ownership, and licensing restrictions limit attractiveness for investment
    - China landing points
- Historical analysis and planning
  - Shipping activity and port backlog
    - Singapore Landings
  - Trawlers and shallow sea fishing activities
    - Taiwan/Formosa Strait and East China Sea
  - Turbidity Current susceptibility
    - Seismic hotspots
    - Undersea canyons and coastal runoff

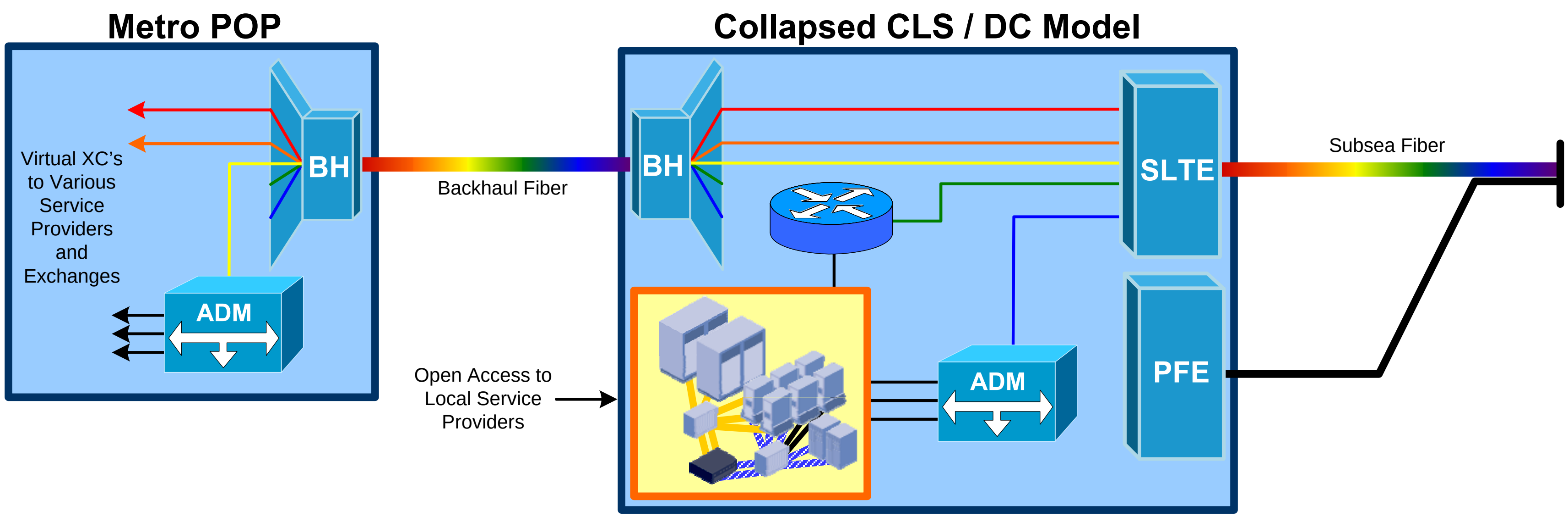
Increasing IP Trunk efficiencies

- Collapsing the Cable Station and POP
  - Shifting SLTE to the City Center
    - CLS remains as a Power Feed Station for repeaters
    - Limitations on DC location and proximity to PFE
      - Beach Landing sites requiring long BH to Metros need to be excluded
        - » Greater China, Japan, Philippines, and Korea tend to be poor candidates for this model
        - » Singapore, Hong Kong, Taiwan, and other coastal cities are more appropriate for this model



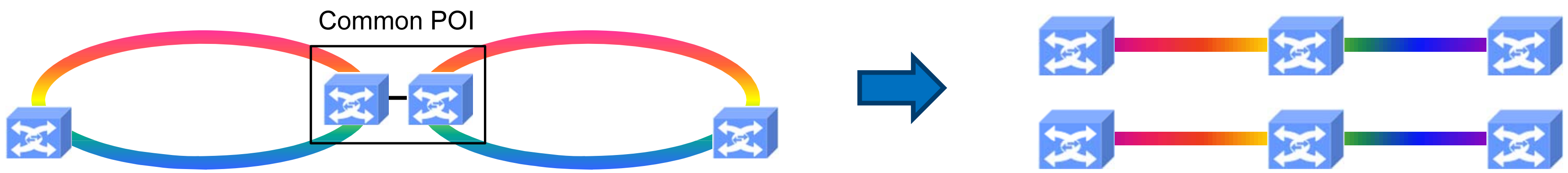
Increasing IP Trunk efficiencies

- Collapsing the Cable Station and POP
  - Moving the POP into the Cable Landing Station
    - Challenges
      - Maintaining carrier neutrality
      - Accessibility to diverse systems and routes
  - Hybrid Approach?



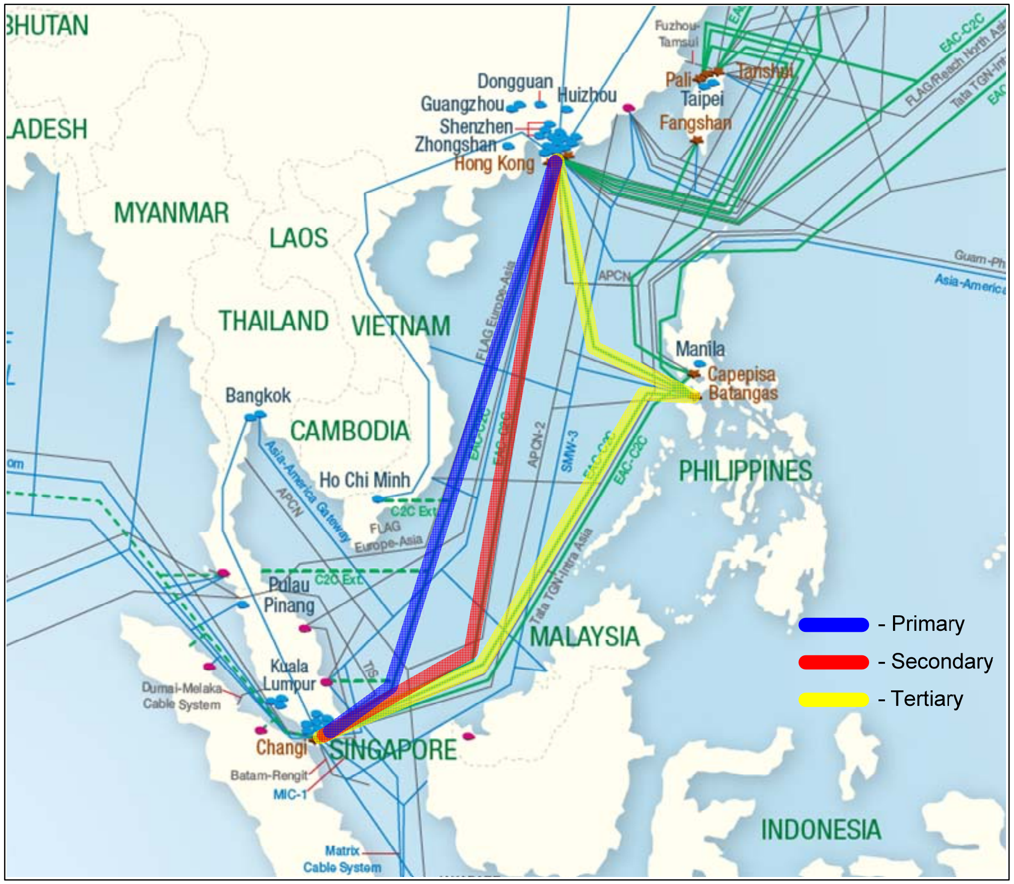
Route Fault Tolerance

- Optical protection versus linear
  - Traditional ring approach presented many issues on control, latency, performance, and route selection
    - Ring Interconnects introduce limitations on path diversity
  - Multiple linear paths helped to guarantee predictability of trunk performance
    - Brute force method of up/down approach
    - Additional routes required to ensure disaster recoverability
    - Introduces significant additional risk on restoration timelines and the responsibilities of suppliers
      - Manual versus automatic
      - Prioritization and SLA commitments
    - Cost considerations



Route Fault Tolerance

- Optical Mesh
  - Intelligent switching using ASON / GMPLS
  - Multiple permutations of route topologies and protection schemes
    - Both dedicated and shared protection path options
  - Incorporates behavioral properties of Layer 1 protection and Layer 3 route selection
  - For permanent protection implementations, switching times can remain in the 50ms range typically associated with traditional ring architectures
    - Requires dedicated bearers for protection capacity



Questions?

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