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國際光纖海纜工程

International Fiber Optic Submarine Cable Construction

物理，政治及技術之挑戰

Physical, Political and Technical Challenges

2014

香港城市大學
City University of Hong Kong

Contact for further discussion:
peterkcyu@yahoo.com

Professor Peter KC Yu's
Public Technical Presentation

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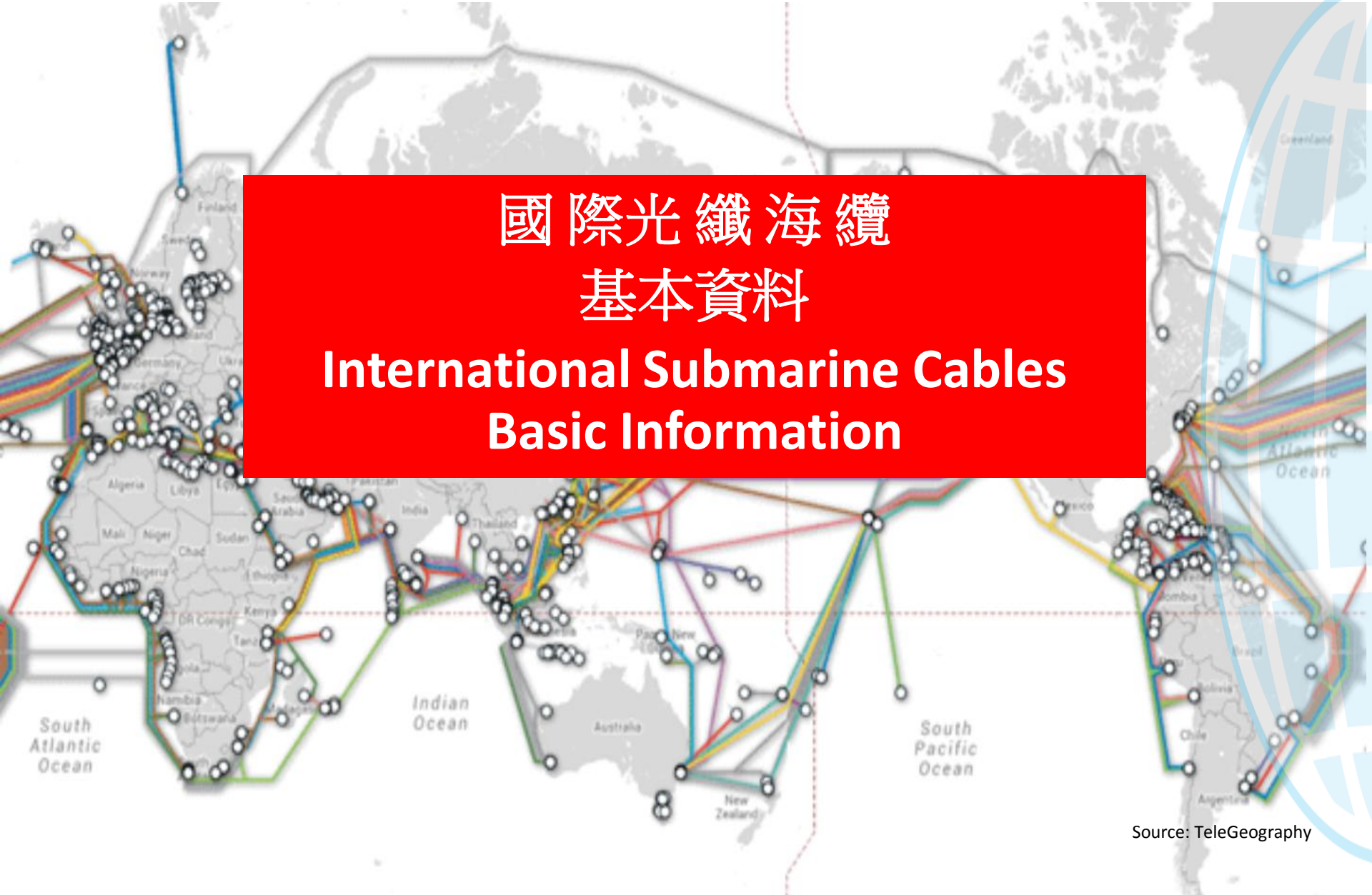
國際光纖海纜
基本資料
International Submarine Cables
Basic Information



Source: TeleGeography

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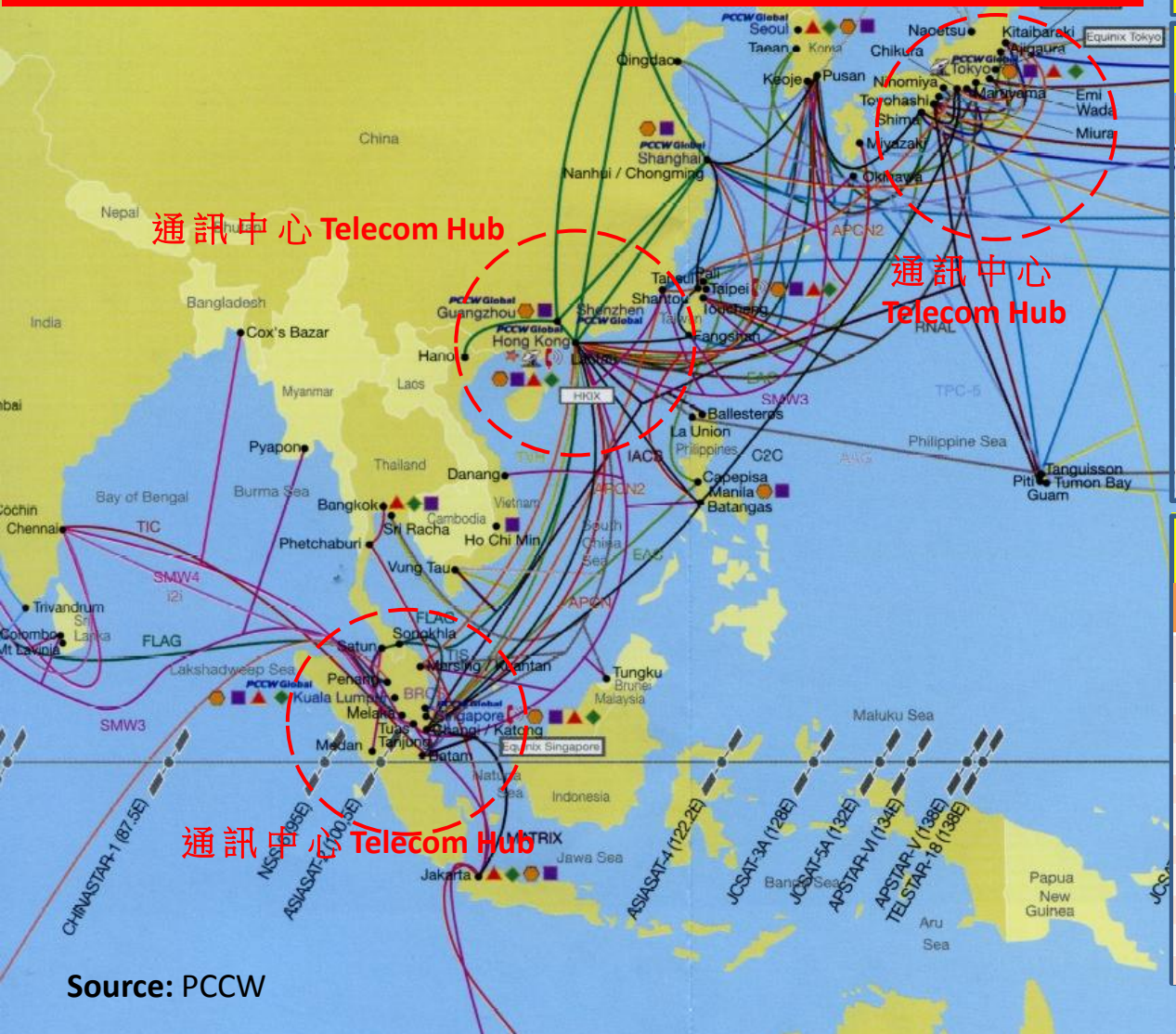
亞太區之光纖海纜圖

Fiber Optic Submarine Cables in Asia Pacific Region



Source: PCCW

當今 **2014** 年：

- 全球有 316** 條海纜
- 亞洲有 50+ 條連接世界
- 22+ 條籌劃興建中

Average Internet Connection Speed *

Country/Region	Q4 2013 Avg. Mbps	QoQ Change	YoY Change
Global (135 Countries)	3.8	5.5%	27%
1 South Korea	21.9	-1.1%	57%
2 Japan	12.8	-4.4%	14%
3 Netherlands	12.4	-0.7%	38%
4 Hong Kong	12.2	-2.6%	22%
5 Switzerland	12.0	3.8%	27%
6 Czech Republic	11.4	0.7%	30%
7 Sweden	10.5	13%	30%
8 Latvia	10.4	-6.7%	11%
9 Ireland	10.4	8.4%	59%
10 United States	10.0	2.0%	25%

Average Internet Peak Connection Speed*

Country/Region	Q4 2013 Peak Mbps	QoQ Change	YoY Change
Global (135 Countries)	23.2	30%	38%
1 Hong Kong	68.0	3.9%	16%
2 South Korea	64.4	1.3%	31%
3 Singapore	59.1	18%	56%
4 Israel	54.6	14%	68%
5 Japan	53.7	3.4%	22%
6 Taiwan	50.9	19%	74%
7 Romania	50.6	11%	15%
8 Latvia	48.8	13%	22%
9 Switzerland	44.2	15%	23%
10 United States	43.7	18%	32%

* From Akamai's Report ** From TeleGeography

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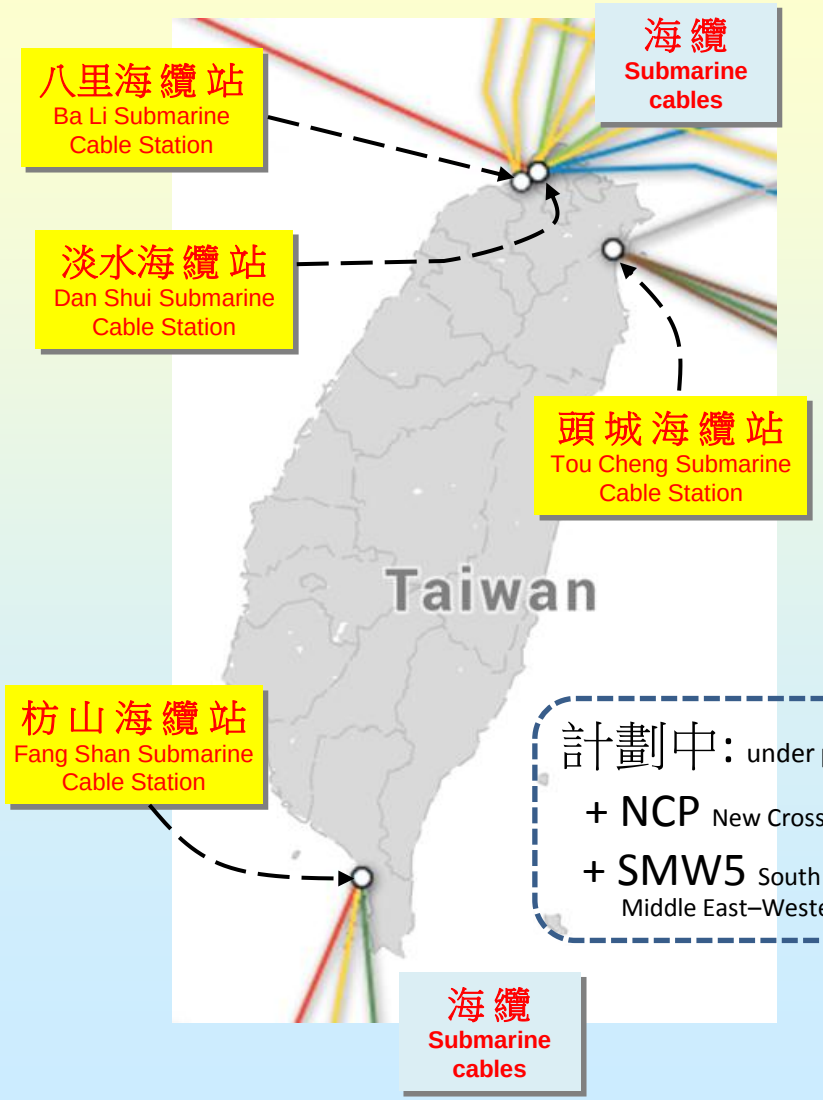
台灣光纖海纜網絡圖 (2014)
Taiwan Submarine Cable Network



台灣有 **4** 個海纜站
Taiwan has 4 cable stations

+ 淡水 Dan Shui
+ 頭城 Tou Cheng
+ 八里 Ba Li
+ 枋山 Fang Shan

有 **7** 條海纜連接世界
has 7 submarine cables connecting the World

+ SMW3 South East Asia–Middle East–Western Europe 3
+ China-US CN China-US Cable Network
+ FLAG FEA FLAG Europe Asia
+ APCN-2 Asia-Pacific Cable Network - 2
+ C2C - EAC City-to-City – East Asia Crossing
+ TSE-1 Taiwan Strait Express
+ APG (最新) Asia Pacific Gateway

計劃中: under planning

+ NCP New Cross Pacific
+ SMW5 South East Asia–Middle East–Western Europe 5

Source: TeleGeography

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台灣光纖海纜網連接世界詳圖(2014)

Detailed Map of Taiwan Submarine Cable Network Connections to the World

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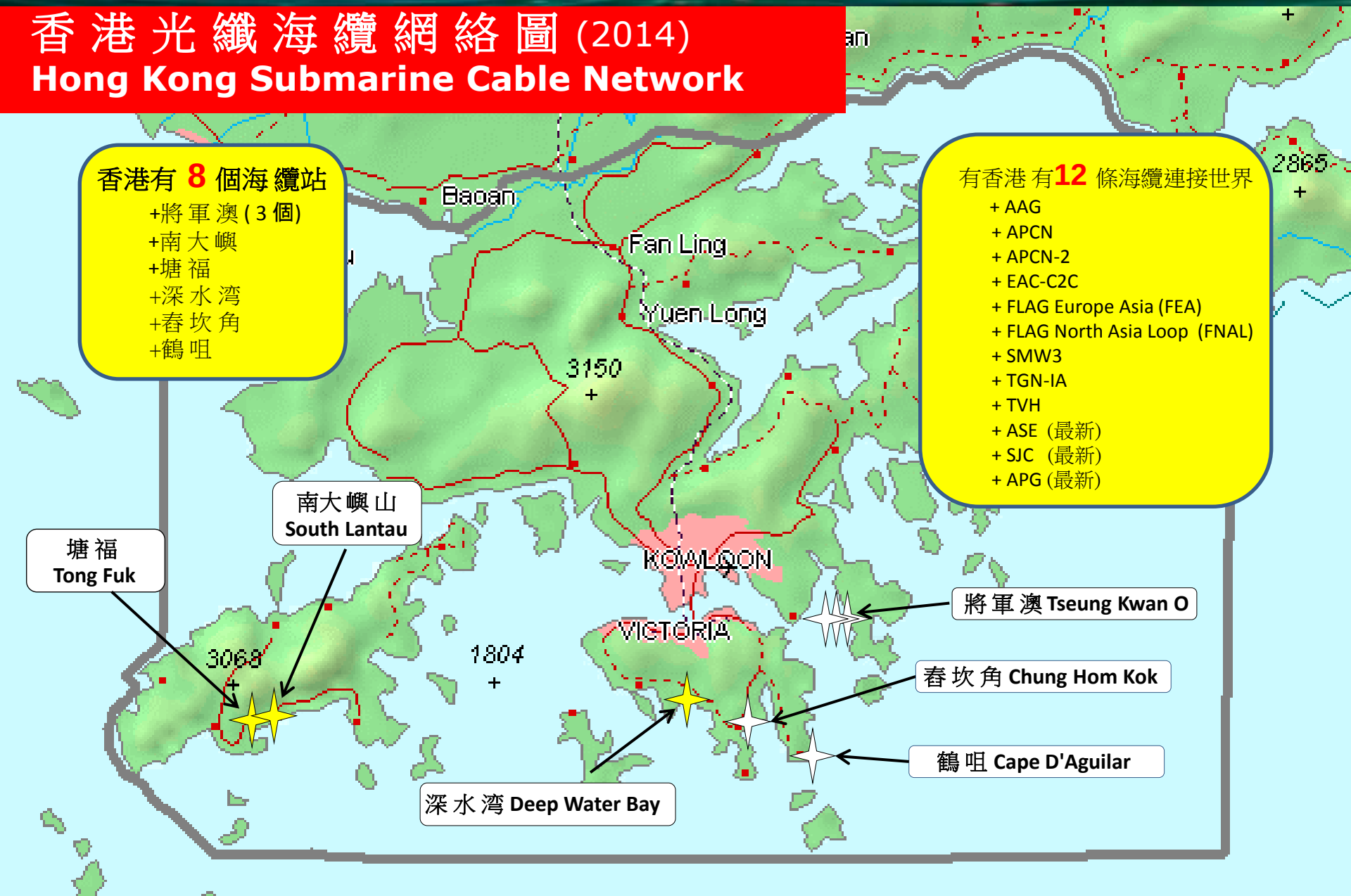
香港光纖海纜網絡圖 (2014)
Hong Kong Submarine Cable Network



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海纜系統 -- 簡單結構圖

Submarine Cable System – A Simple Schematic

海纜站 Cable Station

用户 Customers

End Users

在場點 Point of Presence(POP)

海纜站 Cable Landing Station (CLS)

Cable buried in water depth < 500M

岸邊人孔 Beach Man Hole

500M

埋在海床 Buried under seabed

鋪在海床上
Lay on seabed

海纜 Submarine Cable

中繼器/ 分叉器 Repeater/Branching Unit (BU)

前端電纜
Fronthaul Cable

後端電纜
Backhaul Cable

水平定向鑽挖 或 關節聯接之鋼管

Horizontal directional drilling (HDD) or
Articulated pipe for Protection

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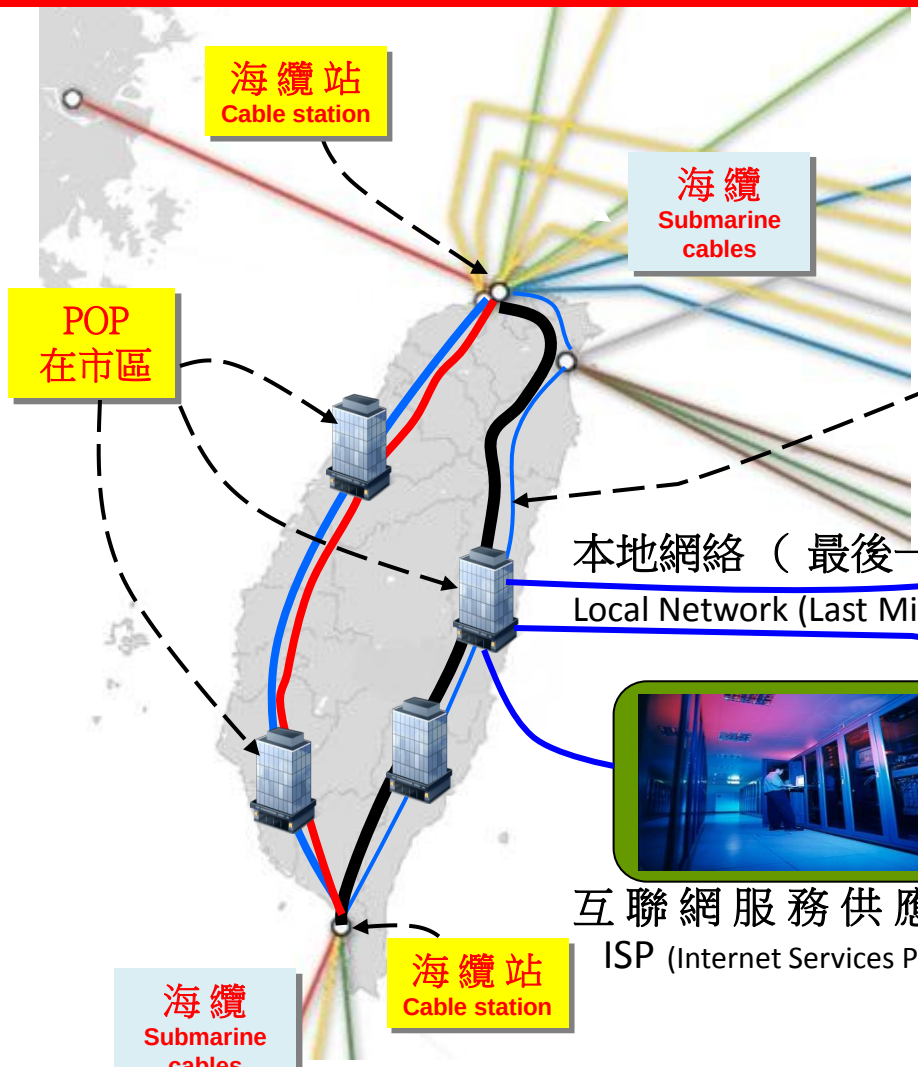
海纜與陸上網絡連接(概念圖)

Submarine Cables interconnection with territorial networks (Conceptual Diagram)



海纜站
Cable station

海纜
Submarine cables

Backhaul Cable
(with back up)
有備份之後端電纜
(由不同營運商提供)

POP
在市區

移動客户
Mobile Customers

移動營運商
Mobile Services Provider

本地網絡（最後一里)
Local Network (Last Mile)

商務客户
Business Customers

互聯網服務供應商
ISP (Internet Services Provider)

家居客户
Residential Customers

海纜站
Cable station

海纜
Submarine cables

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香港典型之海纜站與POP之連接圖
A Typical CLS and POP/NOC in Hong Kong

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亞太地區最新之光纖海纜
New Fiber Optic Submarine Cables in the Region

- **SJC** – South-east asia Japan Cable System
- **ASE** – Asia Submarine-cable Express
- **APG** – Asia Pacific Gateway

籌劃中：

- **SCAN + ASSC** – Submarine Cable Asia Network + Australia Singapore Submarine Cable
- **NCP** – New Cross Pacific Cable
- **SME - 5** – South East Asia–Middle East–Western Europe Cable

+ 這些新海纜的傳輸速度是 **40** 或 **100** Gb/s

+ 如果是 **40** Gb/s光纖海纜，系統設計時已要求之傳輸速度將來可提升至**100** Gb/s

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國際海纜系統之擁有者和主要供應商
Owners and Major Suppliers of International Submarine Cable Systems

■國際海纜系統通常由電信營運商和跨國企業共同擁有

Usually jointly owned by Telecom. Operators and Multi-national Enterprises

例子 Example

APG 擁有者

StarHub, Chunghwa Telecom, facebook, LG U+, NTT Group, GLOBAL TRANSIT, kt, VIETTEL, VTI, 中国移动通信 CHINA MOBILE, China unicom 中国联通, 中国电信 CHINA TELECOM

■遠程國際海纜系統之主要供應商

Major Suppliers of Long Haul International Submarine Cable Systems

Alcatel·Lucent, TE SUBCOM connectivity, NEC, HUAWEI MARINE NETWORKS

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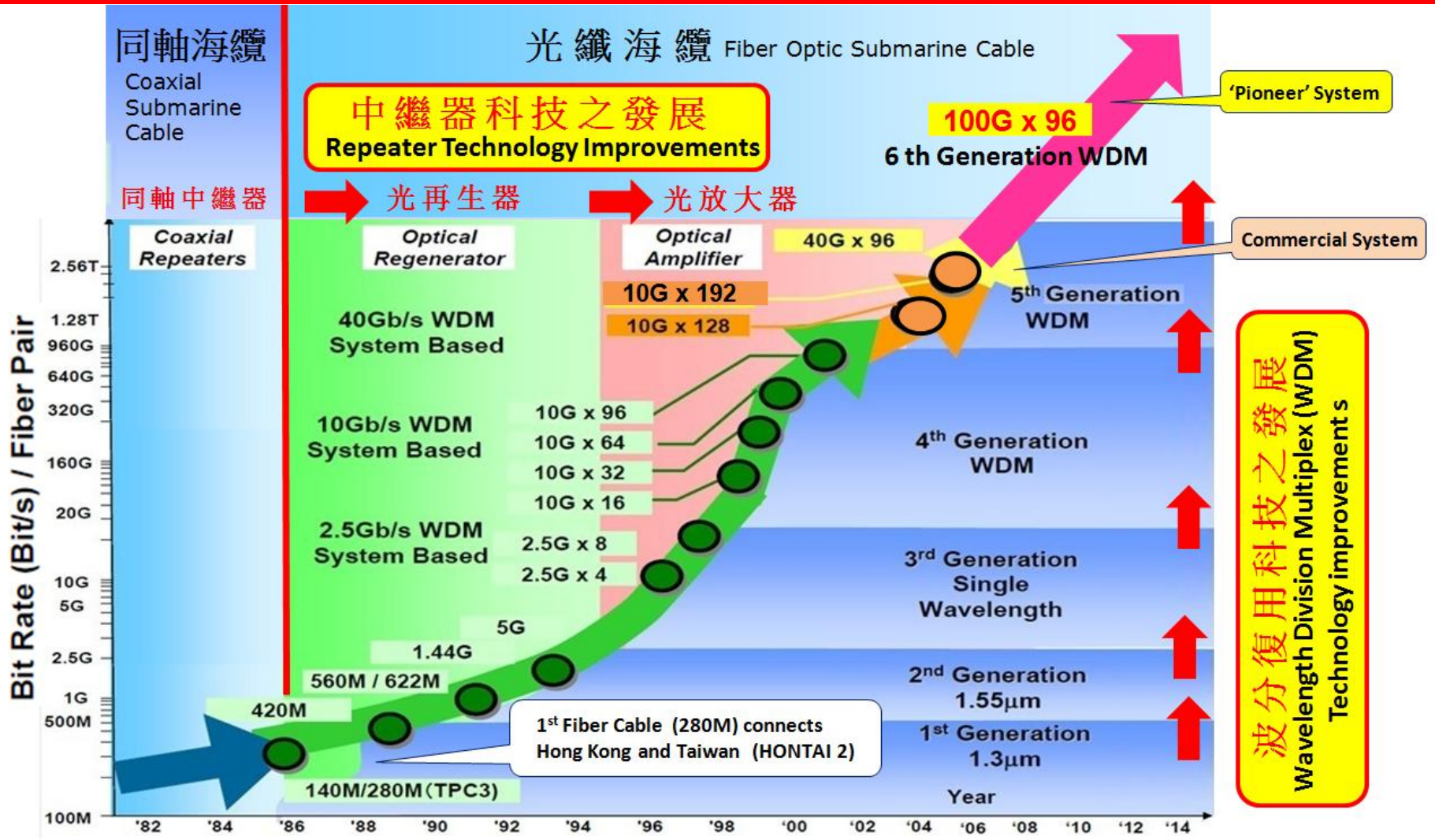
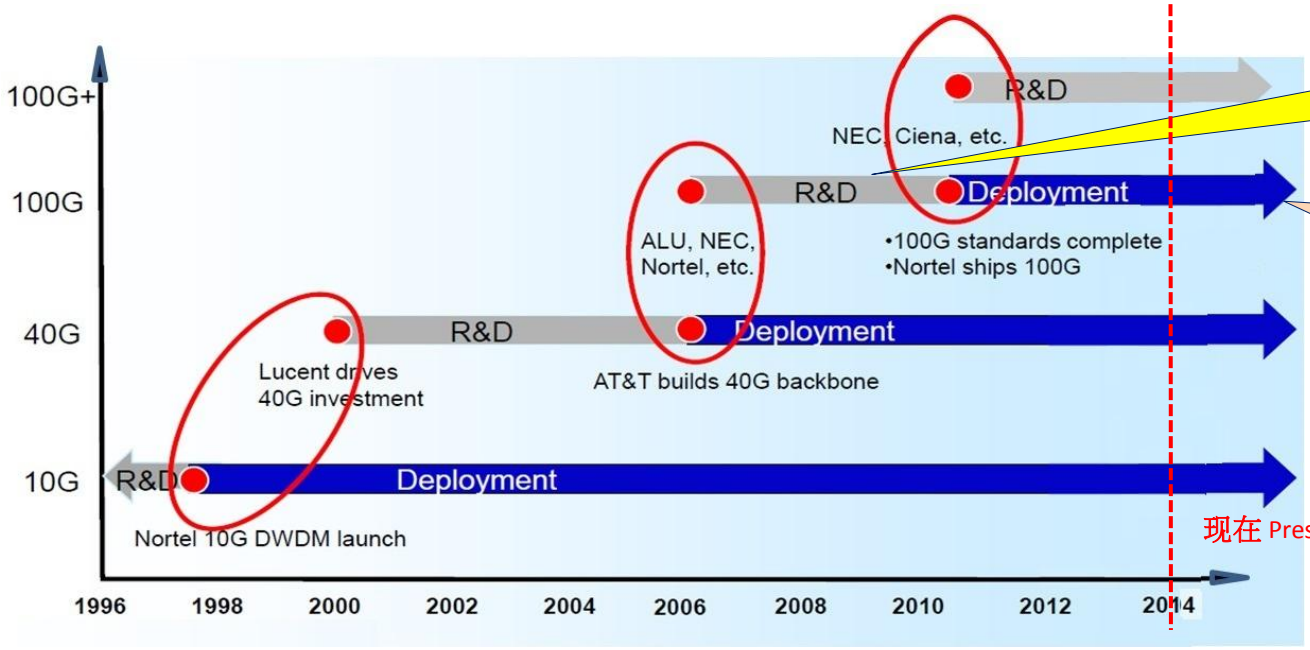
光纖海纜發展歷史 History of Submarine Cable Development



科技應用之潮流 Technology Deployment Trend

- 海纜之維修是非常昂貴及費時 Submarine cable repair is very expensive and time consuming
- 運營商喜歡採用成熟之科技 Commercial operators prefer to deploy proven technology
- 大部份新建的商用系統速度是 40 千兆比 Most new commercial systems are 40 Gbit/sec systems
- 只有少數之「先驅系統」是 100 千兆比 A few 'Pioneer' systems are 100 Gbit/sec systems



「先驅系統」 'Pioneer System'

「商業系統」 'Commercial System'

Source: OIF and Heavy Reading

•It takes 5+ years to move from hero experiments to commercial deployments

「先驅系統」大概要五年多時間才能發展至「商業系統」

第一條及最長的商業100千兆比系統測試
The First and Longest Commercial 100G Submarine Cable System Trial

新聞公報 **Press Release**

PACIFIC CROSSING®
an NTT Communications Company

infinera®
what THE NETWORK will be

11 October 2011

(WEB HOST INDUSTRY REVIEW) -- Digital optical networking systems provider Infinera (www.infinera.com) and transpacific submarine cable system operator Pacific Crossing (www.pc1.com) announced on Tuesday they have completed a 100 Gbs subsea trial.

The subsea trial spanned more than 5,903 miles on Pacific Crossing's PC-1 fiber from California to Japan.

商業第一條及最長的**100** 千兆比系統之成功測試

This is the first and longest successful 100 Gbs trial performed across the Pacific delivering digital coherent transmission, according to the press release.

* Pacific Crossing is a subsidiary of NTT Japan

科技之挑戰 Technology Challenges
(100千兆比系統)

科技之挑戰 Technology Challenges

- 色散(CD) 容忍度降低
  Chromatic Dispersion (CD) tolerance decreases
- 偏振模色散 (PMD) 容忍度降低
  Polarization Mode Dispersion tolerance decreases
- 光信噪比 (OSNR**) 容忍度降低
  OSNR tolerance decreases
- 非線性效應容忍度降低
  Non-linear effects tolerance decreases

100千兆比系統
100 Gbit/sec* System

所需之科技改良(傳輸減損補償)
Technology Improvements Required
(in Impairments Compensation)

	10Gbps	40Gbps	100Gbps
色散 CD	1	x16	**x100**
偏振模色散 PMD	1	x4	**x10**
光信噪比 ONSR**	1	+6db	**+10db**
非線性效應 Non-linear Effects	1	x4	**x10**

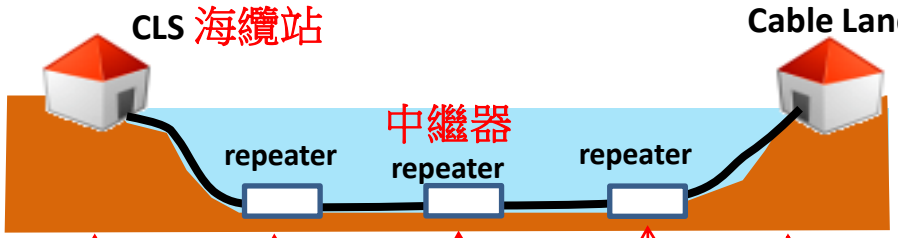
10千兆比系統 10 Gbit/sec System
40千兆比系統 40 Gbit/sec System

香港城市大學 City University of Hong Kong

* **Gbit/sec**: Giga (10^9) bit per second 千兆比
** **OSNR:** Optical Signal to Noise Ratio

促成之科技 Enabling Technologies

(由 40 千兆比 提升 至 100 千兆比系统 from 40 Gb/s to 100 Gb/s system)



100 千兆比系統
100Gbit/sec System

- 雙極偏振 Dual Polarization
- QPSK*調制方案 QPSK Modulation Scheme
- 優化光學放大器 Enhanced Optical Amplifier
- 前向糾錯（FEC）加軟判決譯碼
  Forward Error Correction with Soft-Decision Decoding
- 傳輸損減的數域均衡
  Transmission Impairments Equalization in Digital Domain
- 數字相干解調 Digital Coherent Demodulation

10 千兆比系統 10Gbit/sec System
40 千兆比系統 40Gbit/sec System

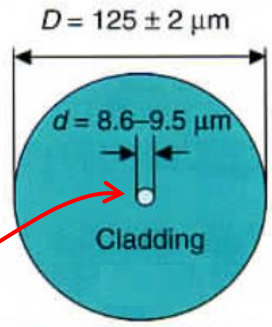
香港城市大學 City University of Hong Kong

***QPSK:** Quadrature Phase Shift Keying
正交相移鍵控

國際海纜系統之傳輸速率
Transmission Rate of International Submarine Cable

- 長程系統：實際最多有 **8 對** 光纖
  For Long Haul System practically only has a maximum of 8 fiber pairs
- 原因: 受所需的**機械強度**及中繼器**高壓供電**所限制
  Reasons: limited by the mechanical strength required & high voltage power feed for repeaters
- 每條光纖之傳輸速率: Transmission Rate per fiber:

每條光纖有多少光波 **No. of wavelengths per fiber**	**X**	每個光波之傳輸速率 **Tx. Rate per wavelength**	**=**	每條光纖之傳輸速率 **Tx. Rate per fiber**



Single Mode Fiber

每條光纖實際最多傳輸約 **96** 個光波
about 96 wavelengths per fiber maximum

決定於 :Depends on:
+長度 length
+ 水下器材 wet plant (such as OADM)

x **40 Gb/s*** = **3.84 Tb/s****

每秒傳 **~102** DVD 光碟之內容
Contents of ~102 DVD disks per sec.

x **100 Gb/s** = **9.60 Tb/s**

每秒傳 **~255** DVD 光碟之內容
Contents of ~255 DVD disks per sec.

一仟伍百萬電話線路
15 million telephone circuits

* **Gbit/sec**: Giga (10^9) bit per second 千兆比

** **Tbit/sec**: Tera (10^{12}) bit per second 千千兆比

國際光纖海纜工程
主要工序
International Submarine Cables Construction
Key Processes

(For Academic Reference Only)

i.e. with no direct or indirect business implications

建設光纖海纜系統
(例子)

Construction of Fiber Optic Submarine Cable System (An Example)

建設海纜所面對之挑戰 Challenges in International Submarine Cable Construction

物 理 Physical

- 地震 Earthquake
- 火山 Volcanoes
- 捕魚船 Fishing boat
- 海床狀況 Seabed conditions ....

政 治 Political

- 領土爭端 Territorial Disputes
- 橫 跨 Crossing:
  - +軍事區 military zone
  - +航道 ship lanes
  - +油田/油管 oil field/pipes
  - +其他海纜 other cables ....

Challenges

技 術 Technical

- 系統設計 System Design
- 水下設備之可靠性 Reliability of Wet Plant
- 承包商的經驗 Experience of Contractors
- 敷設海纜時之天氣 Weather during cable Laying

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建設國際海纜主要工序
Key Processes in International Submarine Cable Construction

桌面(理論)研究 Desk Top (Theoretical) Study

overcomes 克服

物理挑戰 Physical Challenges

牌照申请
Licenses & Permits Application

overcomes 克服

政治挑戰 Political Challenges

施工 Project Implementation

+ 海事測量 Marine Survey
+ 系統設計及製造 System Design & Plants Manufacture
+ 地上及海上之安装 Land & Marine Installation

overcomes 克服

技術挑戰 Technical Challenges

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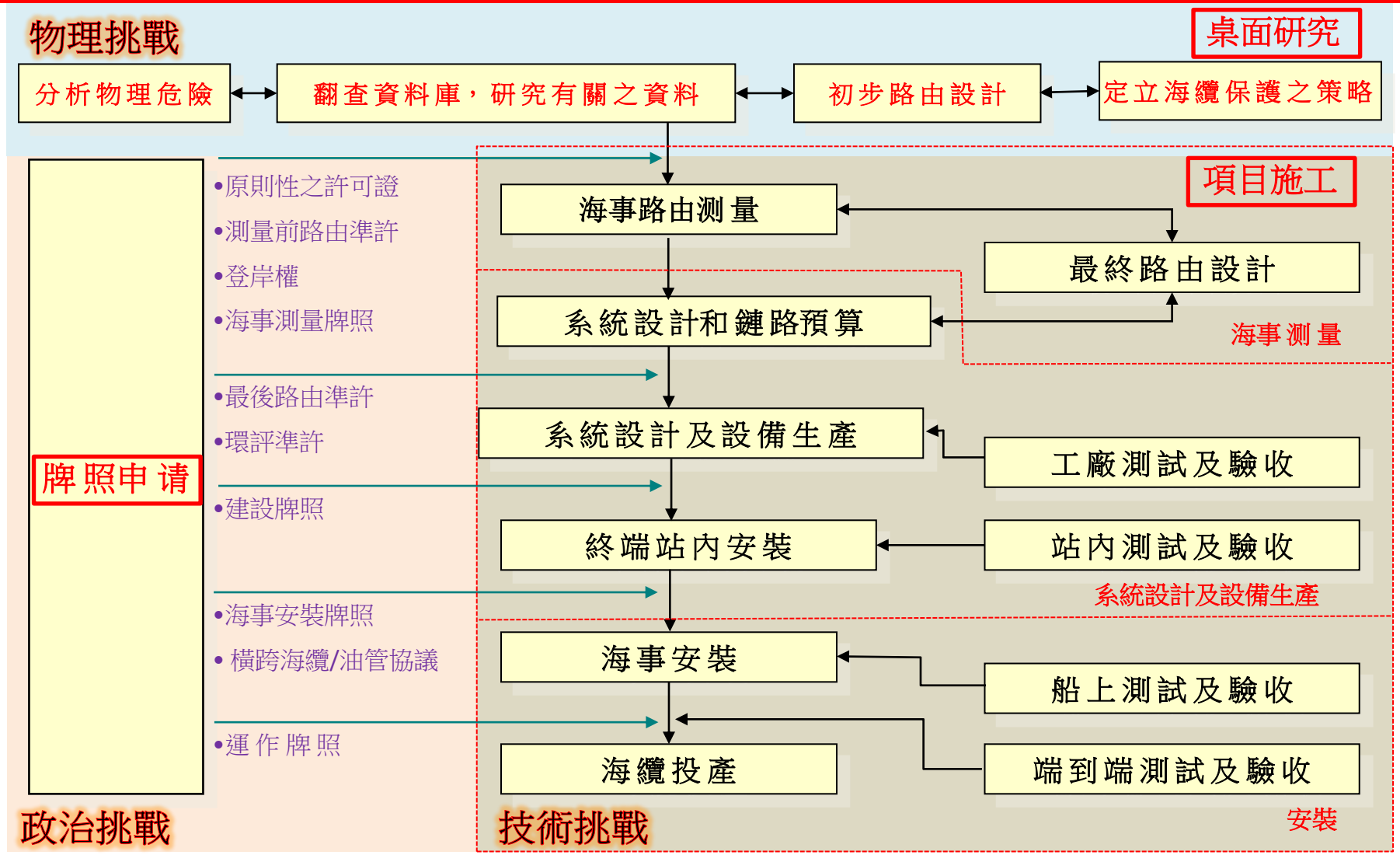
建設國際海纜詳細工序

Detailed Processes in International Submarine Cable Construction

(Reference Materials)
(參考資料)



桌面(理論)研究
Desk Top (Theoretical) Study

牌照申请
Licenses & Permits Application

施工 Project Implementation
+海事測量 Marine Survey
+系統設計及製造 System Design & Plants Manufacture
+地上及海上之安裝 Land & Marine Installation

桌面(理論)研究
Desk Top (Theoretical) Study

- 4個主要工序：3 key Processes
  - + 分析海纜建設之物理危險 Analyze Physical Risks in submarine cable construction
  - + 翻查資料庫，詳細研究有關之資料 Access data bases & study in details related information
  - + 初步路由之設計 Preliminary Cable Route Design
  - + 定立海纜保護之策略 Set Up Cable Protection Strategy

- 要聘請專業海事測量公司作研究
  need to employ professional Marine Surveyor to conduct the study

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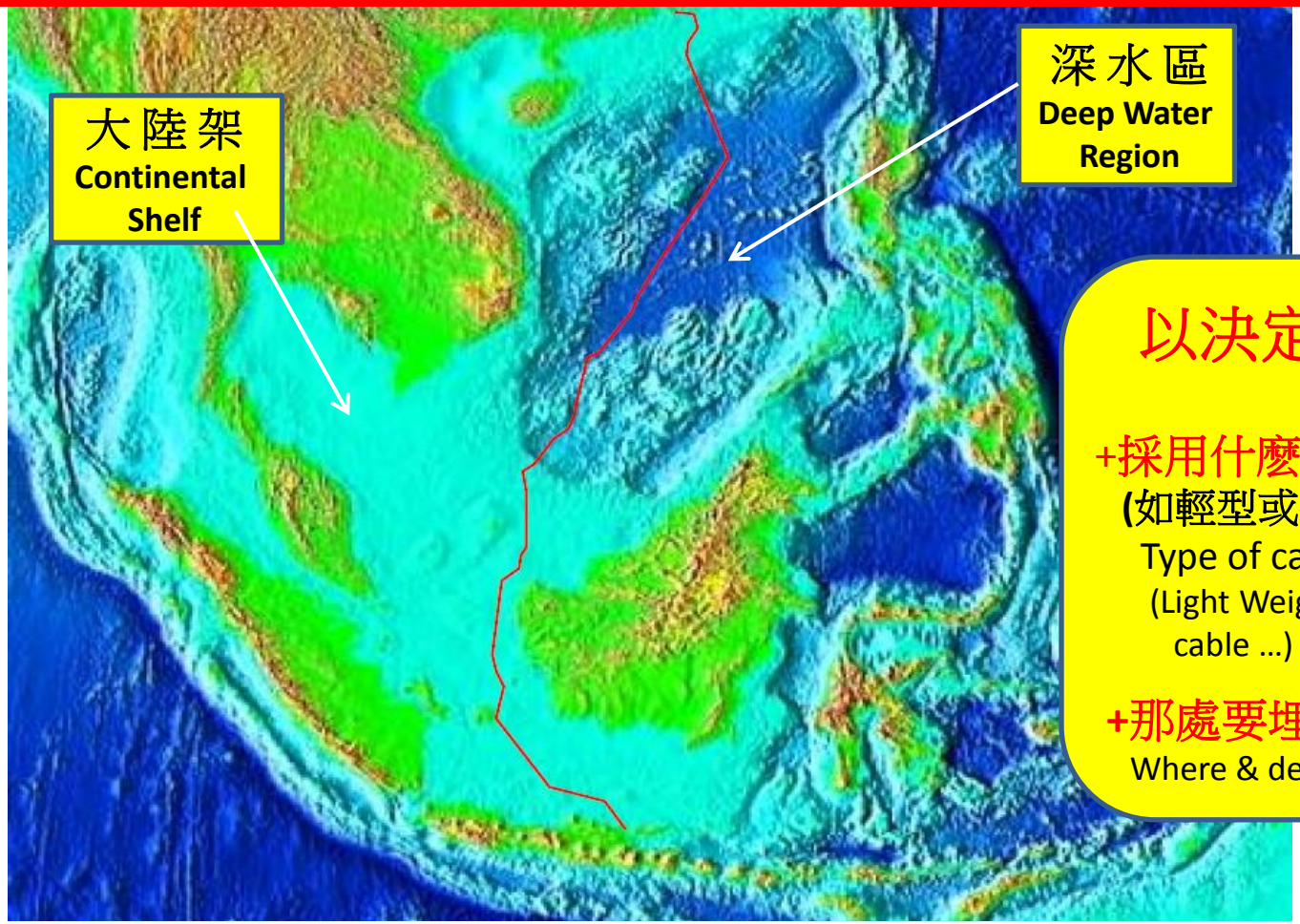
分析海纜建設之十大物理危險

Analyze 10 Typical Physical Risks - in submarine cable construction

- 火山 Volcanoes: 100+ volcanoes in South China Sea
- 地震 Earthquakes: 200+ earthquakes happen per year in the region
- 海床之斜坡及高山 Steep slope and seamount on seabed
- 損磨性之海床及水下急流 Abrasive seabed and undersea currents
- 漁場及船舶停泊處 Fishing grounds and anchorage areas
- 海纜及油管之交會 Cable crossings and pipeline crossing
- 油氣田之開發區 Oil or Gas Exploration Block
- 海上航道 Sea Lane Crossings
- 軍事區及佈雷區 Military zone and minefields
- 海盜 Piracy

研究路由附近之海床地形及物理特質
Study Topography and Physiographic Features of Seabed (Along the Proposed Cable Route)



以決定:Determine:

+採用什麼類型之海纜
(如輕型或裝甲海纜)
Type of cable used
(Light Weight or armored cable …)

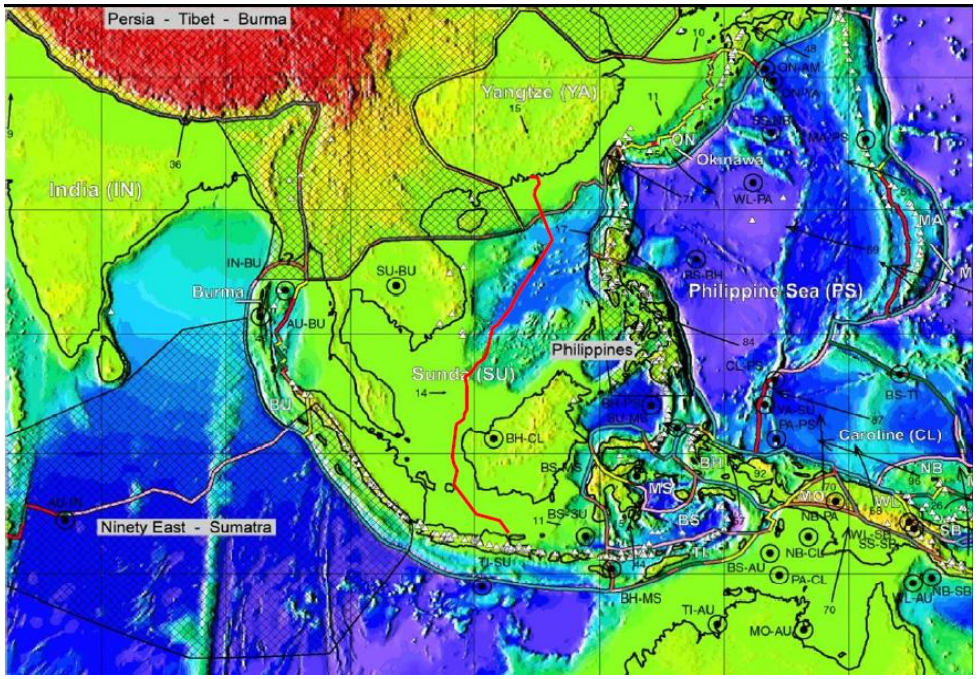
+那處要埋藏海纜及其深度
Where & depth of cable burial

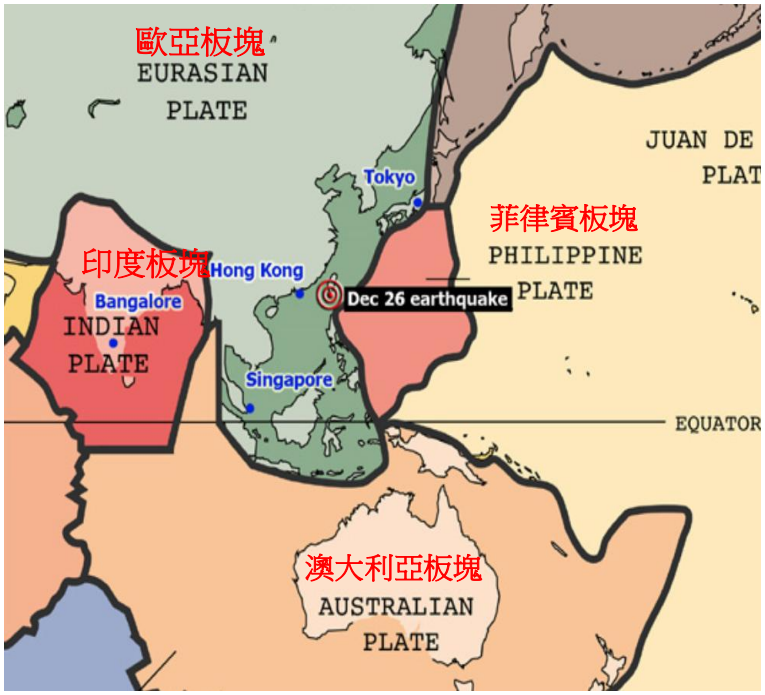
Source: EGS

*Topography: is the study of Earth's surface shape and features

研究路由所經之地層板塊
Study Tectonic Plates (along proposed Cable Route)

- 不在地層板塊邊鋪設海纜
  Avoid laying cable along the edge of tectonic plates

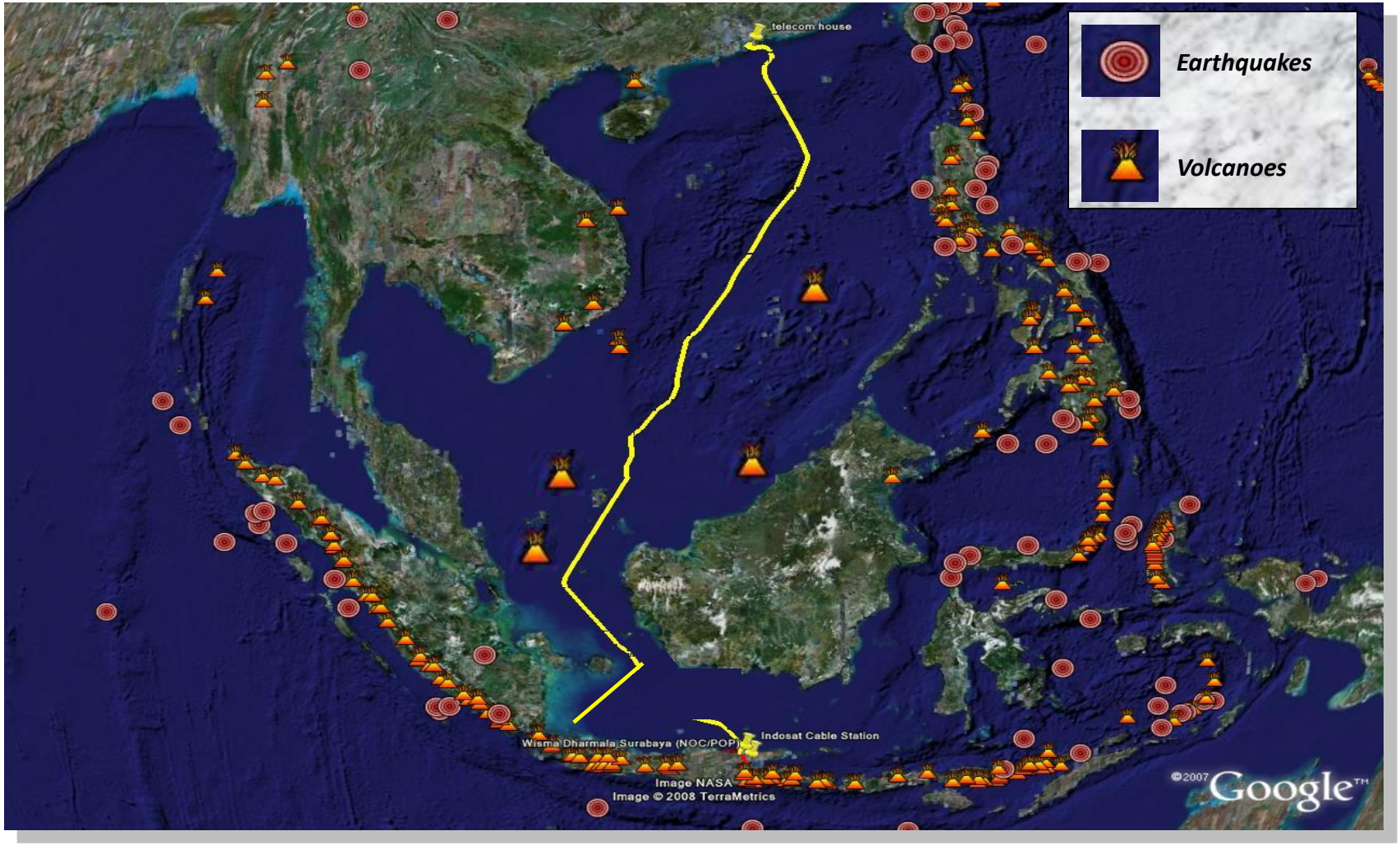




Source: EGS

Tectonic plates : are pieces of the Earth's crust

研 究 區 域 內 之 火 山
Study Volcanoes (in the region)



Source: Google Earth

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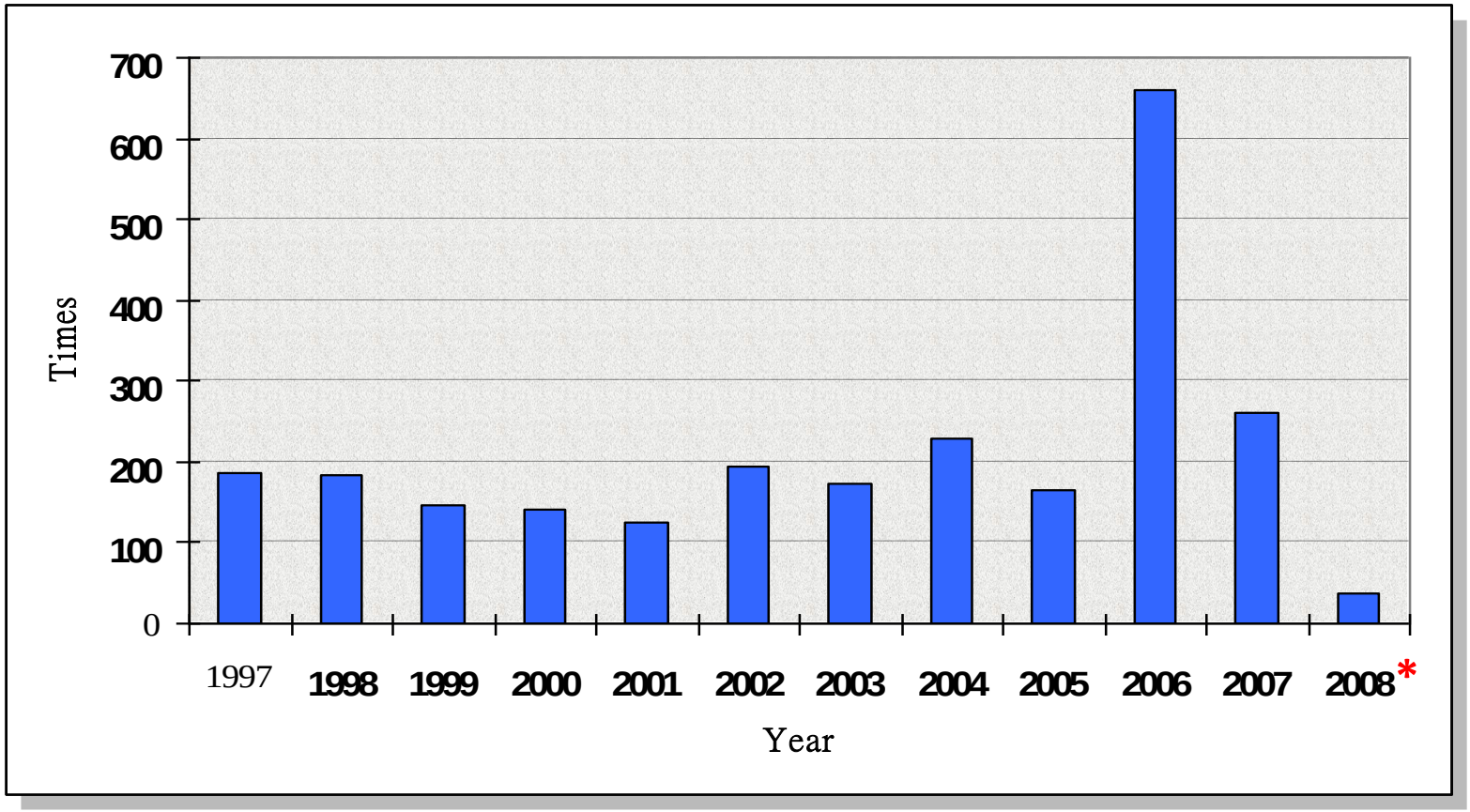
分析地震之數據
Analyze Earthquakes Statistics

- Earthquake times VS year in a radius of 800km of Indonesia landing site during 1997 - 2008

* Figures up to February only



Source: http://neic.usgs.gov/neis/epic/epic_circ.html

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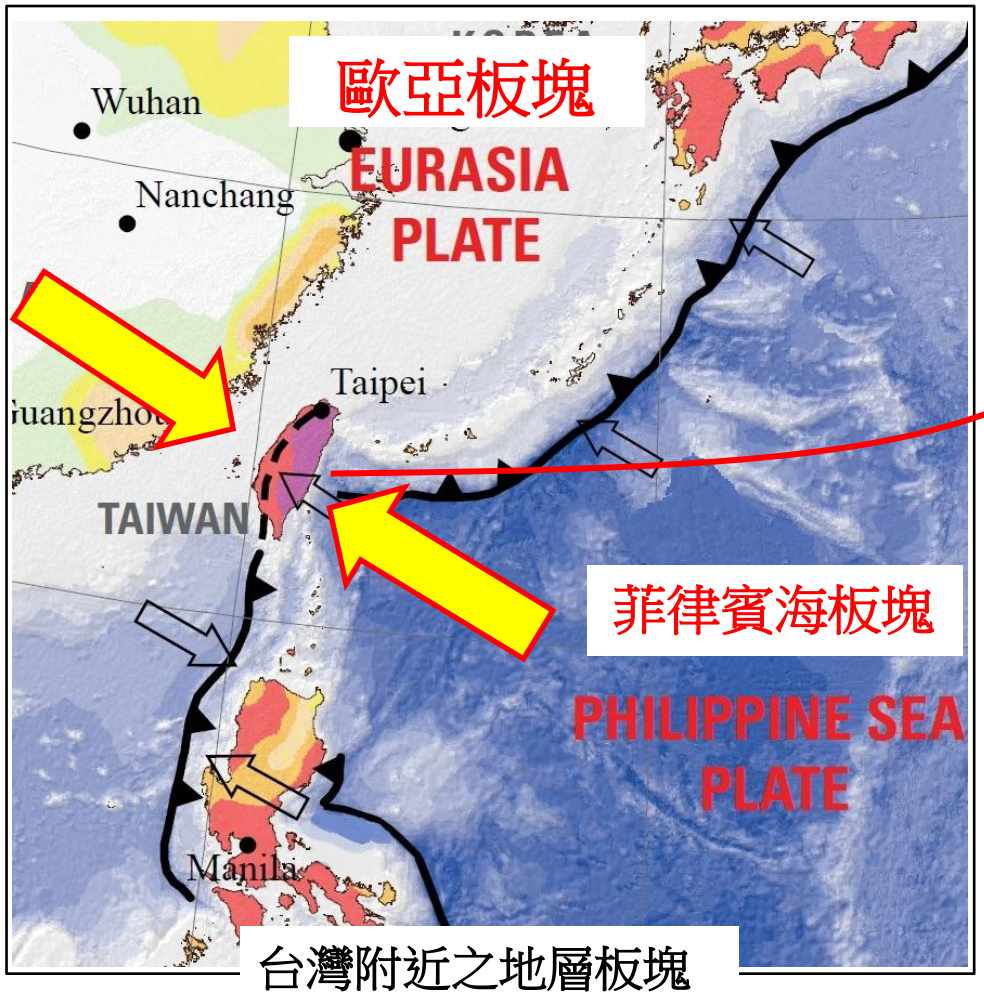
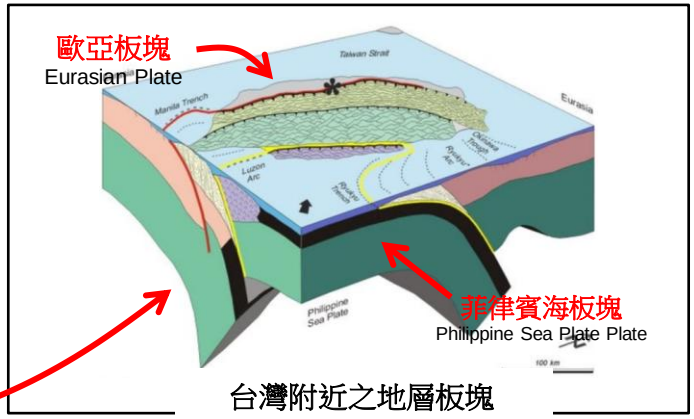
台灣附近之地層板塊與海纜

Tectonic Plates and Cable Submarine Cable near Taiwan



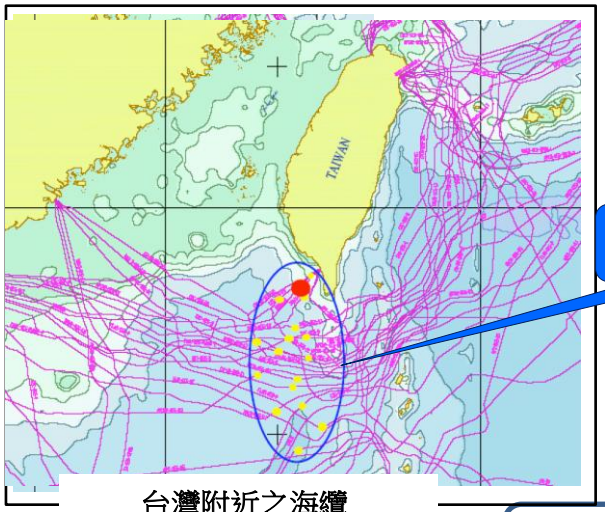
台灣附近之地層板塊

Tectonic Plates near Taiwan



台灣附近之地層板塊

Tectonic Plates near Taiwan

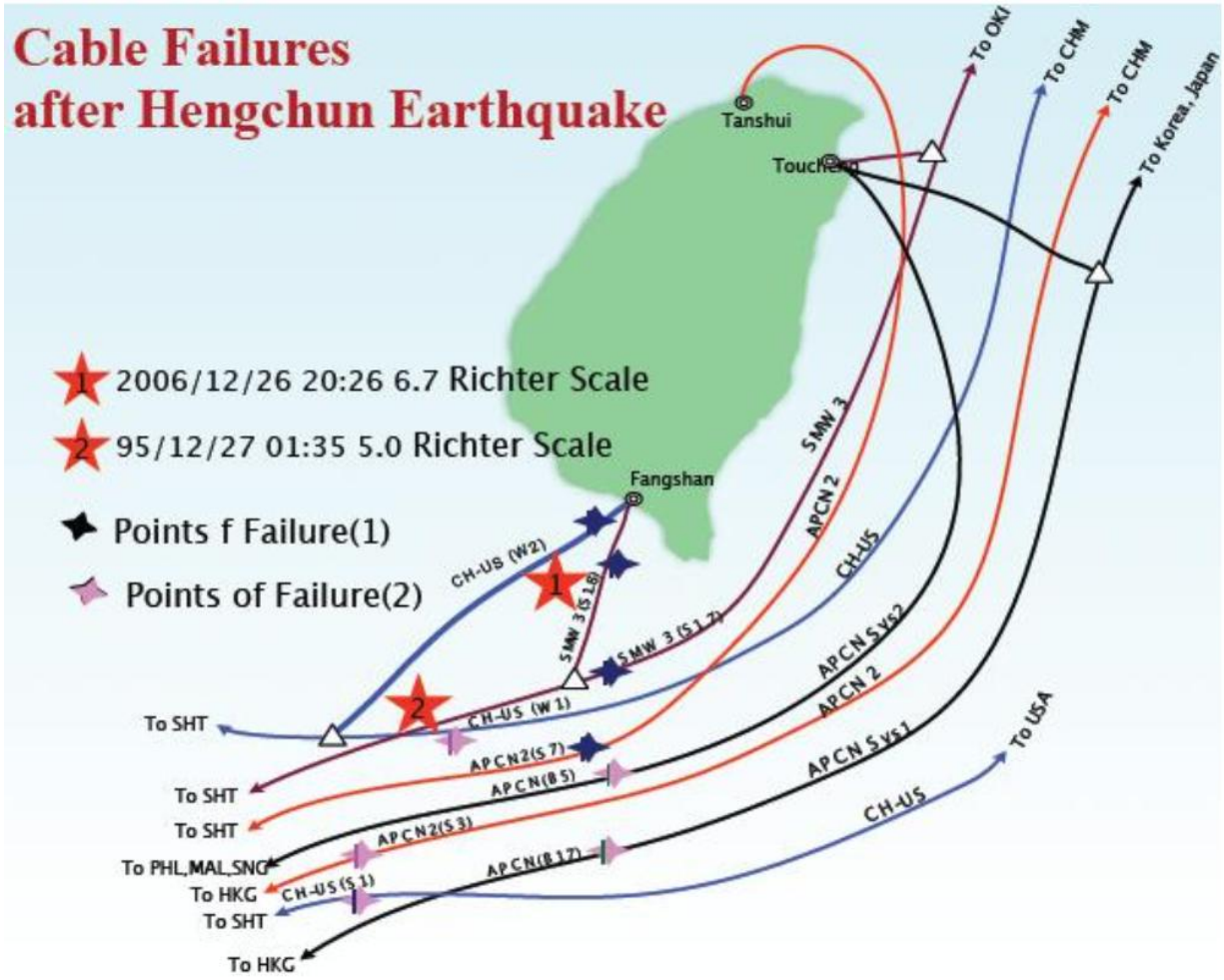


台灣附近之海纜

Submarine Cables near Taiwan

Professor Peter KC Yu's
Public Technical Presentation

地震對台灣附近海纜之影響
Impact of Earthquake to Submarine Cables near Taiwan



2006/12/26 恆春地震

8 條海纜在**18** 處切斷

- APCN, 2 cuts
- APCN-2, 2 cuts
- C2C, 3 cuts
- China-US CN, 3 cuts
- EAC, 3 cuts
- FLAG FEA, 1 cut
- FNAL/RNAL, 2 cuts
- SMW3, 2 cuts

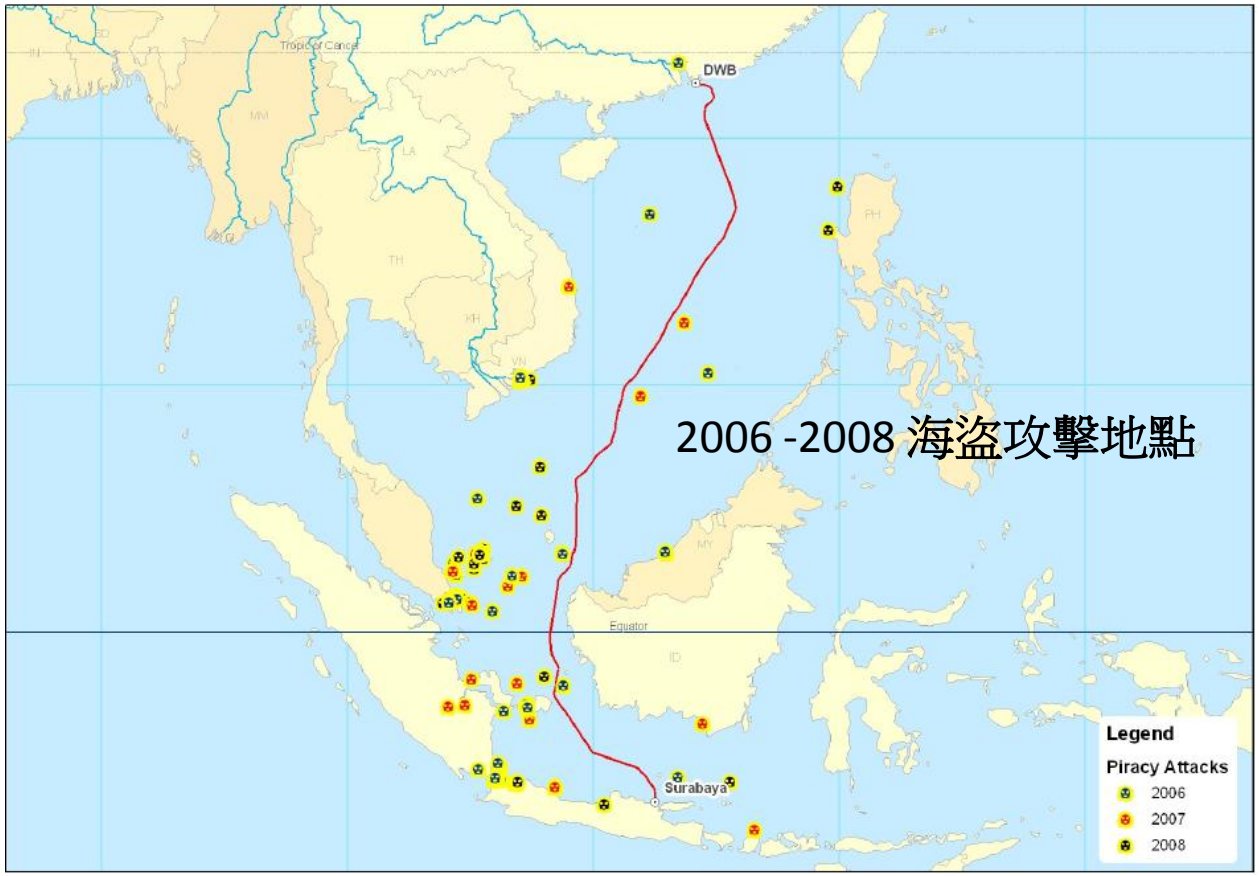
Source: PCCW

地震對台灣附近海纜之影響
Impact of Earthquake to Submarine Cables near Taiwan

- **2006 年 12 月恆春地震，亞太區通訊大受影響**
  2006 December, Taiwan Hengchun Earth Quake greatly affected communications in Asia Pacific area

- **需時超過 50 天才能完全復修**
  Took more than 50 days for full restoration

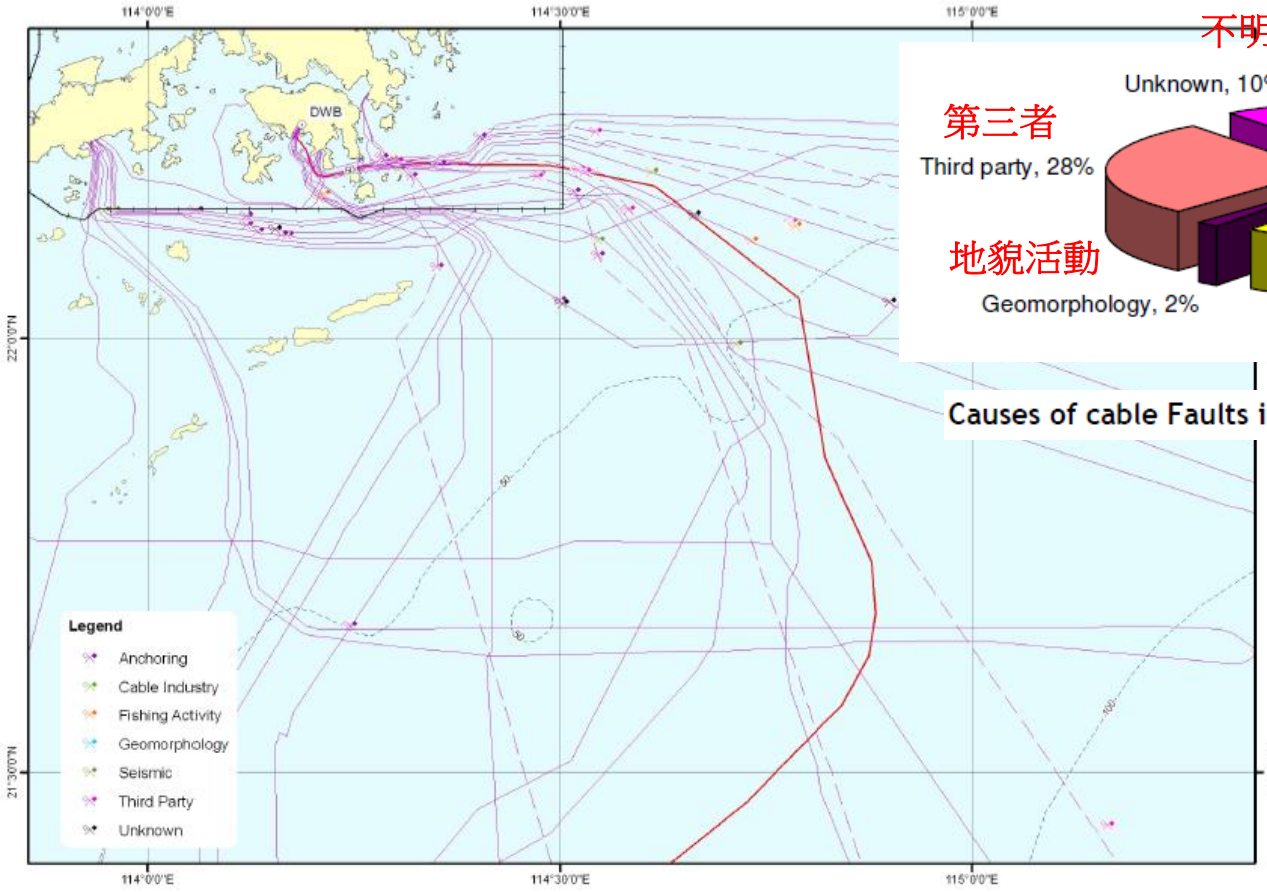
研究海盗之威脅
Study Piracy Threats

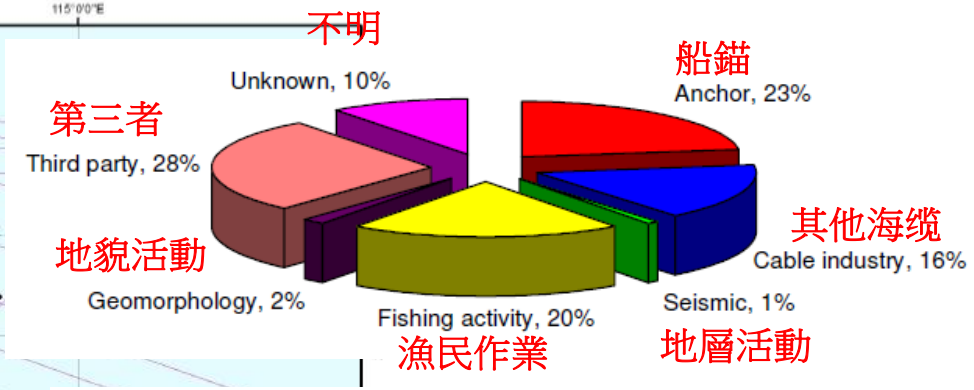


Locations of Piracy Attacks in South China Sea, 2006-2008

Source: EGS

研究區內海纜損壞之資料
Study Cable Faults Data in the Region





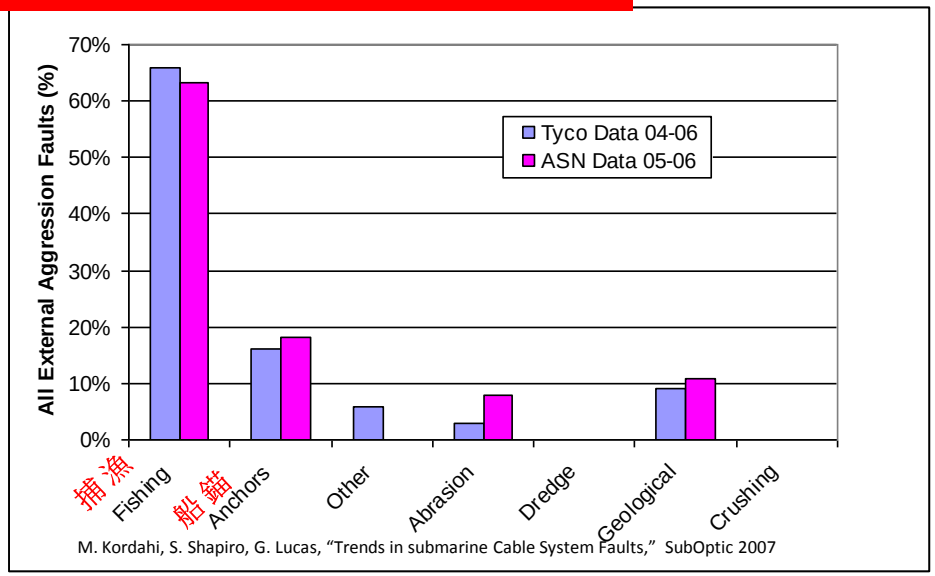
- Anchor 船錨
- Cable industry 其他海纜
- Seismic 地震
- Fishing activity 漁民作業
- Geomorphology 地貌活動
- Third party 第三者
- Unknown 不明

Source: EGS

* **Seismic:** related to earthquake

* **Geomorphology:** study of land or sea formation process

研究漁民作業及船錨之威脅
Study Fishing & Anchoring Threats



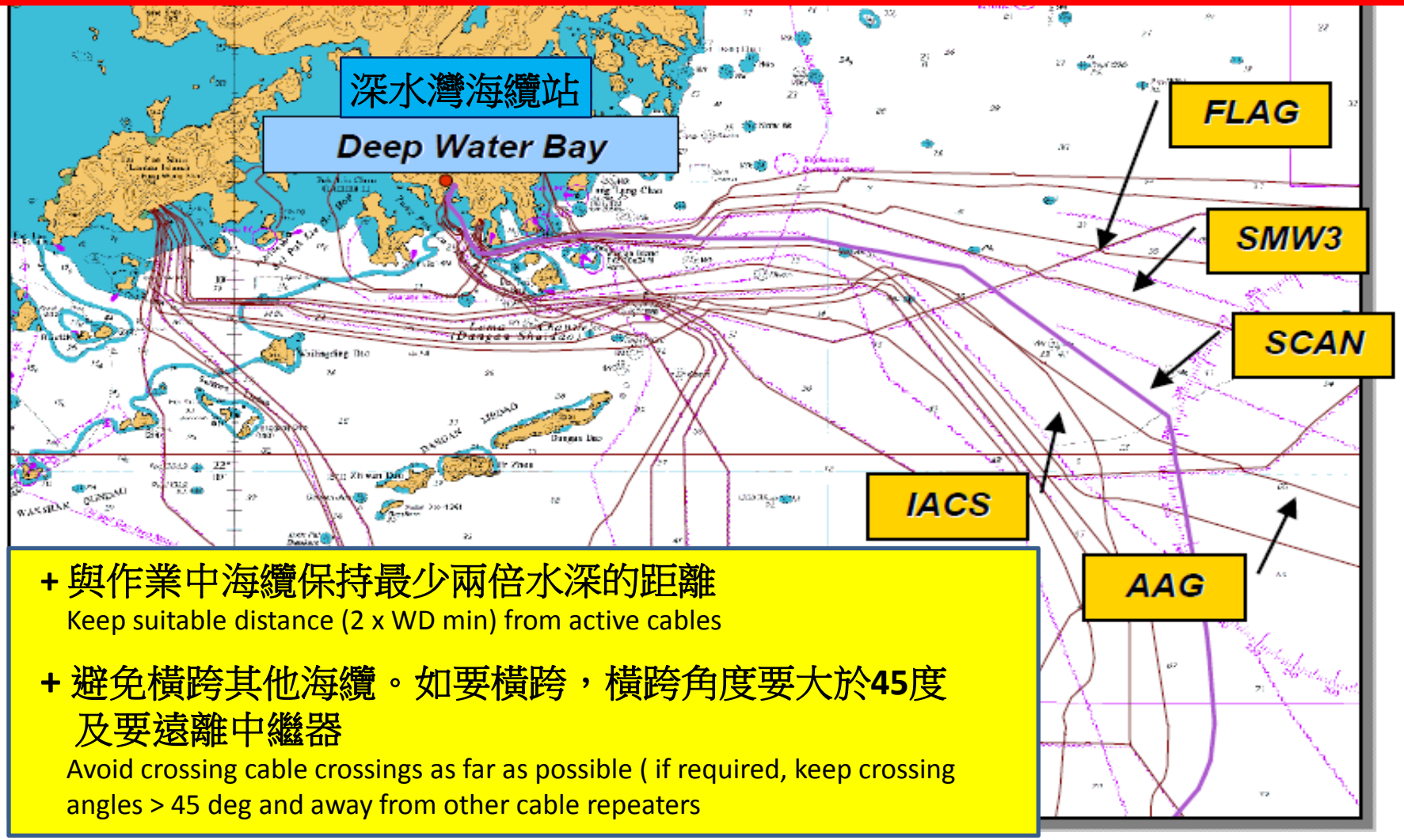
- 漁民作業及船錨是海纜安全之最大威脅
  Fishing and anchoring pose the greatest risk to cable security
- 埋藏海纜是最有效及最經濟之保護方法
  Cable burial remains the most effective and economical method of protection against these threats.

(For Academic Reference Only)

i.e. with no direct or indirect business implications

研究接近香港路由 -- 與其他海纜之距離

Study Cable Route to Hong Kong -- distance in relation to existing cables



+ 與作業中海纜保持最少兩倍水深的距離
  Keep suitable distance (2 x WD min) from active cables

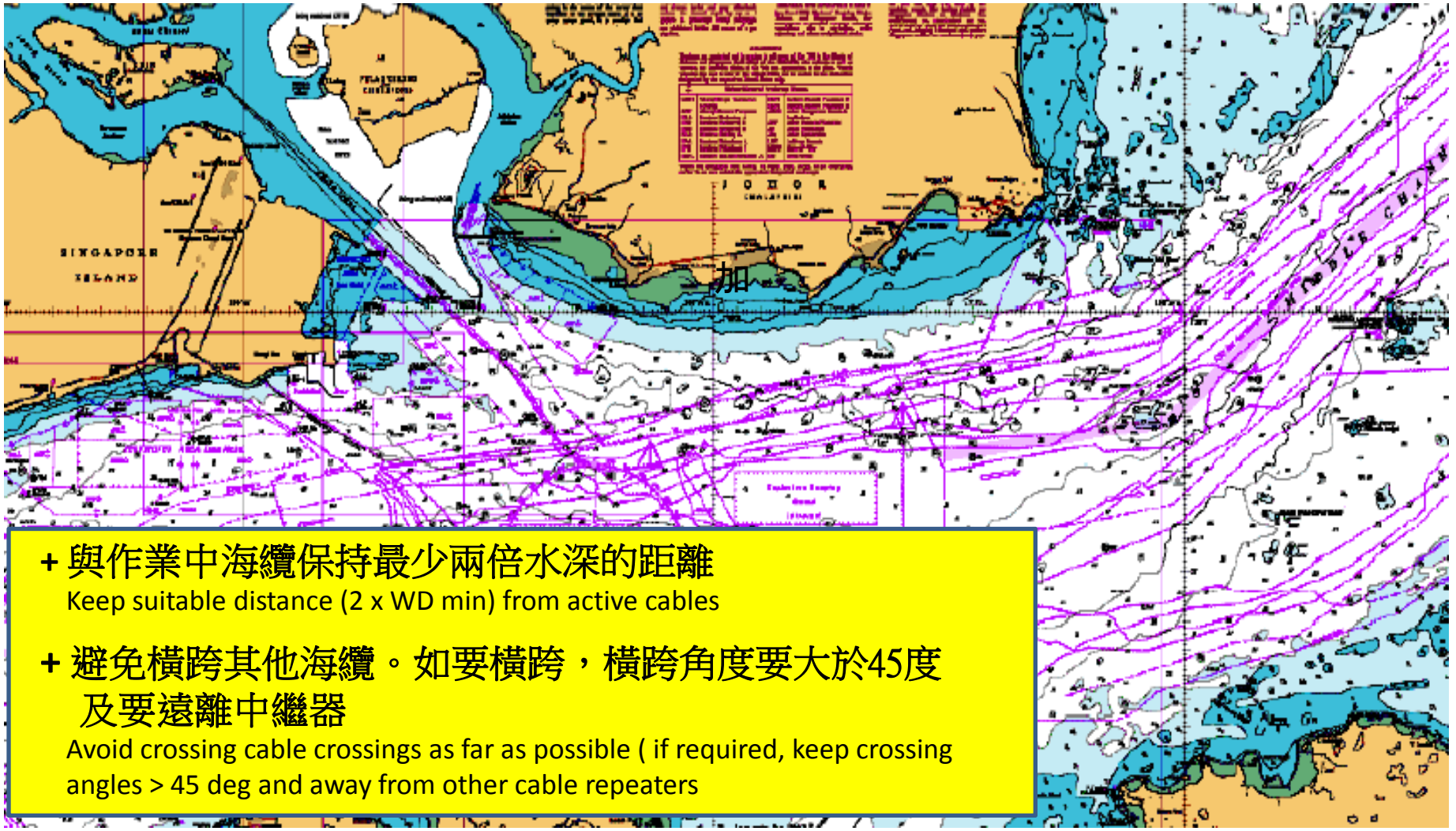
+ 避免橫跨其他海纜。如要橫跨，橫跨角度要大於45度及要遠離中繼器
  Avoid crossing cable crossings as far as possible (if required, keep crossing angles > 45 deg and away from other cable repeaters

(For Academic Reference Only)

i.e. with no direct or indirect business implications

研究接近新加坡路由 -- 與其他海纜之距離

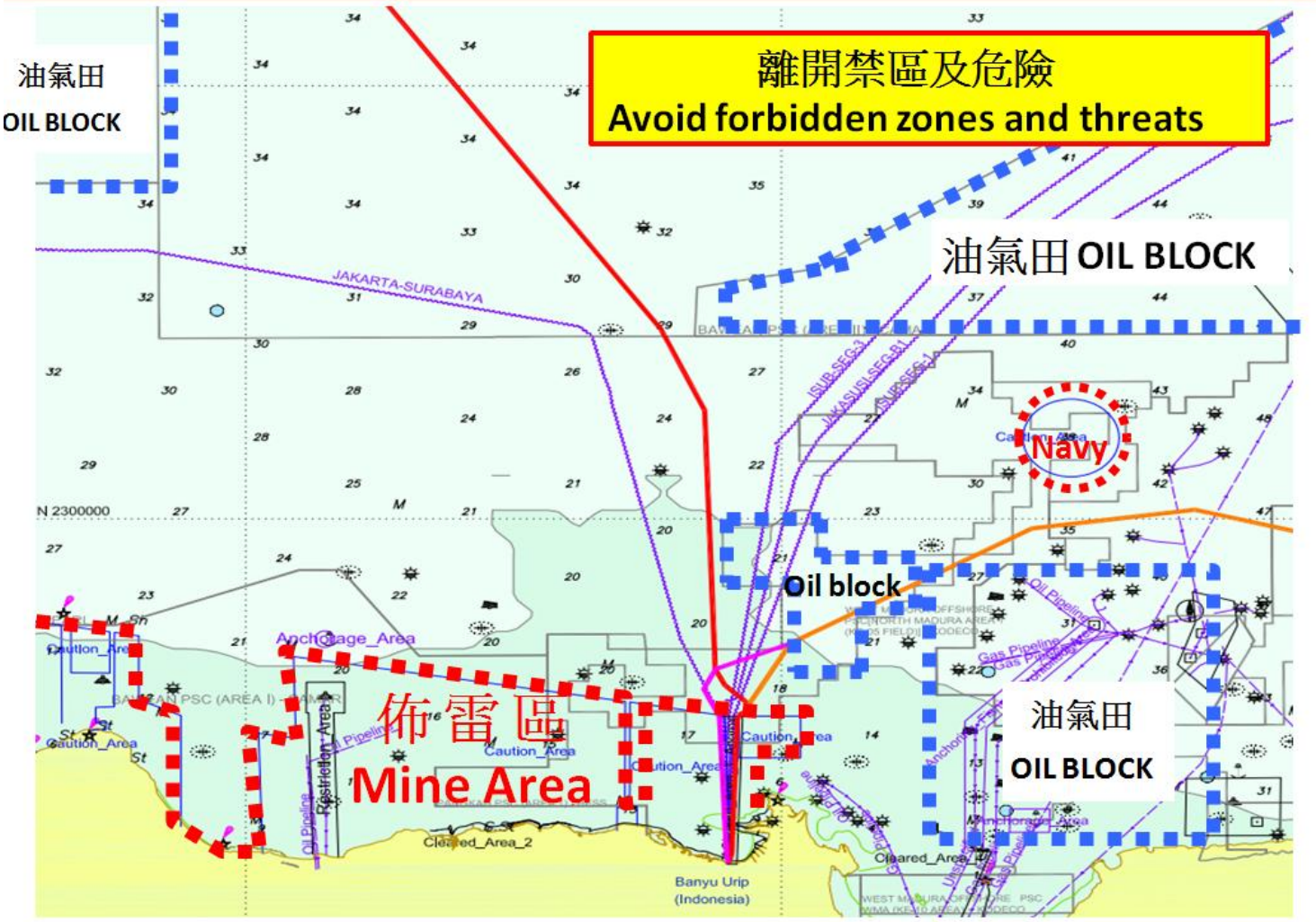
Study Cable Route to Singapore -- distance in relation to existing cables



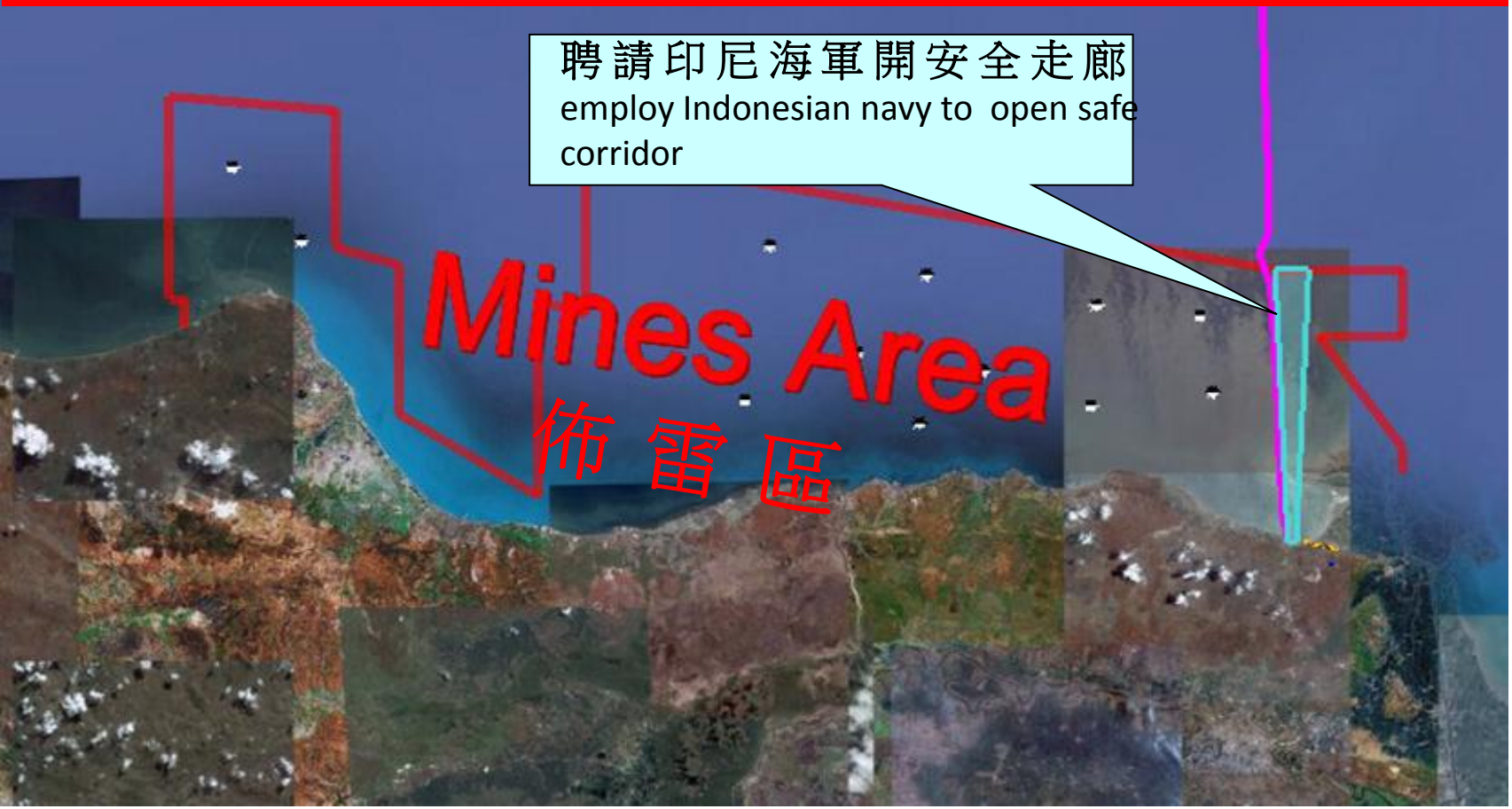
+ 與作業中海纜保持最少兩倍水深的距離
  Keep suitable distance (2 x WD min) from active cables

+ 避免橫跨其他海纜。如要橫跨，橫跨角度要大於45度及要遠離中繼器
  Avoid crossing cable crossings as far as possible (if required, keep crossing angles > 45 deg and away from other cable repeaters

研究接近印尼之路由
Study Cable Route to Indonesia



印尼登岸處要橫跨佈雷區
Crossing Minefield at Indonesia Landing



(For Academic Reference Only)

i.e. with no direct or indirect business implications

研究路由横跨主要航道

Study Cable Routing in Crossing Archipelagic Sea Lane (ASL)

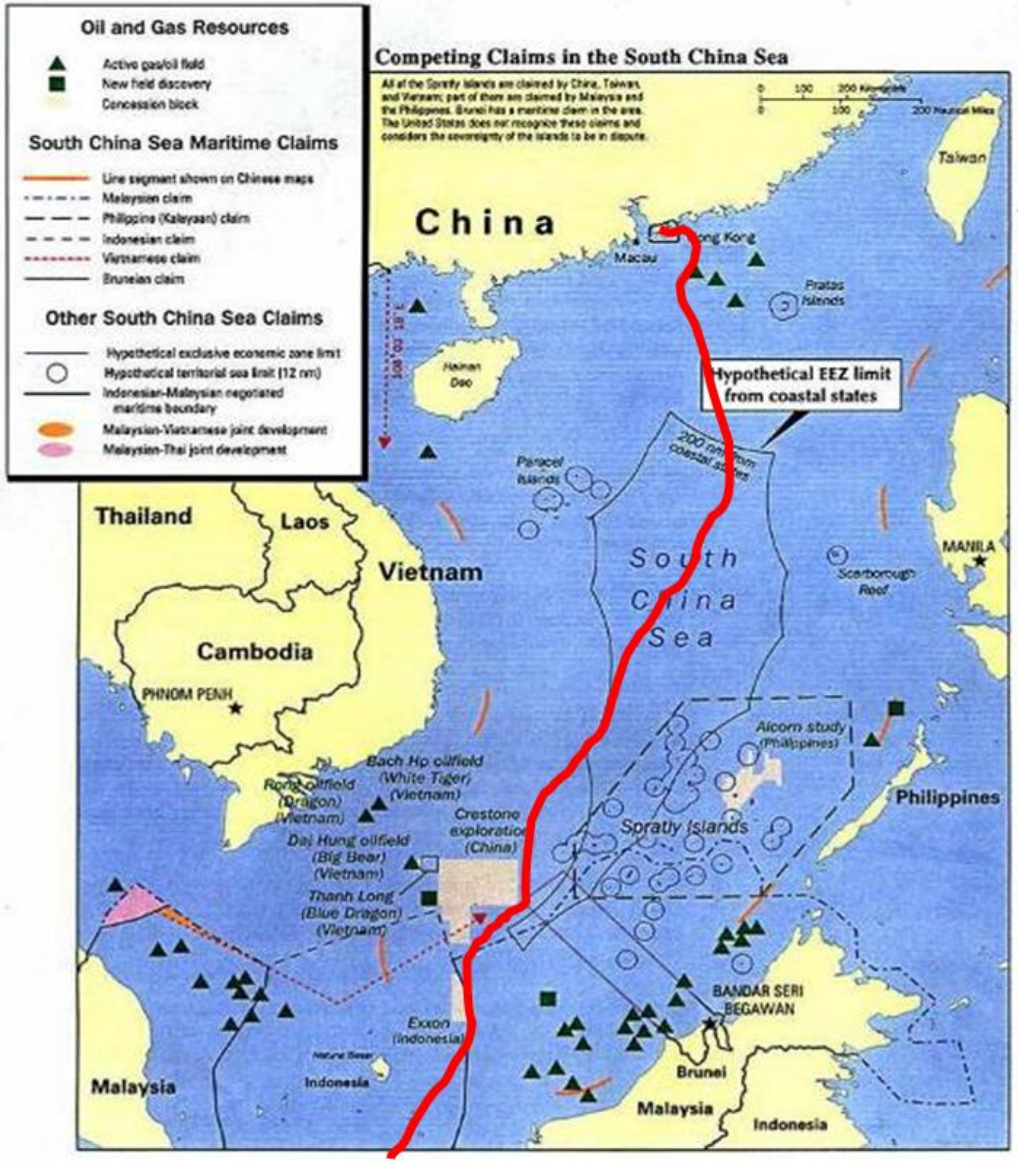
用大角度横跨主要航道

Cross busy shipping lane at steep angle

研究區內油氣田之板塊
Study Oil & Gas Block in the Region

- 避免在油氣田附近鋪設海纜
  Avoid laying cable adjacent to Oil & Gas Blocks

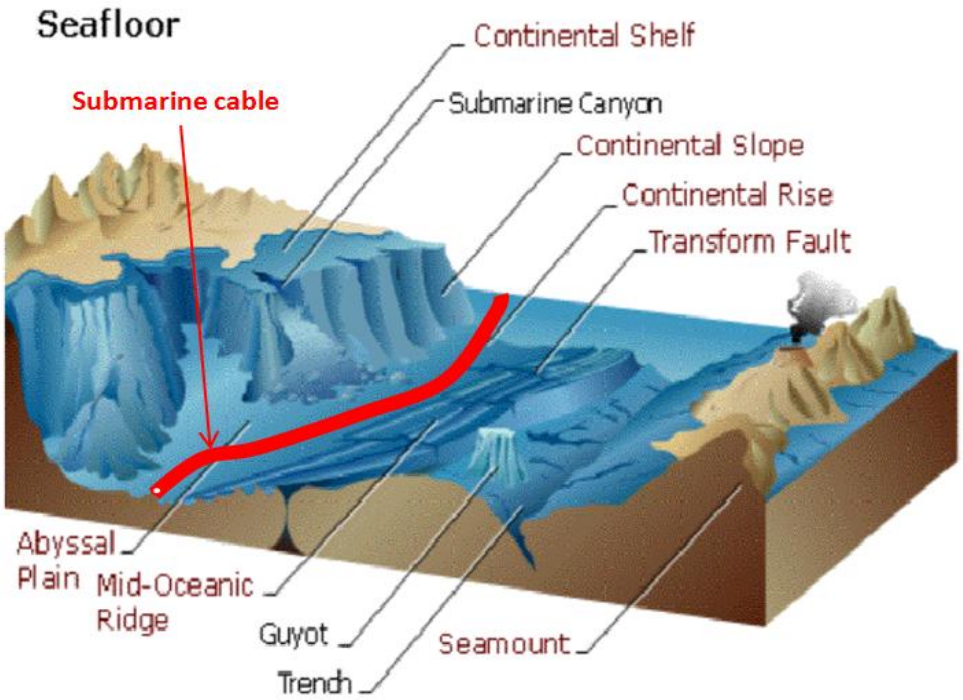
- 跟油田主人協相保護海纜安
  Seek agreement from owners for cable protection when crossing oil or gas blocks



設 計 初 步 之 路 由 Design Preliminary Cable Route

目的：尋找最短和最安全鋪設海纜的路徑， 把海纜鋪設在平滑之海床而遠離一切危險

Objective: Find the shortest and safest route to lay cable on smooth seabed away from all dangers



為達到以上目的

To achieve the above:

(i)要作理論研究

(翻查不同之資料庫)

Desk Top Study

(i.e. study various data bases)

(ii)要作實地測量

Conduct Marine Survey

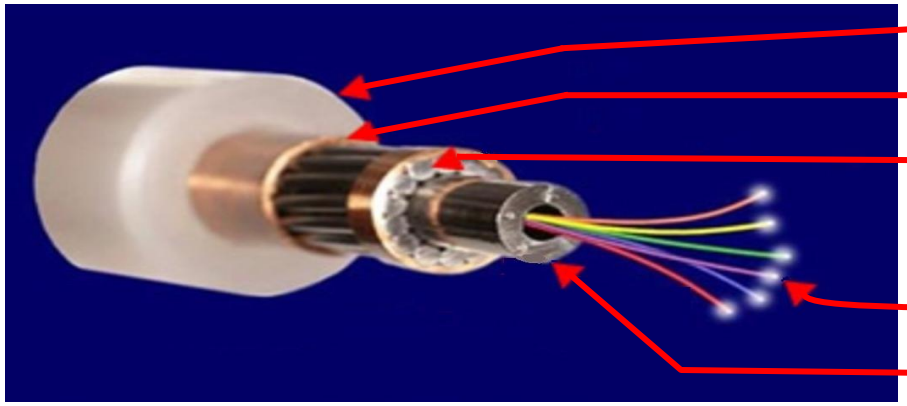
定立海纜保護之策略
Set Up Cable Protection Strategy

ICPC是一個
國際組織 推薦保護 海纜之指引

1) 水深不超過100米處用單裝甲輕型（Single Armored Lightweight SAL）海纜
2) 水深超過100米處用輕型（Light Weight LW）海纜
3) 水深不超過50米處，埋藏海纜於海床至1米深，以保護海纜避免漁民作業之威脅
4) 海纜登岸之保護:
   - 水平定向鑽挖（ Horizontal directional drilling (HDD）
   - 關節聯接之鋼管（ Articulated pipe ）

不同類形之光纖海纜 Different Types of Fiber Optic Submarine Cables

- 輕型海纜之結構 Structure of Light Weight Cable

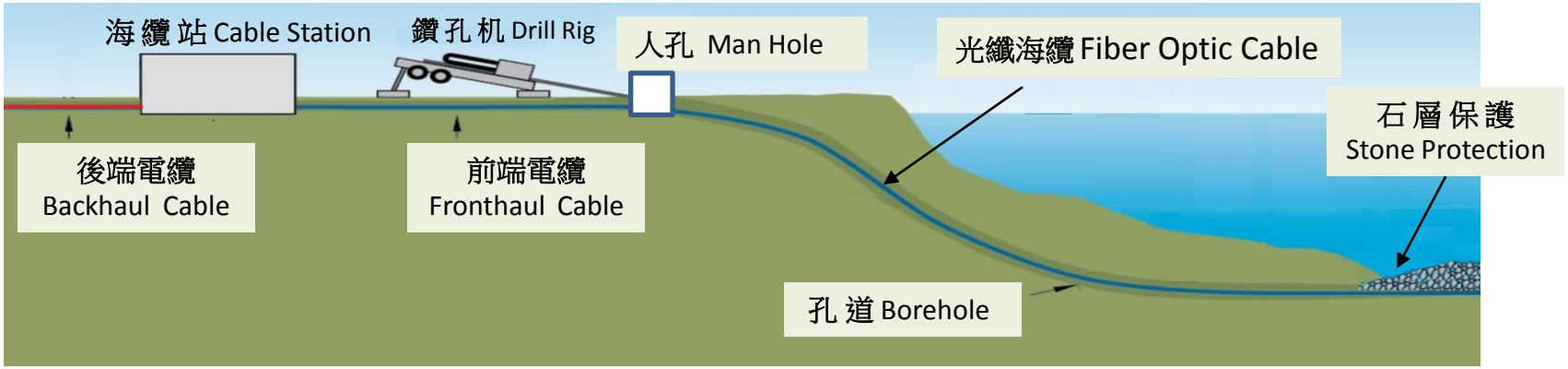


- 根據不同深度和海床情況用不同類型之海纜
  Use different types of cables according to water depth and seabed conditions

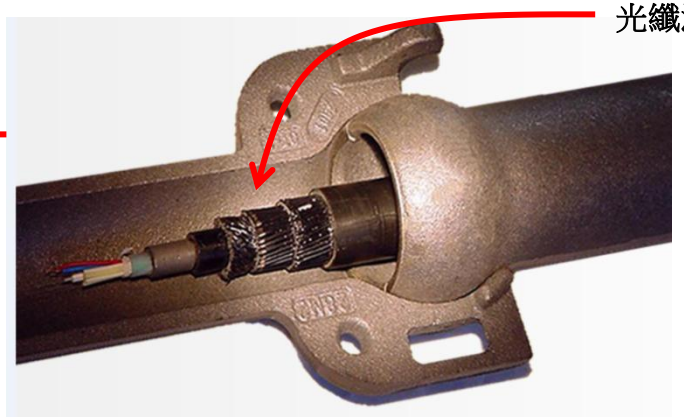
Source: OCC

海纜登岸時之保護之兩種方法 Two Methods for Cable Protection at Landing

- (1) 水平定向鑽挖 Horizontal Directional Drilling (HDD)



- (2) 關節聯接之鋼管 Articulated pipe



桌面研究之詳細工序
Desk Top Study – Detailed Steps

(Reference Materials)
(参考资料)

- 尋找最短的海纜路由
- 尋找平滑海床，遠離火山，地震帶，斜坡和海山
- 遠離損磨性的海床和急速之水流 ，如一定需要，在這些區域使用裝甲海纜
- 遠離石油或天然氣管道，勘探區和軍事區
- 與運作中海纜最少保持水深兩倍距離
- 避免橫跨其他海纜或電纜（如果一定需要，橫跨角度大於45度，及遠離其他海纜中繼器）
- 避免橫跨商業航道（如果一定需要，用大角度橫跨）
- 盡量減小對環景影響（需作環評研究）
- 考慮是否需要埋藏海纜於海床， 以保護海纜免受漁民作業及船錨之威脅
- 放置水下器材之位置，要考慮日後維修
- 確定海事測量和安裝的天氣窗口

主要目的：把海纜鋪設在平滑的海床而遠離一切危險

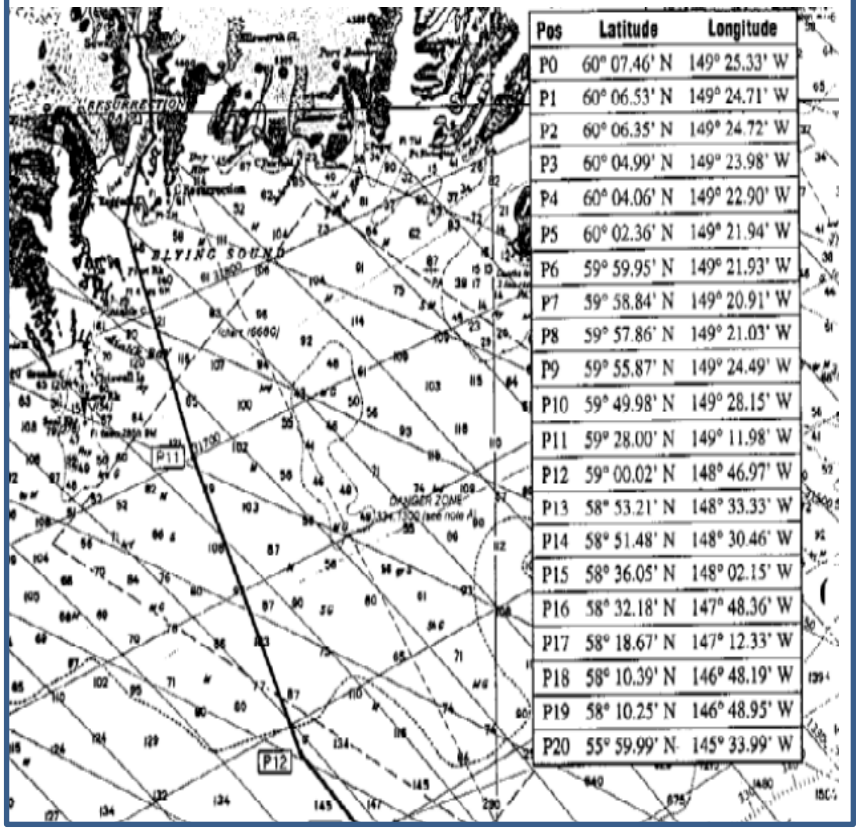
桌面研究之結果報告
Desk Top Study -- Output

- 初步路由位置表
  A preliminary cable route represented by Route Position List (RPL)

- 初步海纜保護之要求
  Preliminary protection requirements:
  + 裝甲海纜 Armored cable segments
  + 埋藏深度.....Burial depth

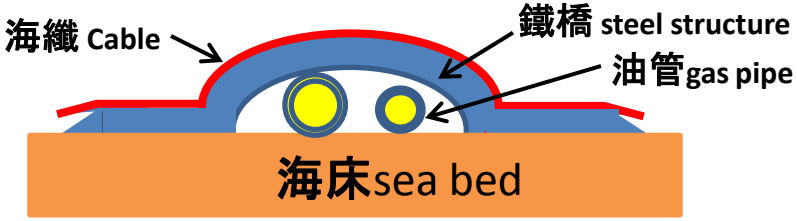
- 海事測量規範 Marine survey specifications

典型路由位置表
A Typical Route Position List



Pos	Latitude	Longitude
P0	60° 07.46' N	149° 25.33' W
P1	60° 06.53' N	149° 24.71' W
P2	60° 06.35' N	149° 24.72' W
P3	60° 04.99' N	149° 23.98' W
P4	60° 04.06' N	149° 22.90' W
P5	60° 02.36' N	149° 21.94' W
P6	59° 59.95' N	149° 21.93' W
P7	59° 58.84' N	149° 20.91' W
P8	59° 57.86' N	149° 21.03' W
P9	59° 55.87' N	149° 24.49' W
P10	59° 49.98' N	149° 28.15' W
P11	59° 28.00' N	149° 11.98' W
P12	59° 00.02' N	148° 46.97' W
P13	58° 53.21' N	148° 33.33' W
P14	58° 51.48' N	148° 30.46' W
P15	58° 36.05' N	148° 02.15' W
P16	58° 32.18' N	147° 48.36' W
P17	58° 18.67' N	147° 12.33' W
P18	58° 10.39' N	146° 48.19' W
P19	58° 10.25' N	146° 48.95' W
P20	55° 59.99' N	145° 33.99' W

典型橫跨油管設施
Typical Gas Pipe Crossing



International Cable Protection Committee

Professor Peter KC Yu's
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桌面(理論)研究
Desk Top (Theoretical) Study

牌照申请
Licenses & Permits Application

施工 Project Implementation
+海事測量 Marine Survey
+系統設計及製造 System Design & Plants Manufacture
+地上及海上之安装 Land & Marine Installation

牌照申请 Licenses & Permits Application

- 費時及有政治挑戰 Political challenging and Time Consuming
- 需要聘請中介公司處理need to employ Special Agent to handle the job

南中國海之政治挑戰
Political Challenges in the South China Sea

- 領土糾紛 Territorial Disputes
  - 中國 China
  - 越南 Vietnam
  - 菲律賓 Philippines
  - 台灣 Taiwan
  - 印尼 Indonesia
  - 馬來西亞 Malaysia
  - 文萊 Brunei
- 需要在有關國家很多部門申請很多牌照

  need to apply many permits from different departments in related countries

- 需要商談很多協議

  need to negotiate many Agreements:

  在最近之工程項目，需要商談 **64** 協議

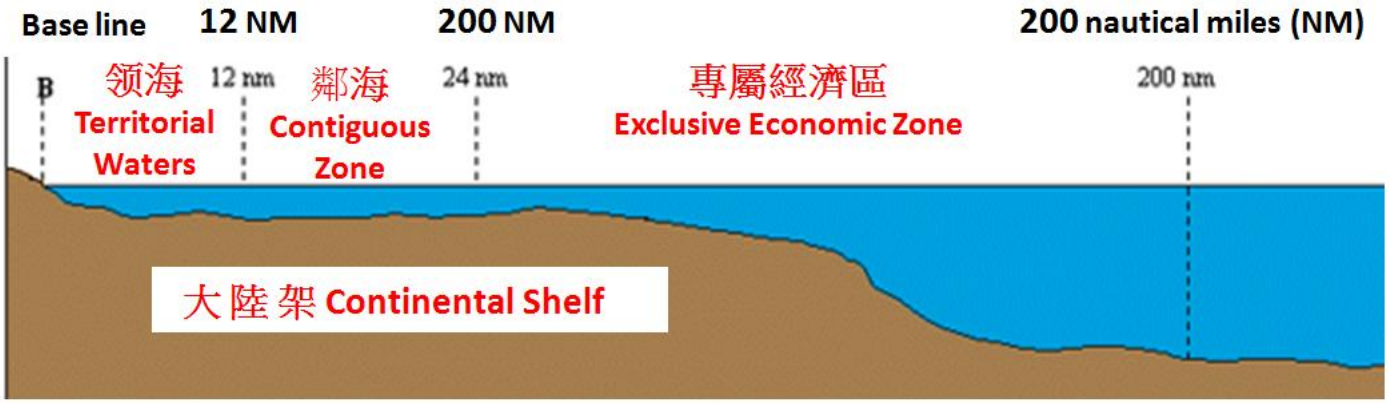
  In a recent project, there is a need to negotiate 64 Agreements:

  - **38** 项横跨操作中海纜
    38 Crossings on In-service Cables
  - **6** 项横跨計劃中之海纜
    6 Crossings on Planned Cables
  - **10** 项横跨油氣田
    10 Crossings in Oil Concession Blocks
  - **8** 项横跨油管
    8 Crossings on Pipelines

領土糾紛之管理
Management of Territorial Disputes

- 在每個有關國家研究 Investigate in each involved states:
  - + 聯合國海洋法之演譯 Interpretation of Law of Sea (UNCLOS -the Law of the Sea)
  - + 外國測量船之使用法規 Regulation for use of foreign flag survey vessels
  - + 海下器材之稅規 Tax Regulation on wet plants
  - + 漁民期望之賠償 Expected compensation for fishermen
- 考慮在有爭議之海域向多國提出申請

  Consider multiple permit applications in disputed waters



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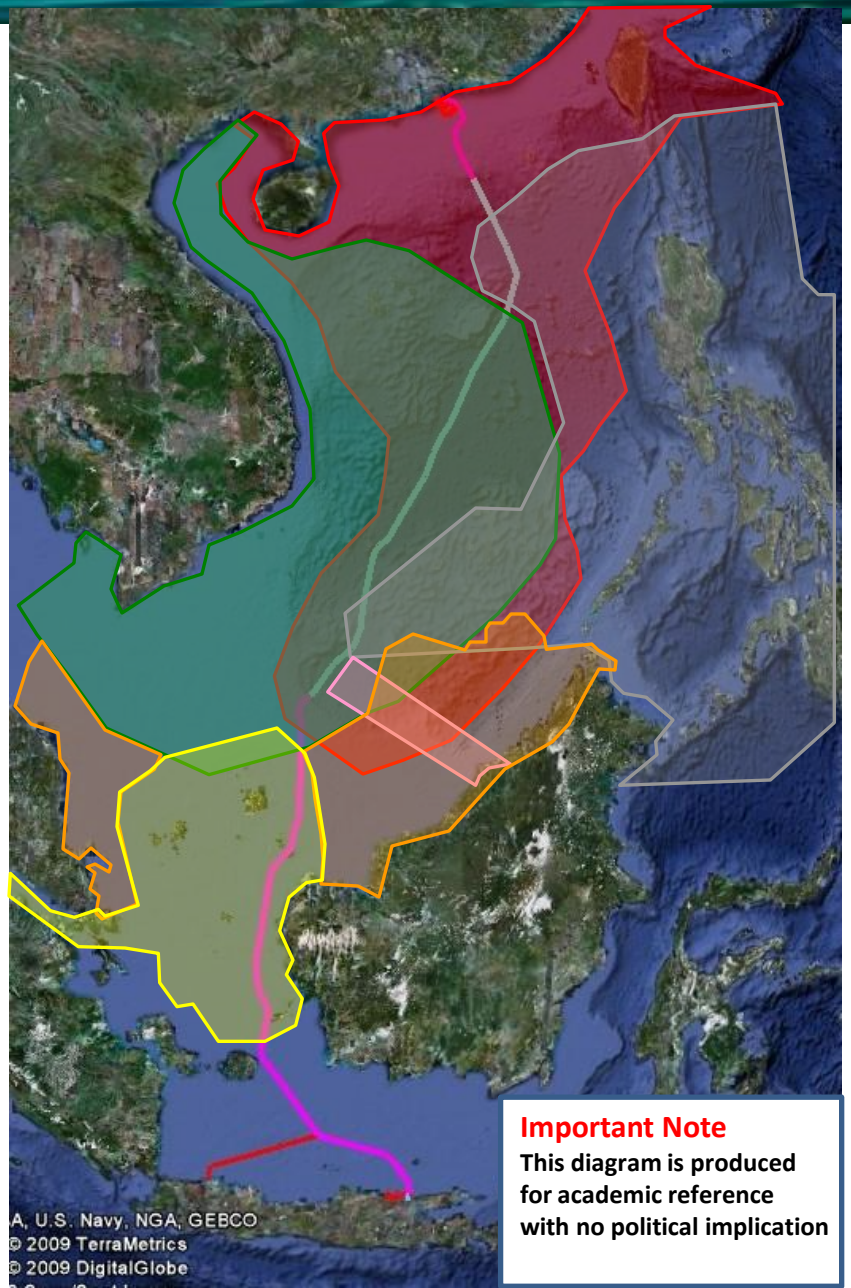
i.e. with no direct or indirect business implications

南中國海領土糾紛
Territorial Claims in the South China Sea



China

The Philippines

Vietnam

Indonesia

Malaysia

Brunei

Important Note

This diagram is produced for academic reference with no political implication

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i.e. with no direct or indirect business implications

香港牌照要求
Permits and Licenses Requirements (Hong Kong)

需要**15+**個牌照 15+ Licenses are required

- 電訊事務管理局 Communications Authority
- 海事處 Marine Department
- 環保署Environmental Protection Department
- 地政署 District Land Office
- 土木工程拓展署Civil Engineering & Development Department
- 漁農自然護理署Agriculture & Fisheries, & Conservation Department
- 其他海纜主人 Cable owners
- 油管主人Pipeline owners
- 油田開發區主人 Exploration Block owners
- 等等Others

Item No.	Permit Name	Regulator or Agency	Activity
AA	Letter of no objection from OFTA	OFTA	Policy Support
1a.	Environmental Permit by Direct Application	EPD	Right of Way
1b.	Environmental Permit by Full EIA Process	EPD	Right of Way
1c.	Environmental Permit Requirements & conditions	EPD	Right of Way
2	Fore-Shore Seabed Reclamation Ordinance Approval (FSRO)	DLO	Right of Way
3	Town Planning Ordinance Approval	DLO	Right of Way
4	Future Development/Cable Burial Protection - Letter of No Objection	Civil Engineering Dept.	Right of Way
5	Marine Impact Assessment (If required)	Marine Dept.	Right of Way
6	Agreement with Fishermen	AFCD & Fishery Union	Right of Way
7	Cable Route Approval	Marine Dept.	Right of Way
8	Cable Crossing Agreement	Cable Owners	Right of Way
9	Pipeline Crossing Agreements/Oil Concession Block Crossing Agreement	Pipeline/Oil Concession Block Owners	Right of Way
MARINE SURVEY			
10	Notice to Mariners	Marine Dept.	Marine Survey Works
11	Cable Ship - Temporary Local License	Marine Dept.	Marine Survey Works
12	Work Permit for crews / shore end installation	Marine Dept.	Marine Survey Works
MARINE INSTALLATION - S/E, PLGR, Main Lay, PLIB			
13	Notice to Mariners	Marine Dept.	Marine Installation Works
14	Cable Ship - Temporary Local License	Marine Dept.	Marine Installation Works
15	Work Permit for crews / shore end installation	Marine Dept.	Marine Installation Works

印尼牌照要求
Permits and Licenses Requirements (Indonesia)

22+ Licenses are required :

- Telecom Authority
- Military
- Marine/Port Control
- Environmental Bodies
- Fishermen
- Cable owners
- Pipeline owners
- Exploration Block owners
- Local /Provincial Authority
- Others

Item No.	Permit Name	Regulator or Agency	Activity
1	Ijin Prinsip	DGSC Director General of SEACOM	Permit in Principle
2	Environmental Approval (Environmental Impact Analysis Study)	Ministry of Environment	Right of Way
3	Project Acknowledgement	POSTEL	Permit in Principle
4	No Objection Letter (Oil Concession Block)	BP Migas	Right of Way
5	Cable Crossing Agreement	Cable Owners	Right of Way
6	Pipeline Crossing Agreement	Pipe Line Owners	Right of Way
7	Fisherman Agreement	Local Fisherman Union	Right of Way
8	Land Cable Route Approval from BMH to Station	Local Government	Right of Way
9	NO Objection Letter for Landing Site	Local Government	Right of Way
MARINE SURVEY			
9	Survey Permit (No Objection Letter)	DGSC	Route Survey Work
10	Security Clearance	Departmen Pertahanan	Route Survey works
11	Approval of Foreign Flag Vessel (PPKA)	DGSC	Route Survey works
12	Under Water Permit	DGSC	Route Survey Work
13	Local Government Permit (No Objection Letter)	Local Government	Route Survey Work
14	Local Government Permit (No Objection Letter)	Local Government / SEACOM	Route Survey Work
15	Vessel Temporary Importation OB23	Customs	Route Survey Work
MARINE INSTALLATION - S/E, PLGR, Main Lay, PLIB			
16	Cable Route Approval	DGSC	Right of Way
17	Local Government Permit (No Objection Letter)	Local Government / SEACOM	Marine Cable Installation
18	Installation Permit (No Objection Letter)	DGSC	Marine Installation works
19	Security Clearance	Departmen Pertahanan	Marine Installation works
20	Approval of Foreign Flag Vessel (PPKA)	DGSC	Marine Installation works
21	Underwater Permit	DGSC	Marine Installation works
22	Vessel Temporary Importation OB23	Customs	Marine Installation works

中國牌照要求
Permits and Licenses Requirements (PRC China)

8+ Licenses are required from:

- State Oceanic Administration
- Chinese Navy
- Marine/Port Control (via SOA)
- Environmental Bodies (via SOA)
- Fishermen (via SOA)
- Cable owner
- Pipeline owner
- Exploration Block owner
- Local /Provincial Authority (via SOA)
- Others

Item No.	Description	Permit/Activiy	Regulator or Agency
1	Cable Route Approval	Pre-Survey Cable Route Approval	State Oceanic Administration (SOA)
1.1	Military / Navy Compensation	Agreement on new route and compensation agreement with Military / Navy	Chinese Navy
3	Security audit on Electronic Survey/BAS Data	Submission of Raw survey data for security audit	SOA
4	Final Cable Route Approval	Co-ordination meeting for Final Route Approval	SOA
5	Right of Way - "Permit to Install Submarine Cable in China TZ & EEZ"	Requires :- 1. Approval of Raw Survey Data 2. Provision of Vessel and Crew Details to SOA 3. Fisherman Compensation for Loss of Livelihood 4. Pipeline Crossing Agreement 5. Military/Navy Compensation 6. Marine resources and environmental impact assessment report approval	SOA
5.1	Fishermen compensation	Compensation payment for loss of lively hood related to right of way	SOA
5.2	Pipeline Crossing Agreements/Oil Concession Block Crossing Agreement		SOA
5.3	Marine resources and environmental impact assessment report approval		SOA
5.4	Maritime Utilisation Assessment		SOA
MARINE SURVEY			
6	Operational Permit for Survey Activity	1. Notice to Mariners 2. Notice to Local Authority and South Sea Navy 3. Arrangement of Navy Representative on board 4. Vessel Position Report Daily to SOA	SOA
Marine Installation Permits -S/E, PLGR, Main Lay, PLIB			
7	Operational Permit for Marine Installation	1. Notice to Mariners 2. Notice to Local Authority and South Sea Navy 3. Arrangement of Navy Representative on board 4. Vessel Position Report Daily to SOA	SOA

(For Academic Reference Only)

i.e. with no direct or indirect business implications

越南牌照要求
Permits and Licenses Requirements (Vietnam)

10+ Licenses are required from:

Telecom Authority

- Military
- Marine/Port Control
- Environmental Bodies
- Fishermen
- Cable owner
- Pipeline owner
- Exploration Block owner
- Local /Provincial Authority
- Others

Item No.	Permit Name	Regulator or Agency	Activity
1	LICENSE FOR THE INSTALLATION OF TELECOMMUNICATION CABLES IN VIETNAM'S EXCLUSIVE ECONOMIC ZONE OR CONTINENTAL SHELF	Ministry of Telecommunication	Cable Route, Landing Station, Project Approval
2	Cable Crossing Agreement on Behalf of Purchaser	Cable Owners	Cable Route
3	Pipeline Crossing Agreement on behalf of the Purchasers	Pipeline Owners	Cable Route
4	Oil Concession Route Permission	Concession Owner	Cable Route
5	Environmental Assessment (if required)	Ministry of Nature Resources and Environment	Cable Route
6	Fisherman Agreement	Fishery Union	Local Fisherman Union
MARINE SURVEY			
7	Approval For Foreign Flag Vessel	Ministry of Post and Telematics - Telecommunication Dept	Route survey works
8	Operation Permits	Min. of Post and Telematics, Min.of Defense, Min. of Public Security, Min. of Police, Min. of Transport, Min. of Fishery, Min. of Foreign Affairs, Min. of STE, Min. of Nature Resources and Environment, Immigration Dept., Customer Dept., Harbour Dept., Provincial Governor, DG Naval Operations Dept	Route survey works
MARINE INSTALLATION - S/E, PLGR, Main Lay, PLIB			
9	Approval For Foreign Flag Vessel	Ministry of Post and Telematics - Telecommunication Dept.	Marine Installation
10	Operation Permits	Min. of Post and Telematics, Min.of Defense, Min. of Public Security, Min. of Police, Min. of Transport, Min. of Fishery, Min. of Foreign Affairs, Min. of STE, Min. of Nature Resources and Environment, Immigration Dept., Customer Dept., Harbour Dept., Provincial Governor, DG Naval Operations Dept	Marine Installation

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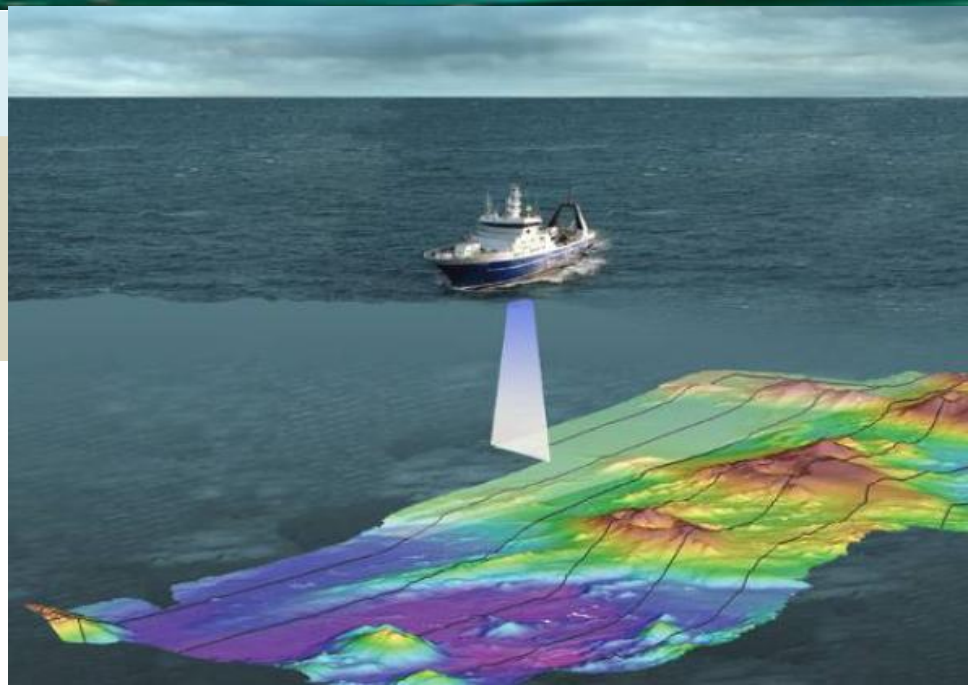
施工 Project Implementation
+海事測量 Marine Survey
+系統設計及製造 System Design & Plants Manufacture
+地上及海上之安裝 Land & Marine Installation

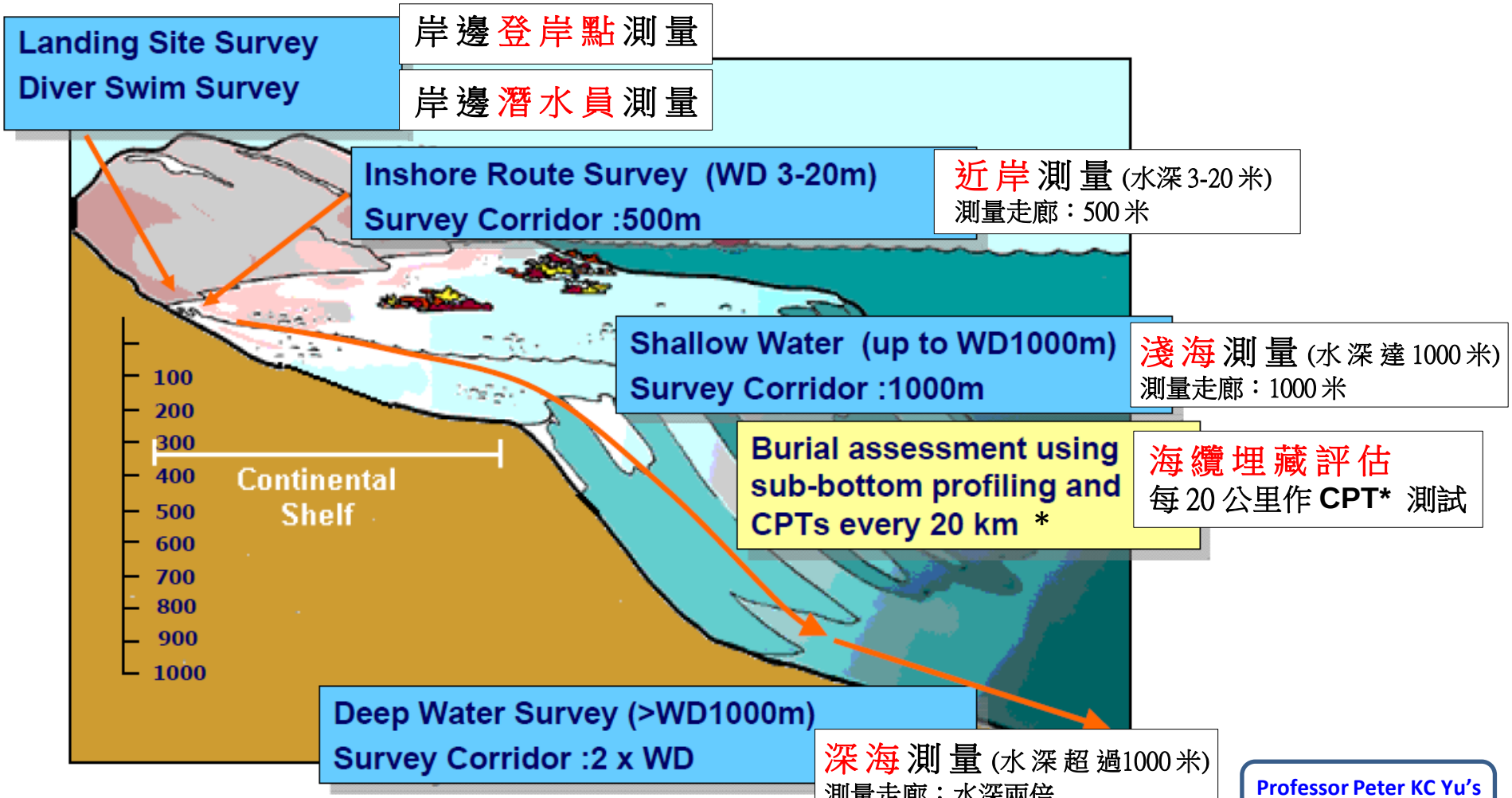


海事測量 Marine Survey

- 需要聘請專業海事測量公司
  Need to employ professional surveyor

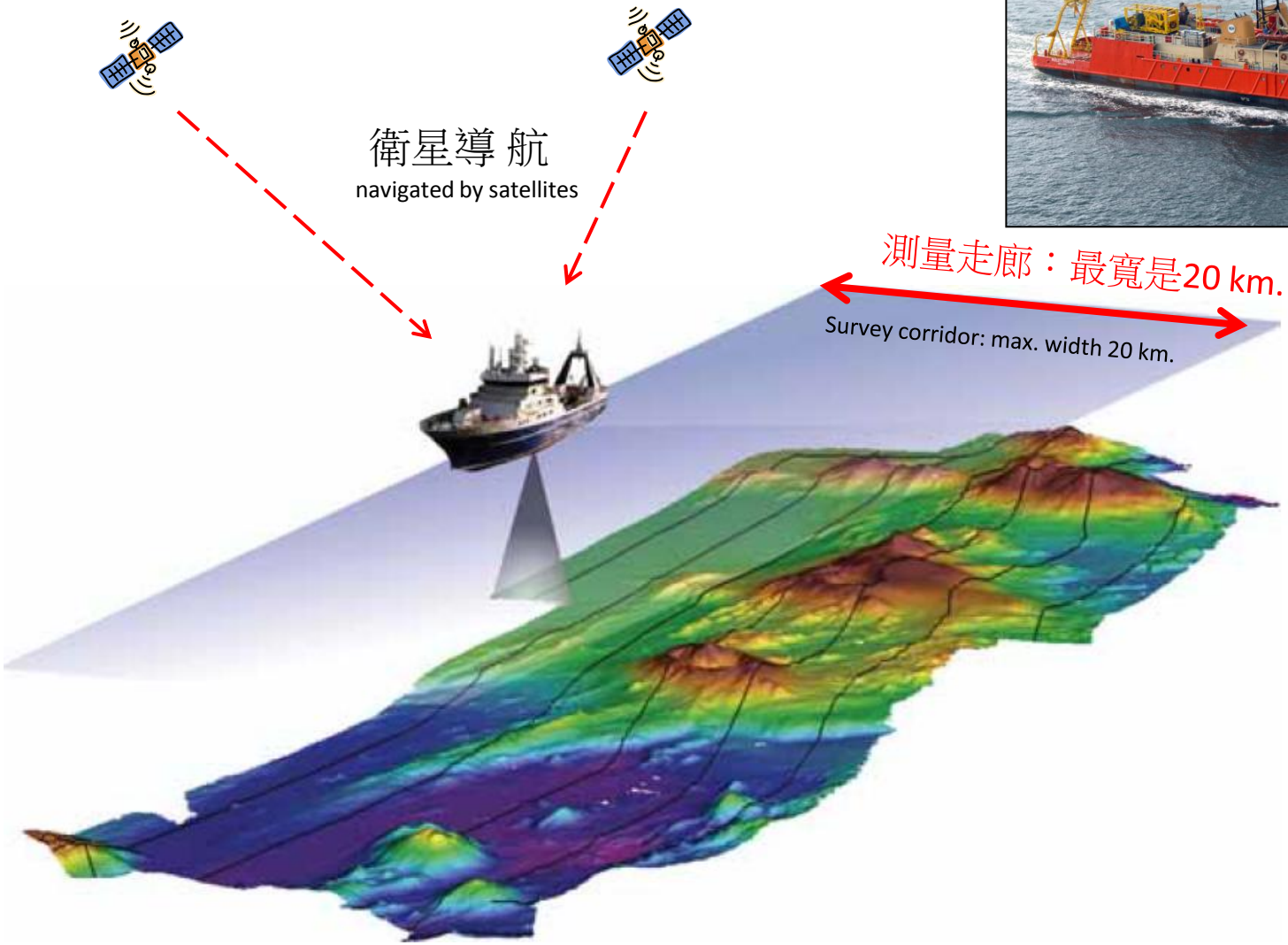
Source Photo: NIWA

不同類別之路由測量
Different Categories of Route Survey



***CPT :** Cone Penetrometer Tests 圓錐貫入器測試

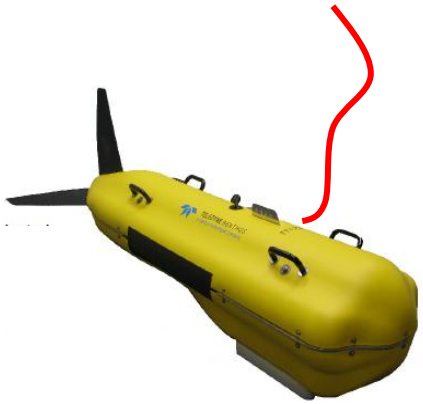
典型離岸路由測量船
A Typical Offshore Route Survey Vessel



路由測量 - 需要採集之資料 Route Survey - Data to be collected

- **Bathymetric* data** (海洋深度) – **by Echo Souder** 由回音器收集
- **Seabed imagery data** (海床影像) – **by Side Scan Sonar** 由橫掃聲納收集
- **Sub-bottom** profiling data** (海床硬度) – **by Side Scan Sonar** 由橫掃聲納收集
- **Burial assessment data** (海床土壤) – **by Gravity Drilling / CPT *** 由重力鑽探

橫掃聲納Side Scan Sonar

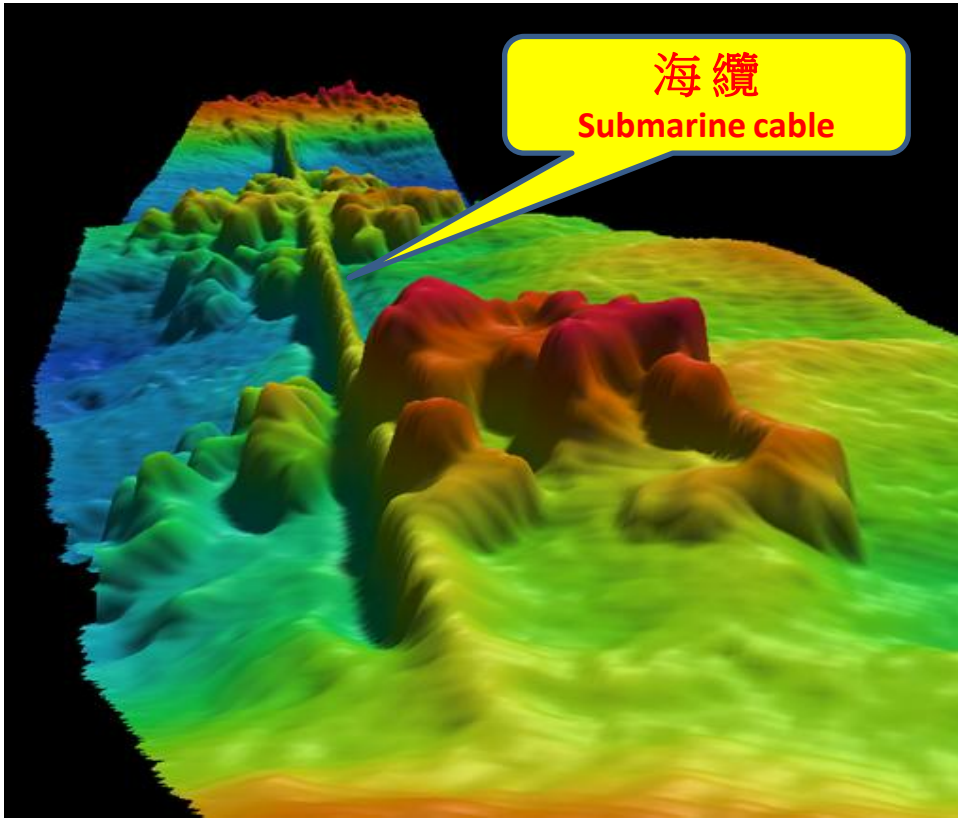


回音器 Echo Sounder

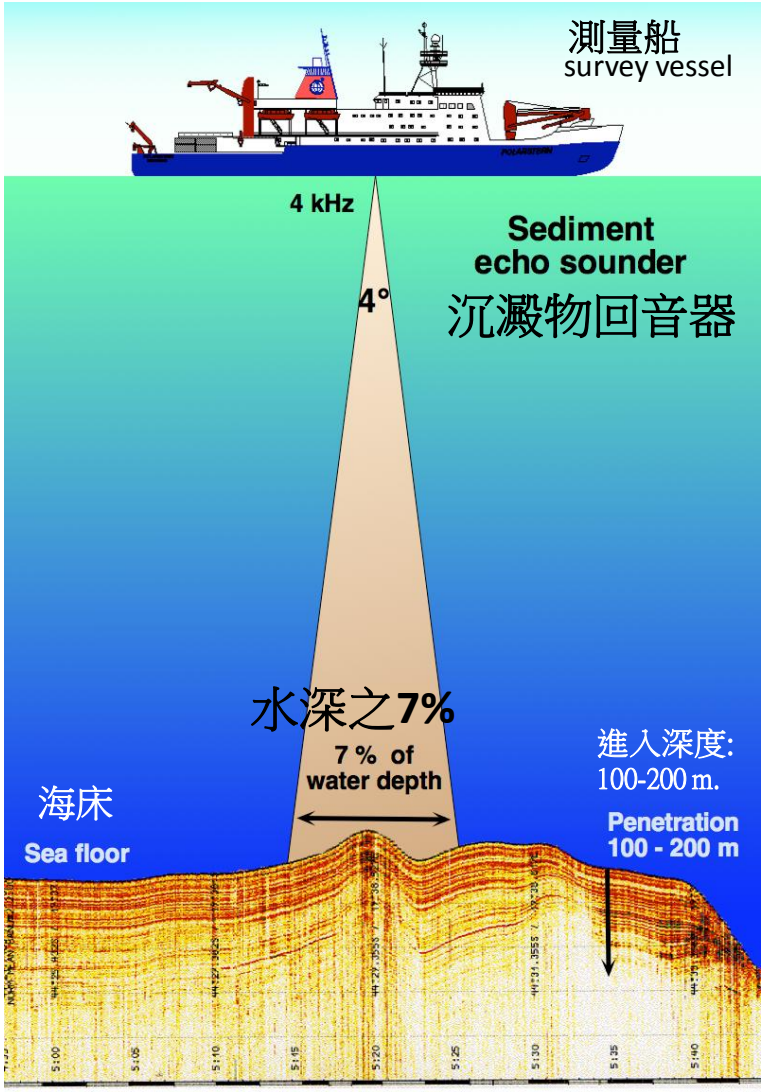
重力鑽探 Gravity Drilling/CPT

* Bathymetry : study of underwater depth of ocean
** Sub-bottom: means below sea bottom
*** CPT : Cone Penetrometer Tests 圓錐貫入器測試

海洋測深學之3D影像 (例子1)
Bathymetry Image – (Example 1)



海洋測深學之影像 Bathymetry Image



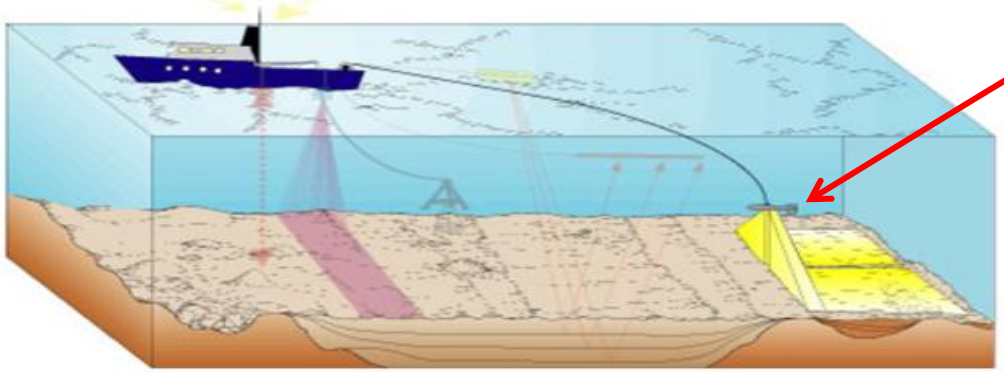
回音器之工作圖 Echo Sounder in Operation

Source: EGS

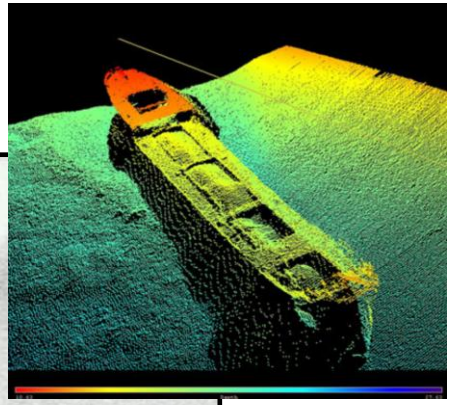
橫掃聲納之影像
Side Scan Sonar Image

橫掃聲納 Side Scan Sonar

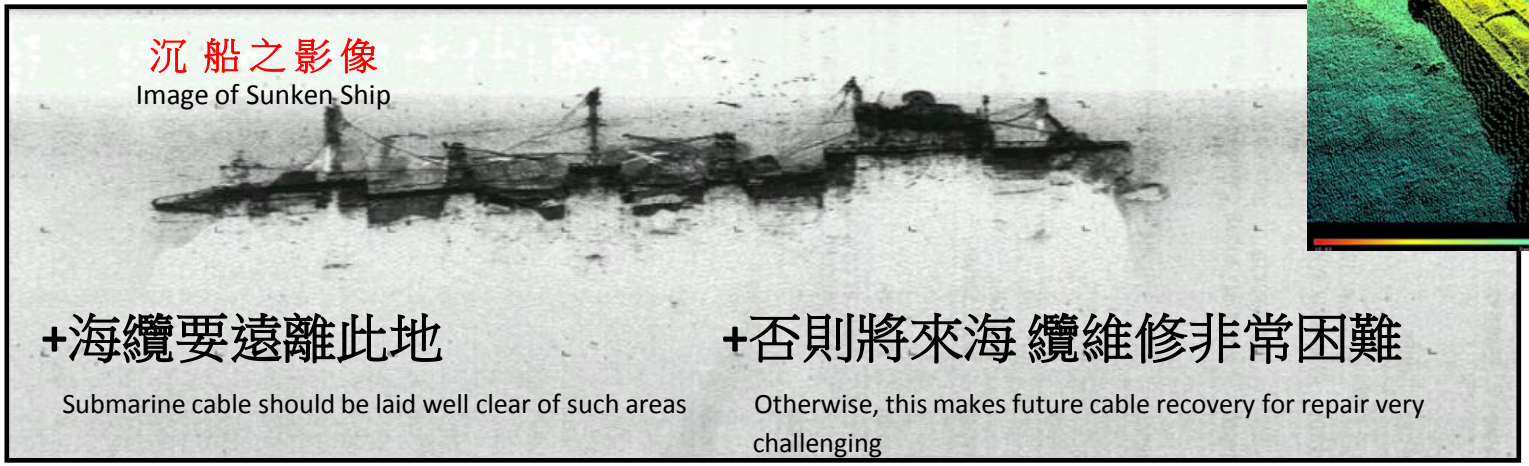
- 橫掃聲納之工作圖 Side Scan Sonar in Operation



沉船之影像
Image of Sunken Ship



- 橫掃聲納之影像 Side Scan Sonar Image



+海纜要遠離此地

Submarine cable should be laid well clear of such areas

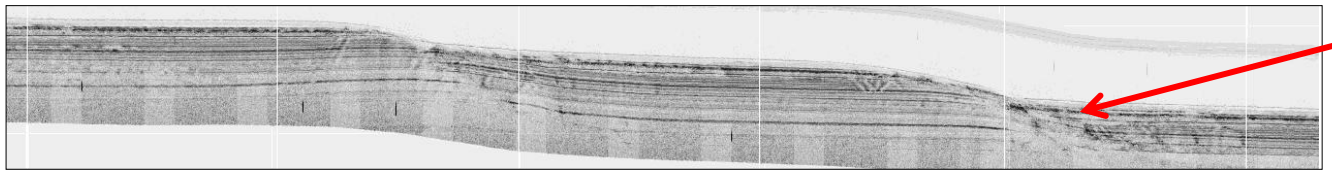
+否則將來海纜維修非常困難

Otherwise, this makes future cable recovery for repair very challenging

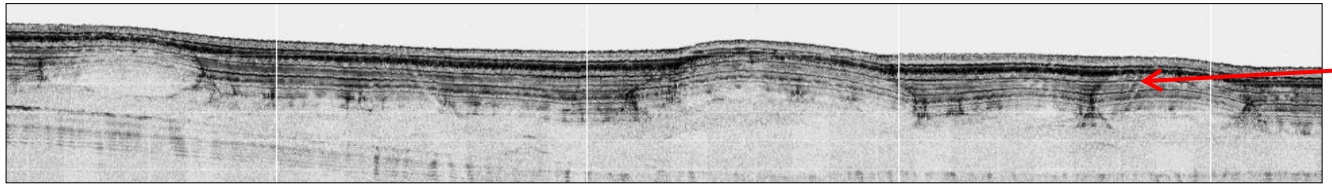
Source: EGS

橫掃聲納之影像
Side Scan Sonar Image

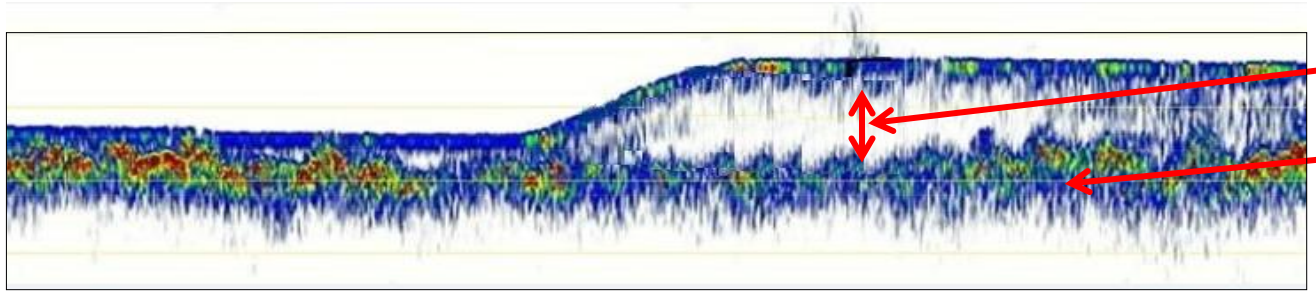
- 海床聲納反射强度顯示海床之硬度
  Back-scatter intensity can be used as indicator of seabed hardness
- 資料用以找尋適當埋藏海纜位置
  Use to identify suitable location for cable burial



軟海床 Soft Seabed



硬海床 Hard Seabed



軟泥層 Soft Mud Layer

硬海床 Hard Seabed

Source: EGS

海事測量報告
Marine Route Survey Report

(Reference Materials)
(参考资料)

- 埋藏海纜之方法， 深度與其要注意之地方
  Cable burial methodology, deep burial and precautions,
- 橫跨油管或其他海纜之保護
  Cable/pipeline crossing protection
- 海事作業之天氣窗口及日程
  Weather windows scheduling for marine operation
- 系統直線圖顯示不同路段之長度，中繼器及分叉器之位置，水深及埋藏要求
  A straight line diagram (SLD) indicating type/length of cable sections, location of repeaters/ branching units, water depth and burial requirement
- 最後路由位置表
  A final cable route represented by Route Position List (RPL)
- 確定不同路段採用不同種類之海纜
  Confirmation of types of cable to be used in different segments

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典型之海纜系統設計及鏈路預算
A Typical Submarine Cable System Design and Link Budgeting

香港城市大學
City University of Hong Kong

Professor Peter KC Yu's
Public Technical Presentation

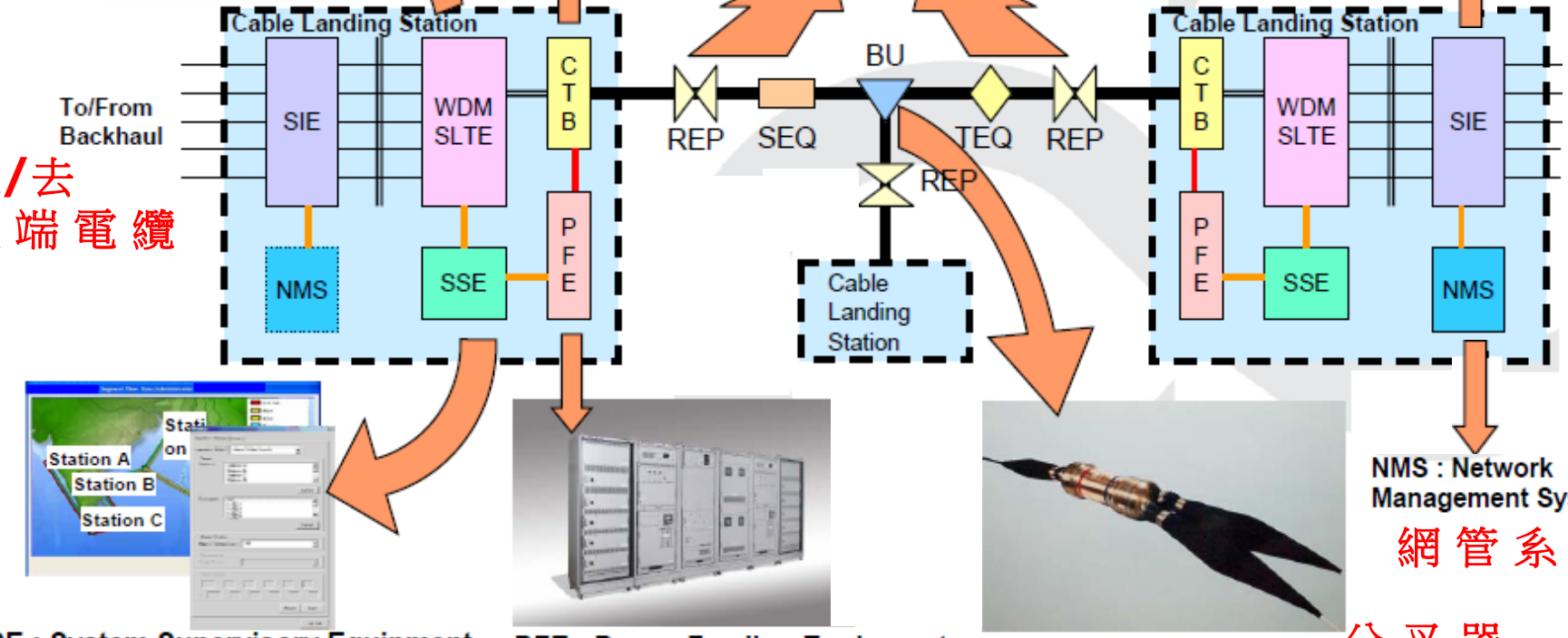
海纜系統之典型設備 Typical Equipment in a Cable System

海纜終端設備
SLTE : Submarine Line Terminal Equipment

電纜終端盒
CTB : Cable Termination Box

REP : Repeater 中繼器

SDH 復用設備
SIE : SDH Interconnection Equipment
SDH: Synchronous Digital Hierarchy



來/去後端電纜

SSE : System Supervisory Equipment
系統監察設備

PFE : Power Feeding Equipment
電力供給設備

BU : Branching Unit 分叉器

NMS : Network Management System
網管系統

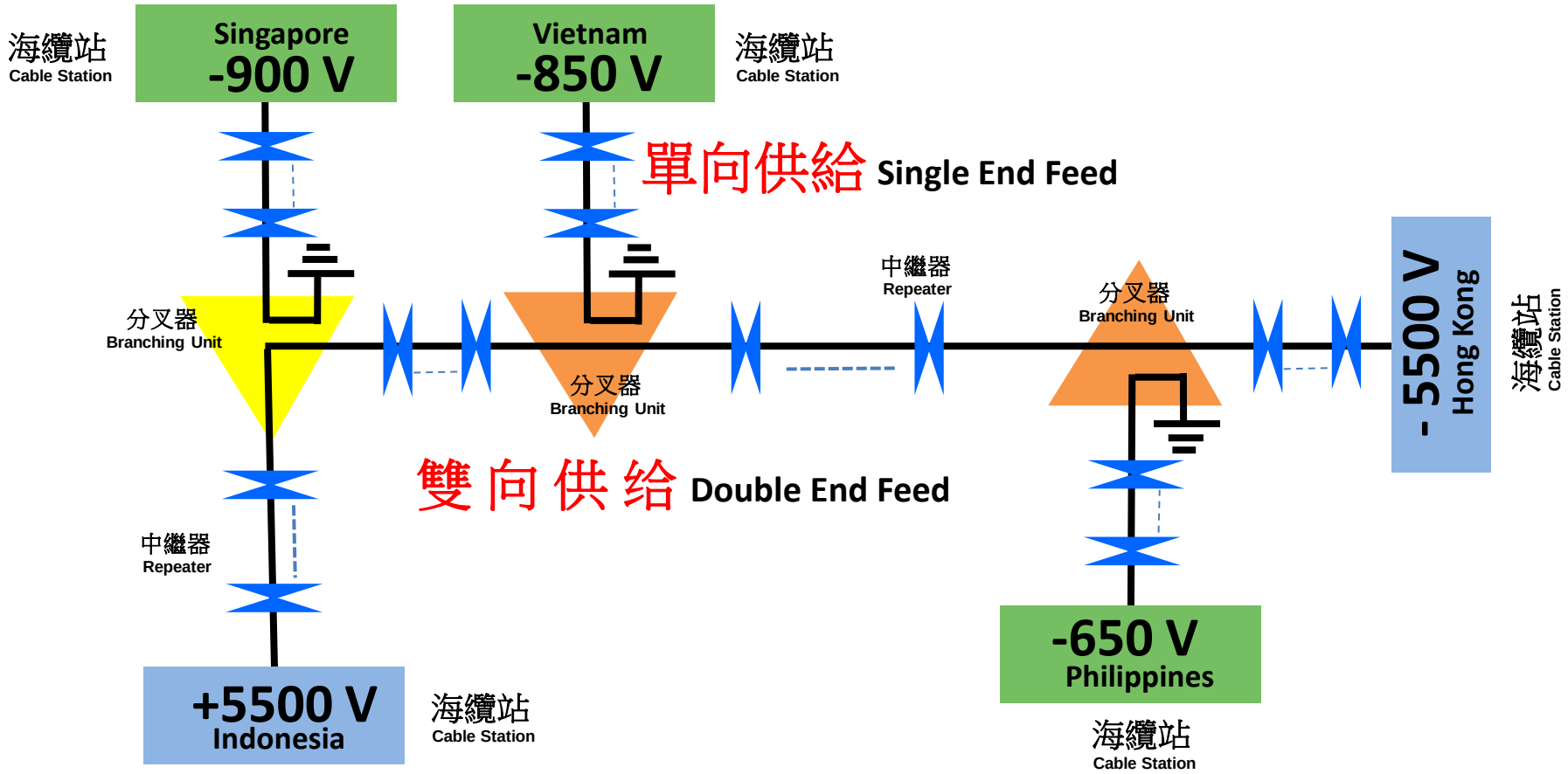
典型海纜系統之設計規範 Typical System Design Specifications

四大類系統規範4 Key Specifications:

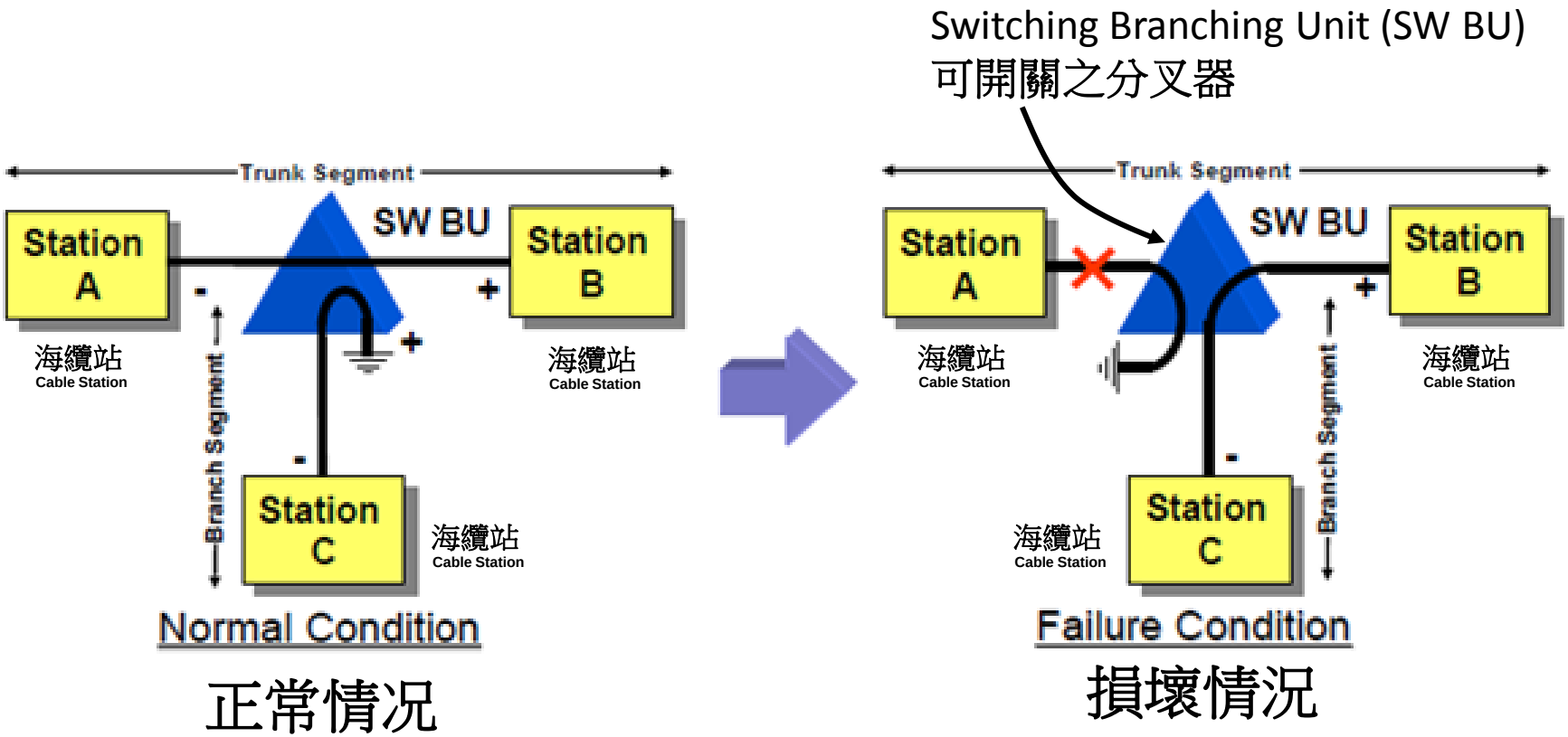
- 系統速度 如 40 Gb/s 或100 Gb/s (System Speed: e.g. 40 Gb/s or 100 Gb/s)
  - 影響 : + 採用不同科技 Choice of Technologies
- 系統可用度 (Availability Requirements: >99.9%, BER < 10^{-13})
  - 影響：+採用不同科技 Choice of Technologies
    +系統備份之設計 Design of system redundancy (n+1 or 1+1 …)
- 期望船維修次數 (No of expected ship repair: <1 time during system life)
  - 影響：+水下器材之保護 Wet plant protection
    + 海纜埋藏之深度及長度 Depth & length of cable burial
- 電力供給再配置能力 (Power feeding path reconfiguration capability)
  - 影響：+海纜中斷時服務之影響 Service interruption in case of cable break

BER: Bit Error Rate 誤碼率

典型之電力供給配置
Typical Power Feeding Configuration



典型之電力供給再配置能力
Typical Power Feeding Reconfiguration Capability



典型海纜鏈路Q預算表 (ITU-T G977 格式)

Typical Q-Budget Table for a Submarine Link (ITU-T G977 Format)

	Length(km)	3973	
	Repeater Number	52	
		BOL Q in dB	EOL Q in dB
1	MEAN Q VALUE (from simple SNR type calculation)	19.7	16.5
1.1	Propagation impairments due to combined effects of chromatic dispersion, non-linear effect, four-wave mixing effects, stimulated Raman scattering effects, etc.	3.5	3.5
1.2	Gain flatness impairments	Included in item 1.4	
1.3	Non-optimal optical pre-emphasis impairment	Included in item 1.4	
1.4	Wavelength tolerance impairment	0.4	0.4
1.5	Mean PDL penalty	Included in item 1.1	
1.6	Mean PDG penalty		
1.7	Mean PMD penalty		
1.8	Supervisory impairment	0.2	0.2
1.9	Manufacturing and environmental impairment	1.0	1.0
2	Time varying system performance (5 sigma rule)	1.2	1.2
3	Line Q value (1-1.1 to 1.9-2)	13.4	10.2
4	Specified TTE Q value (back-to-back)	21.0	21.0
5	Segment Q value (computed from 3 and 4)	12.7	9.9
5.1	BER corresponding to segment Q without FEC	9E-06	
5.2	BER corresponding to segment Q with FEC	<9E-14	
5.3	Effective Segment Q value with FEC	>17.34	
6	Q Limit for compliance with G.826 after FEC correction	8.8	8.8
7	Repair margins		2.8
	Component and fibre ageing penalty	Included in item 7	
	Pump(s) failure penalty		
	Non optimal decision threshold	Included in item 1.9	
8	Segment margins	3.8	1.0
9	Commissioning limits	12.6	

生命開始 (BOL) Beginning of Life

生命終结 (EOL) End of Life

線性理論Q值：只包括鏈路之光信噪比(OSNR) 不包括接收器噪聲

Theoretical linear Q Factor due only to link OSNR excluding any receiver noises

考慮所有時間不變之損減

Consider all time non-variant impairments

考慮所有隨時間而變之損減

Consider all time variant impairments

考慮設備之不完善

Consider all imperfections of equipment

考慮前向糾錯編碼效應 **Consider FEC Coding effects**

考慮電纜維修及元件老化

Allow for cable repair & components aging

用以計算所需之中繼器和均衡器和它們的位置和距離

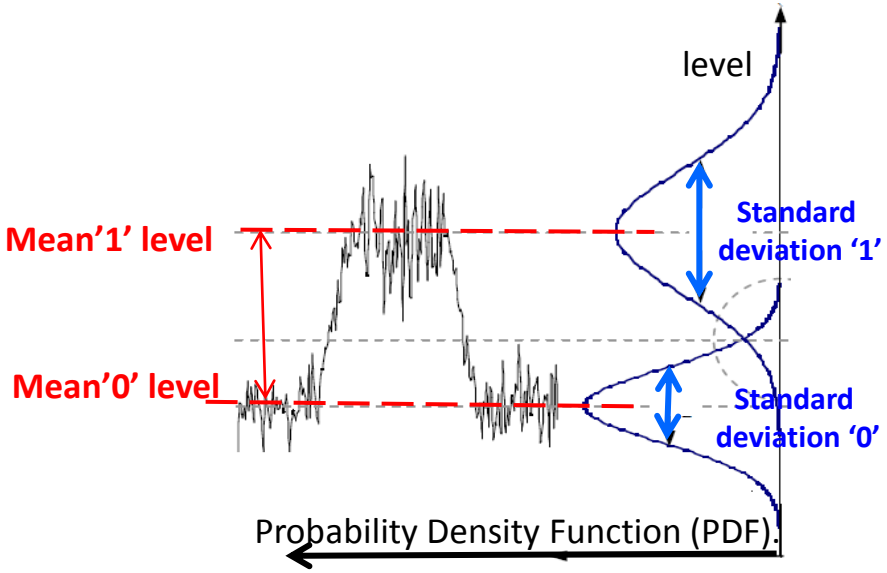
To determine No of repeaters and equalisers required and their locations and spacing

Q Factor - 定義
Q- Factor - Definition

(Reference Materials)
(参考资料)

- **Definition of Q Factor:** Q系數定義

$$Q = \frac{\text{mean}"1" - \text{mean}"0"\ \text{(level)}}{\text{standard deviation}"1" + \text{standard deviation}"0"\ \text{(noise RMS level)}}$$



- **Bit Error Rate (BER):** 誤碼率
  - **digital approach in measuring Performance**
    用數字方式衡量性能
- **Q Factor:** Q系數
  - **analog approach in measuring Performance**
    用模擬方式衡量性能
- **Relation between Q Factor & BER:** Q系数和误码率之间的关系

$$\text{BER} = \frac{1}{2}\,\text{erfc}\left(\frac{Q}{\sqrt{2}}\right)$$

where **erfc (complementary error function)**:

$$\text{erfc}(x) = 1 - \frac{2}{\sqrt{\pi}}\int_x^{\infty} e^{-t^2}\,dt.$$

Q Factor - 用 途
Q- Factor - Usage

(Reference Materials)
(参考资料)

Why use Q Factor:
為什麼要用Q factor

- **independent of speed & bit patterns**
  獨立於傳輸速度和數位模式
- **takes < 1 minutes in measurement, much faster than BER test**
  測量所需時間少於1分鐘，遠遠少過BER測試

Time to measure BER at different bit rates

BER	10^{-4}	10^{-8}	10^{-14}	10^{-15}	10^{-16}	10^{-18}	10^{-20}
STM-16/ OC-48	0.004 ms	0.04 s	11 h	6 days	46 days	13 y	1268 y
STM-64/ OC-192	0.001 ms	0.01 s	3 h	28 h	12 days	3 y	317 y

Usage of Q Factor Meter:
Q因數計的用途:

- **Manufacturing - for system performance test**
  製造 --系统性能測試
- **System Acceptance - for a fast BER estimation (BER pre-qualification)**
  系統驗收 -- 快速BER估計（BER 測試之先前資格)
- **Installation and operation - for system optimization**
  安裝和操作 -- 系統優化
- **Maintenance, troubleshooting and monitoring**
  維護 -- 故障診斷和監測

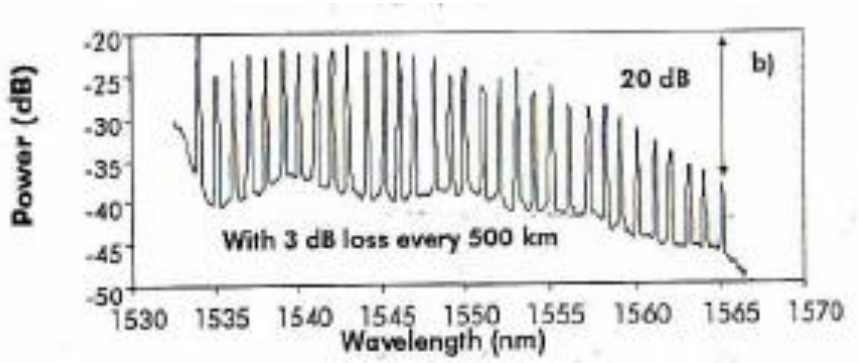
Q 預算表 -- 每主項詳細解釋 (1) (Reference Materials) (參考資料)

Q-Budget Table – Key Items Detailed Explanations

Line	Parameters	Detailed Explanations
0	Begin of Life (BOL) End of Life (EOL)	Performance of the system when put into service Performance of the system at end of design life (usually 25 years)
1.	Mean Q Value (from simple SNR type calculation)	This is a theoretical linear Q factor due only to fiber link optical signal to noise ratio (OSNR) excluding any receiver noise. This is calculated from the following formula: $$Q = \frac{2(D)OSNR\sqrt{\frac{B_o}{B_e}}}{\sqrt{1 + 4(D)OSNR\left[1 + \frac{r_e}{1 - r_e}\right]} + \sqrt{1 + 4(D)OSNR\left[\frac{r_e}{1 - r_e}\right]}}$$ $$(D) = \frac{1 - r_e}{1 + r_e}$$ Where Q = mean Q-factor assuming NRZ signal format, linear OSNR = link OSNR, linear B_o = optical channel bandwidth set by DWDM bandwidth, GHz Be = receiver electrical bandwidth available from transceiver specifications, GHz (D) = extinction ratio power penalty inverse, linear r_e = extinction ratio (inverse) available from transceiver specifications, GHz

Q 預算表 -- 每主項詳細解釋 (2) (Reference Materials) (參考資料)

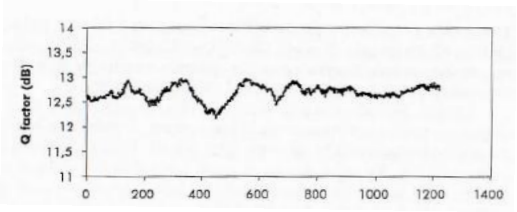
Q-Budget Table – Key Items Detailed Explanations

Line	Parameters	Detailed Explanations
1.1	Propagation Impairment penalties	Corresponds to impairment due to interplay between fiber chromatic dispersion and non-linear effects
1.2	Gain flatness impairments	Corresponds to the gain of the system (amplifiers ..) is not flat 
1.3	Non-optimal optical pre-emphasis impairment	Launched power of each wavelength into the link has to be adjusted in order to ensure same transmission quality for all wavelength at the link output. This process is called power pre-emphasis
1.4	Wavelength toleration impairment	WDM (Wavelength Division Multiplex) channel passband ripple misalignment between WDMs can result in additional signal loss during laser wavelength drift, which can lead to Q factor degradation

Q 預算表 -- 每主項詳細解釋 (3)

(Reference Materials)
(參考资料)

Q-Budget Table – Key Items Detailed Explanations

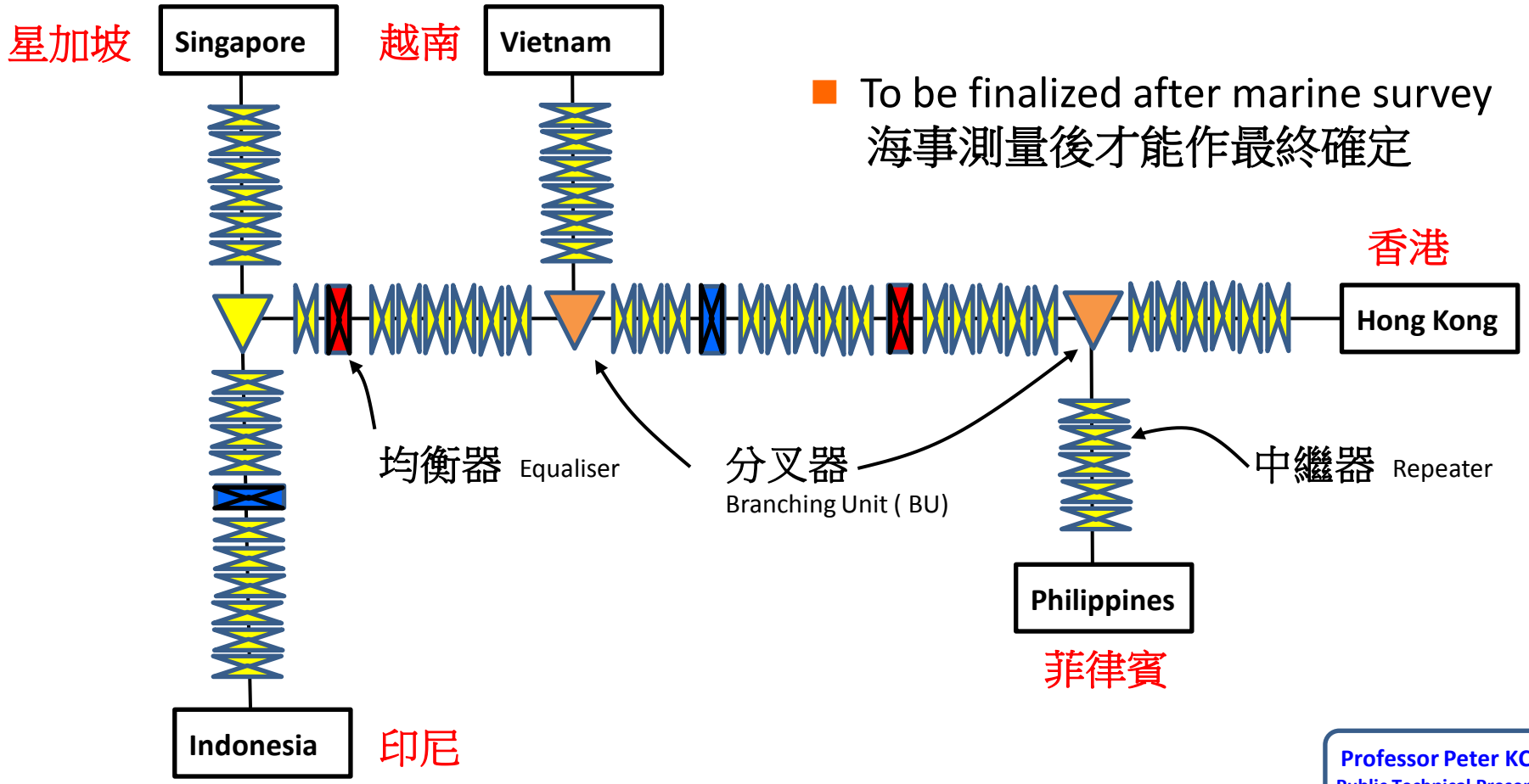
Line	Parameters	Detailed Explanations
1.5	Mean Polarization Loss (PDL) penalty	Corresponds to dependence of insertion loss of passive components to signal state of polarization (SOP)
1.6	Mean Polarization Gain (PDG) penalty	Corresponds to dependence of amplifier gain to the pump SOP.
1.7	Mean Polarization Dispersion (PMD) penalty	Corresponds to dependence of fiber refractive index on signal SOP
1.8	Supervisory impairment	For submarine system, the supervisory commands are sent to sub sea amplifiers and other equipment by low frequency amplitude modulation of optical signal, This modulation amplitude is small compared to data signal but does result in a small Q-factor penalty
1.9	Manufacturing & environment impairments	Corresponds to performances difference between specified and manufactured equipment, including performance degradation induced by environment effects, temperature, shock….
2	Time varying system performance	This corresponds to the Q factor fluctuation mainly due polarization effects 

Q 預算表 -- 每主項詳細解釋 (4) (Reference Materials) (參考資料)

Q-Budget Table – Key Items Detailed Explanations

Line	Parameters	Detailed Explanations
3	Line Q value (Line 1-1.1to Line 1-1.9)	Corresponds to sum up Line 1-1.1to Line 1-1.9
4	Specified TTE Q value (back to back)	This is due to non- infinitive SNR and non-perfect electronic of TTE (Terminal Transmission Equipment). TTE Q is the Q factor obtained when the transmitting terminal is directly looped back to the receiving terminal
5	Segment Q value (computed from line 3 and 4)	Segment Q factor is deduced from the following formula: $\frac{1}{\text{Segment Q}} = \frac{1}{Q^2_{\text{TTE}}} + \frac{1}{Q^2_{\text{Line}}}$
5.3	Effective Segment Q value with FEC	This corresponds to the minimum Q factor required before error correction to achieve the required transmission quality after correction. This value depends on the types of Forward Error Correction (FEC) used

典型海纜系統之直線圖 (由鏈路Q預算表計算後得到)
Typical Straight Line Diagram for the whole System (Derived after link Q Budget Calculation)



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+地上及海上之安裝 Land & Marine Installation

海上安裝 Marine Installation

- 需要聘請專業海纜船
  Need to employ professional Cable ship

海上安裝之工序
Marine Installation Process

在船上組合水下器材 Onboard splicing or assembly of wet plants

清理路由 Route Clearance & Pre-lay Grapnel Run

鋪設及埋藏海纜 Cable Lay and Burial

海纜登岸 Shore End Landing

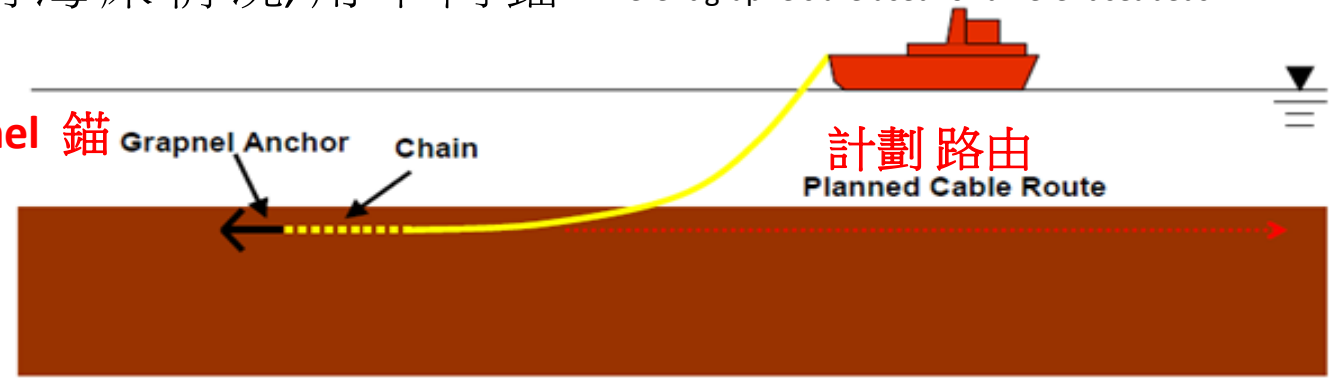
初步完成

遙控潛水器視察 Post Lay Inspection by ROV (Remote Controlled Vehicle)

如有需要,再埋海纜 Post Lay Burial , if required

路由之清理 Route Clearance & Pre-Lay Grapnel Run

- 在所有需要埋藏之區域進行 Conduct in all burial sections
- 目的是清理所有垃圾, 漁具.... Purpose is to clear all debris, fishing gears.....
- 方法是用特別的船錨, 在路由上走一遍 Use special grapnels to run along the cable route
- 不同海床情況, 用不同錨 Different grapnels are used for different seabeds

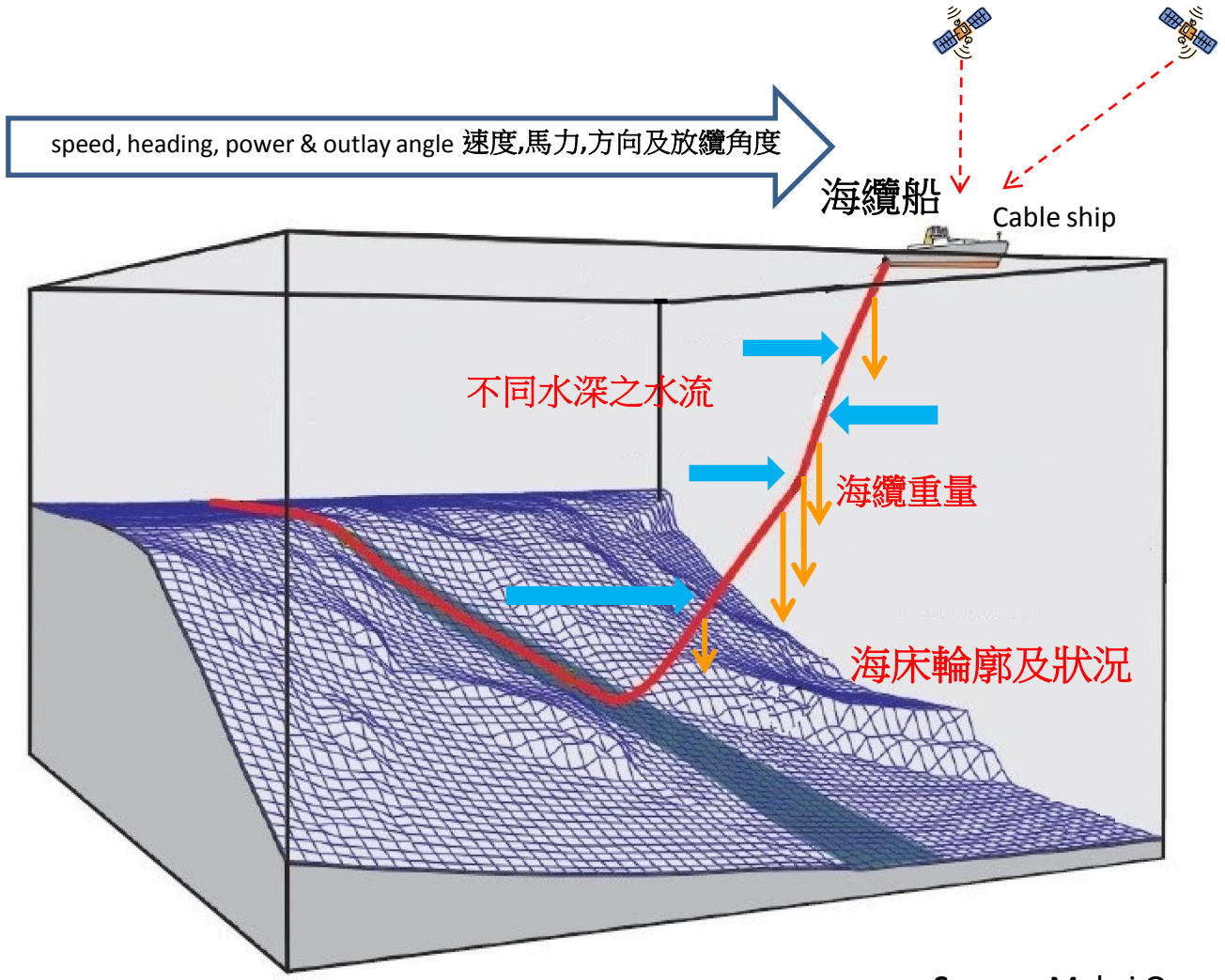


用於路由清理不同種類的錨 Grapnel

SG Gifford

Short Prong

鋪設海纜是復雜之操作 Cable Lay – Sophisticated Operation



根據： according to

- 不同水深之水流
  Under sea current at different depth
- 海纜重量
  Cable weight
- 海纜鬆弛度
  Cable slag
- 海床輪廓及狀況
  Sea bed profile & condition
- 水深
  Water depth

+ 衛星導航
  Navigated by satellites
+ 電腦實時控制
  Computer real time control

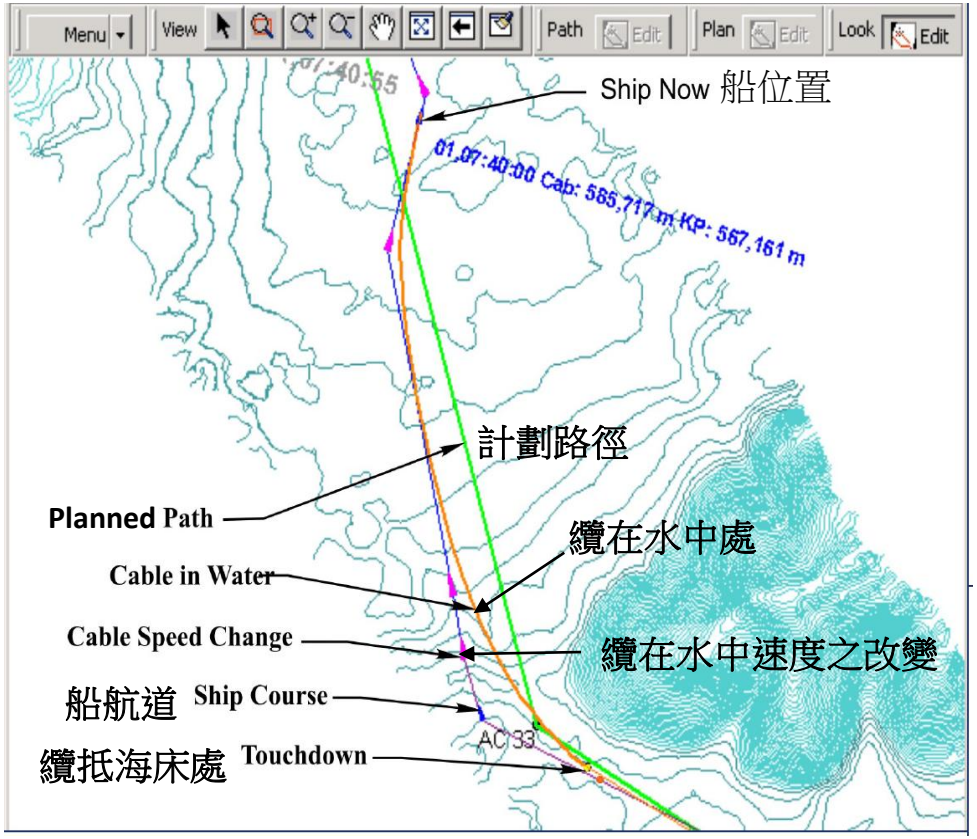
海纜船之： Cable ship

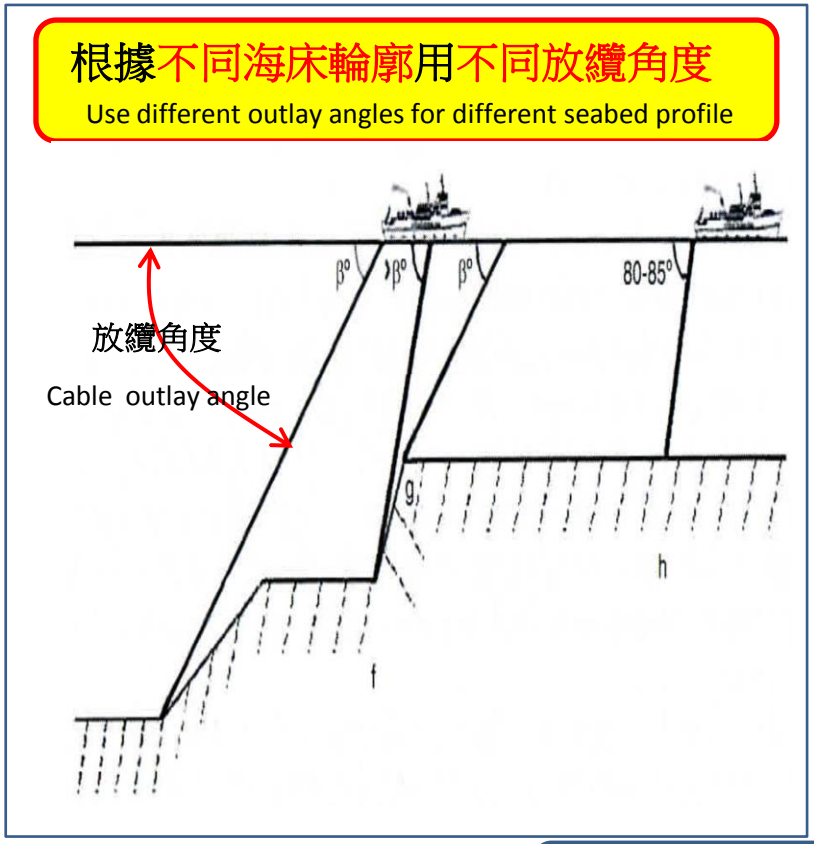
- 速度 speed
- 馬力 power
- 方向 heading
- 放纜角度 outlay angle

Source: Makai Ocean Engineering

鋪設海纜是復雜之操作 Cable Lay – Sophisticated Operation

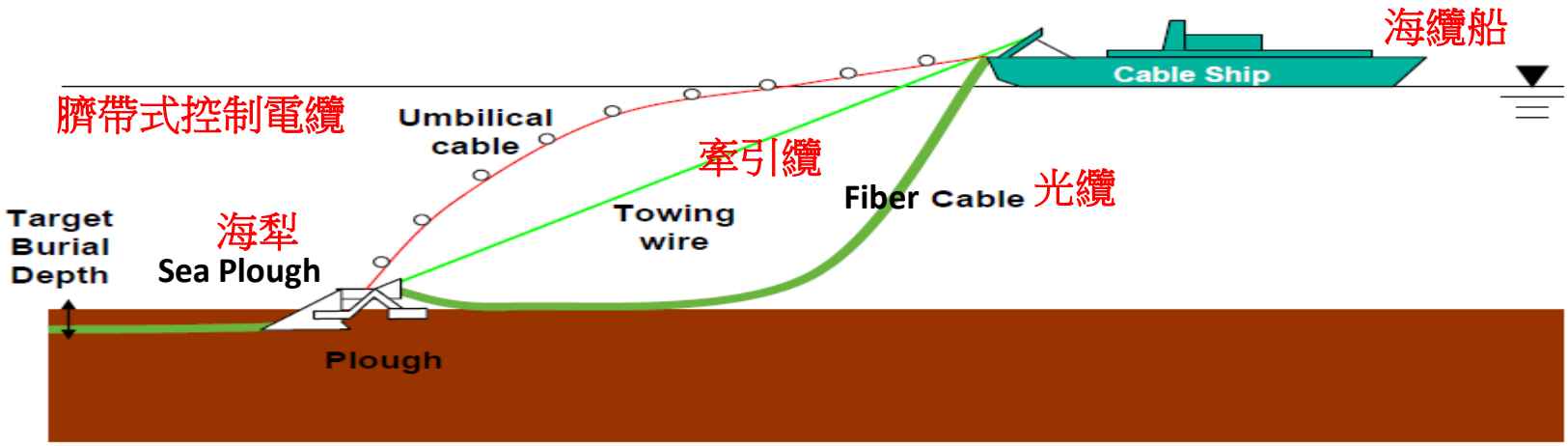
- 在深海要準確地鋪設海纜到海底指定的地方是有挑戰性的
  Laying cable at specific location in deep water is a very challenging task





Source: Makai Ocean Engineering

大陸架上埋藏海纜 Cable Burial over Continental Shelf



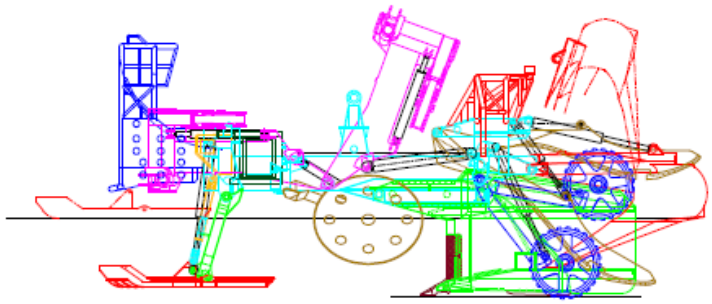
- **是由電腦控制操作**is a computerized controlled operation

  準確控制 precisely controlled:

  + 船之速度,馬力及方向
    Speed, power and direction of ship
  + 海纜之鬆弛度
    Slack of the cable

- **對抗常變之水下水流及不同之海床**
  against changing undersea current and seabed conditions

海犁 Sea Plough



三種海纜埋藏操作 Three Types of Burial Operation

用海犁埋藏 Burial by Sea Plough

- 埋藏深度1到1.5米 burial depth around 1 to 1.5 meter
- 用於大陸架 apply on Continental Shelf

用强水噴法埋藏 Burial by Strong Water Jet

- 埋藏深度1.5到3米 burial depth around 1.5 to 3 meters
- 用於近岸 apply near shore

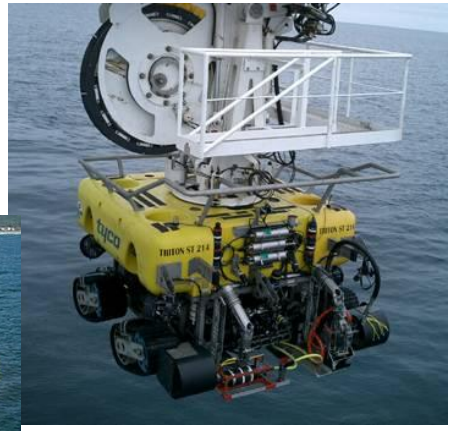
用挖溝法埋藏 Burial by Trenching

- 埋藏深度達12米 deep burial up to 12 meters
- 用於船舶拋錨區和繁忙航道
  apply in heavy anchoring areas and busy ship lanes

不同種類之海犁 Different Types of Sea Ploughs

- 不同種類之海犁用於 Different Types of Ploughs for:
  - + 不同深度 Different burial depth
  - + 不同海床 Different types of seabed

遙控潛水器
Remote Operated Vehicle



輕型犁
Light Plough

中型犁
Medium Plough

重型犁
Heavy Plough

强水噴式埋藏法 Burial by Strong Water Jet

- 通常用於近岸及近海安裝
  Usually for shore end or near sea installation

挖溝法埋藏海纜 Burial by Trenching

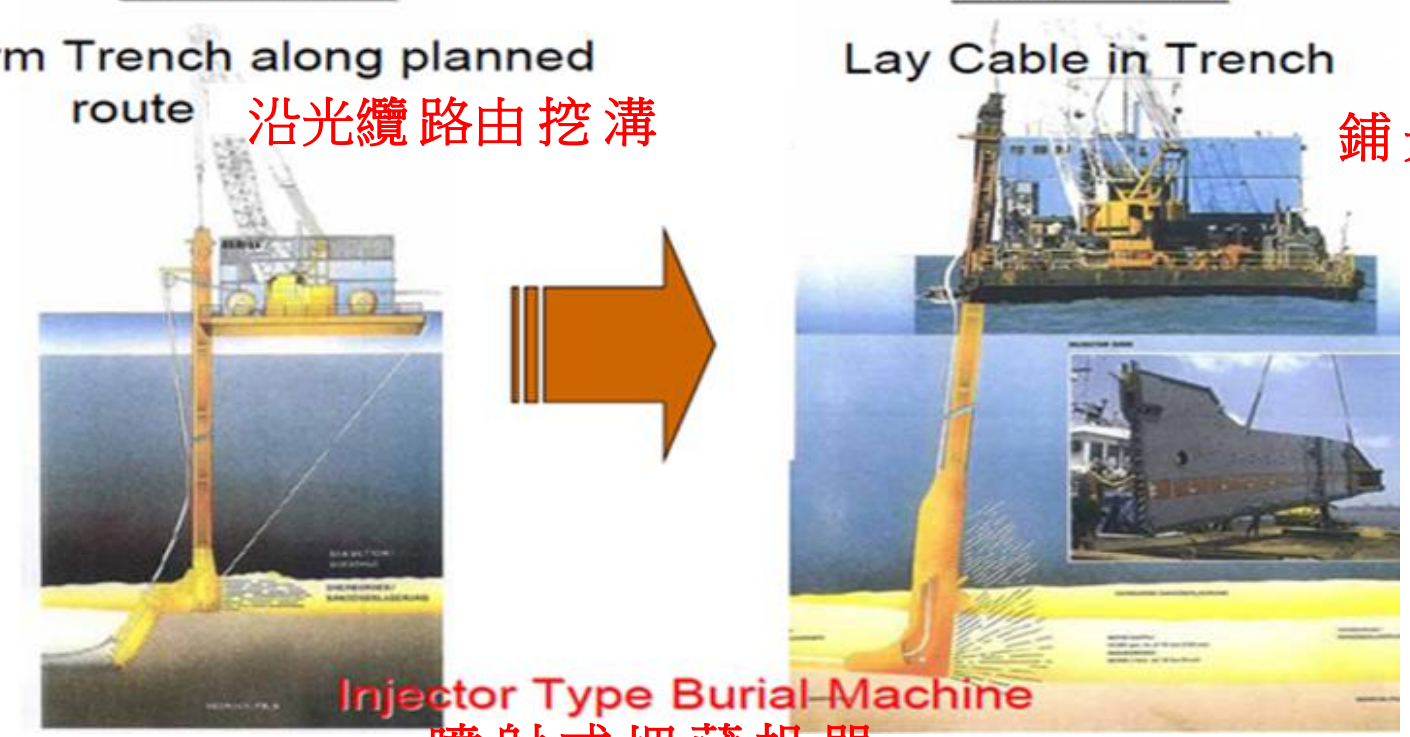
- 可深埋達 **12** 米, 通常用於近岸安裝
  Usually for shore installation (up to 12 meters)

Phase One 第一步

Form Trench along planned route 沿光纜路由挖溝

Phase Two 第二步

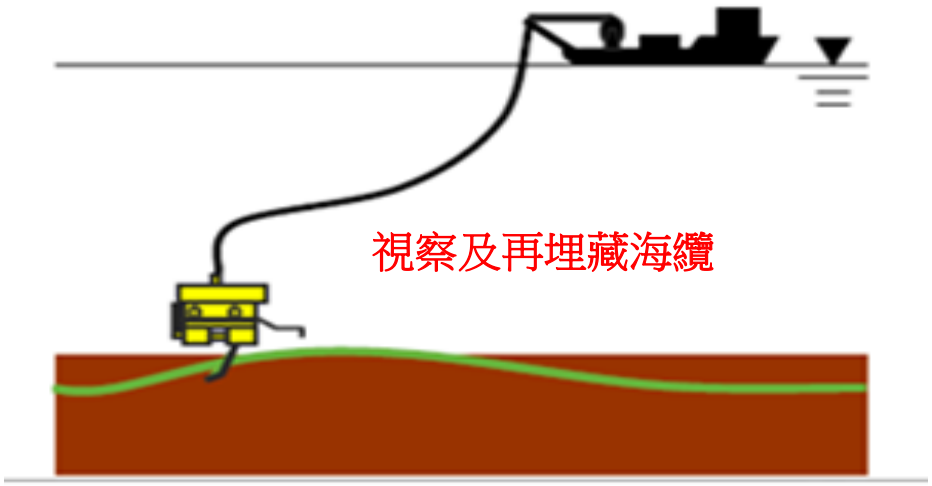
Lay Cable in Trench 鋪光纜到溝內



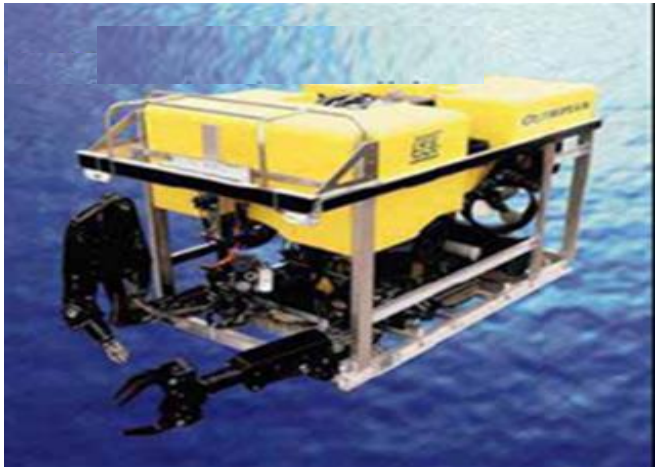
Injector Type Burial Machine
噴射式埋藏机器

鋪設海纜後之視察及再埋藏
Post Lay Inspection and Burial (PLIB)

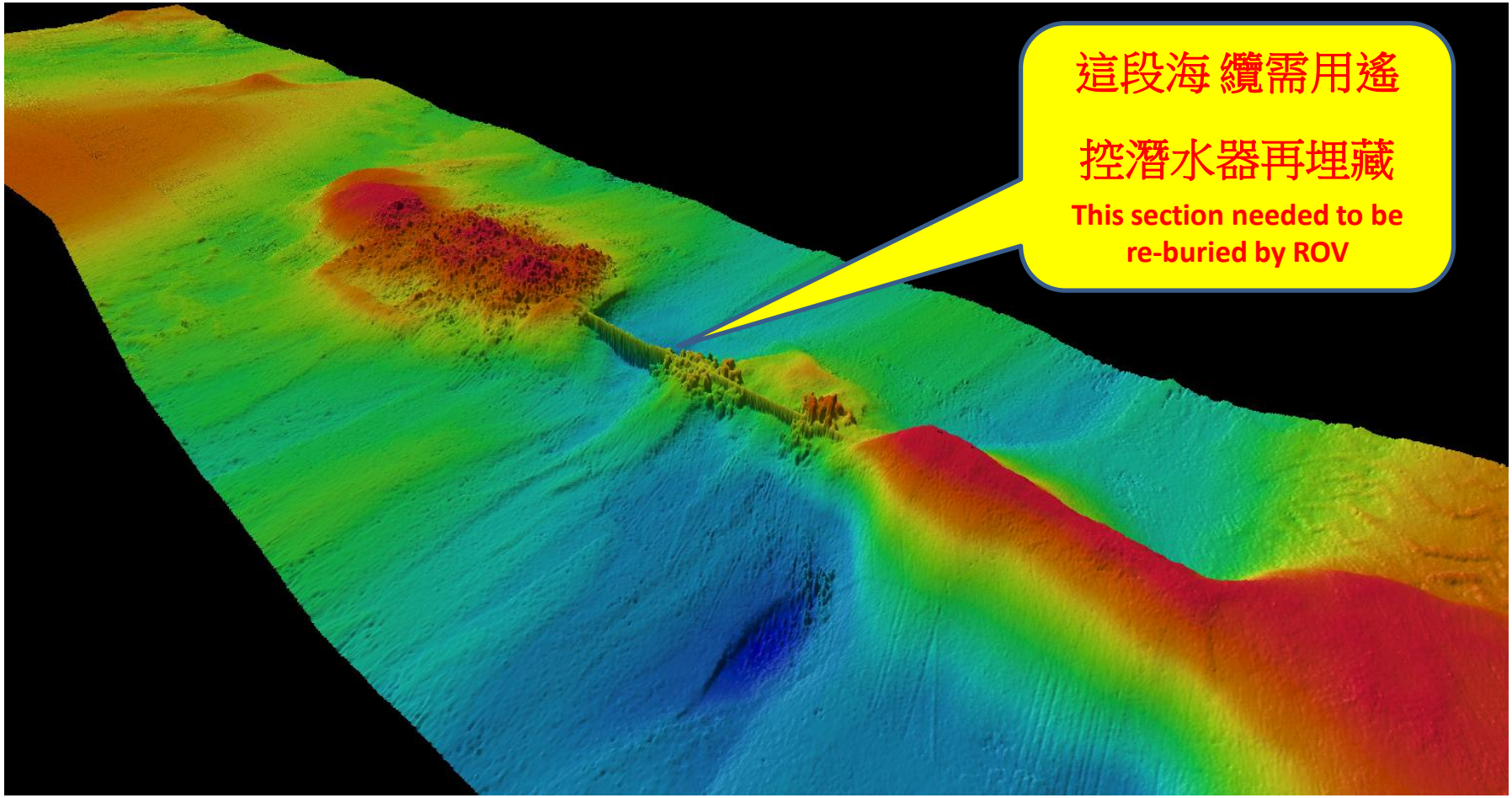
- 由遙控潛水器執行
  Carry out by Remote Operated Vehicle (ROV)
- 遙控潛水器能視察及用水噴再埋藏海纜
  Capable of inspection and Cable Burial by water jet



遙控潛水器
Remote Operated Vehicle (ROV)



鋪設海纜後之視察及再埋藏
Post Lay Inspection and Burial (PLIB)



Source: EGS

淺水海纜鋪設平底船 ("Networker" 号)

Shallow Water Cable Laying Barge "Networker"

海纜船 用於鋪設和維修海纜
Cable ships for cable laying and repair

KDD OCEAN LINK

CABLE RETRIEVER

SEGERO

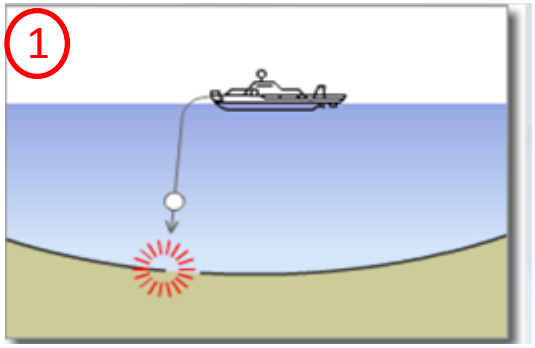
KDD PACIFIC LINK

ASEAN RESTORER

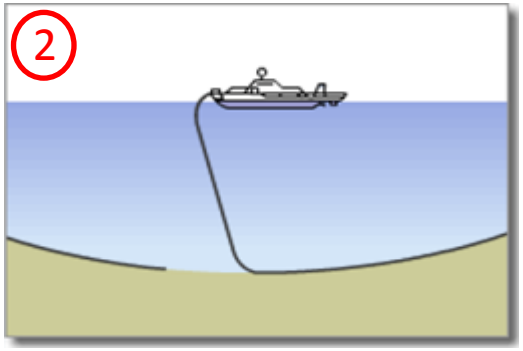
海纜船復修海纜之工序 -- 費時,複雜及昂貴

Cable Ships Repair Process – Complicate, expensive and time consuming

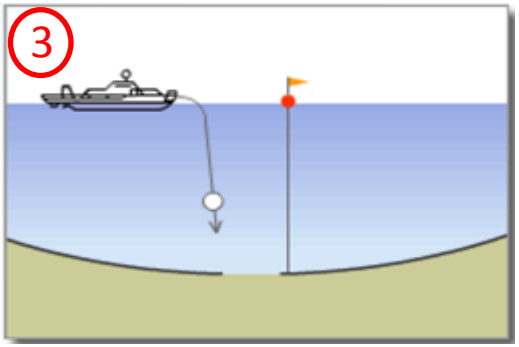
(Reference Materials)
(參考資料)



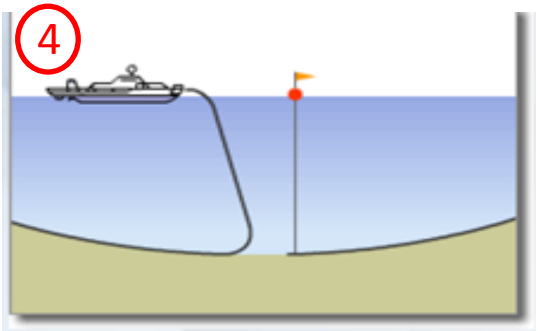
海纜船開到損壞點附近，放下搜巡撈勾，將海纜截斷撈起



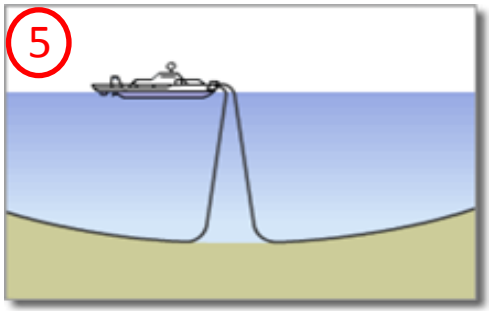
將截斷後之海纜一端撈至船上，進行測試



把海纜密封，繫上浮標放回海中後，海纜船再打撈另一端海纜



撈起另一端海纜收回船上，把受損段切除，再接駁新海纜，完成測試後鋪設海纜至浮標處



將浮標端海纜收到船上，與新海纜接駁，再與兩端海纜站測試，最後把海纜放回海中

費時：

+ 集合各地之船員和技術員到電纜船停泊處
+ 到倉庫上載電纜和器材
+ 申請進入有關國家之海域
+ 受天氣所限制

複雜：

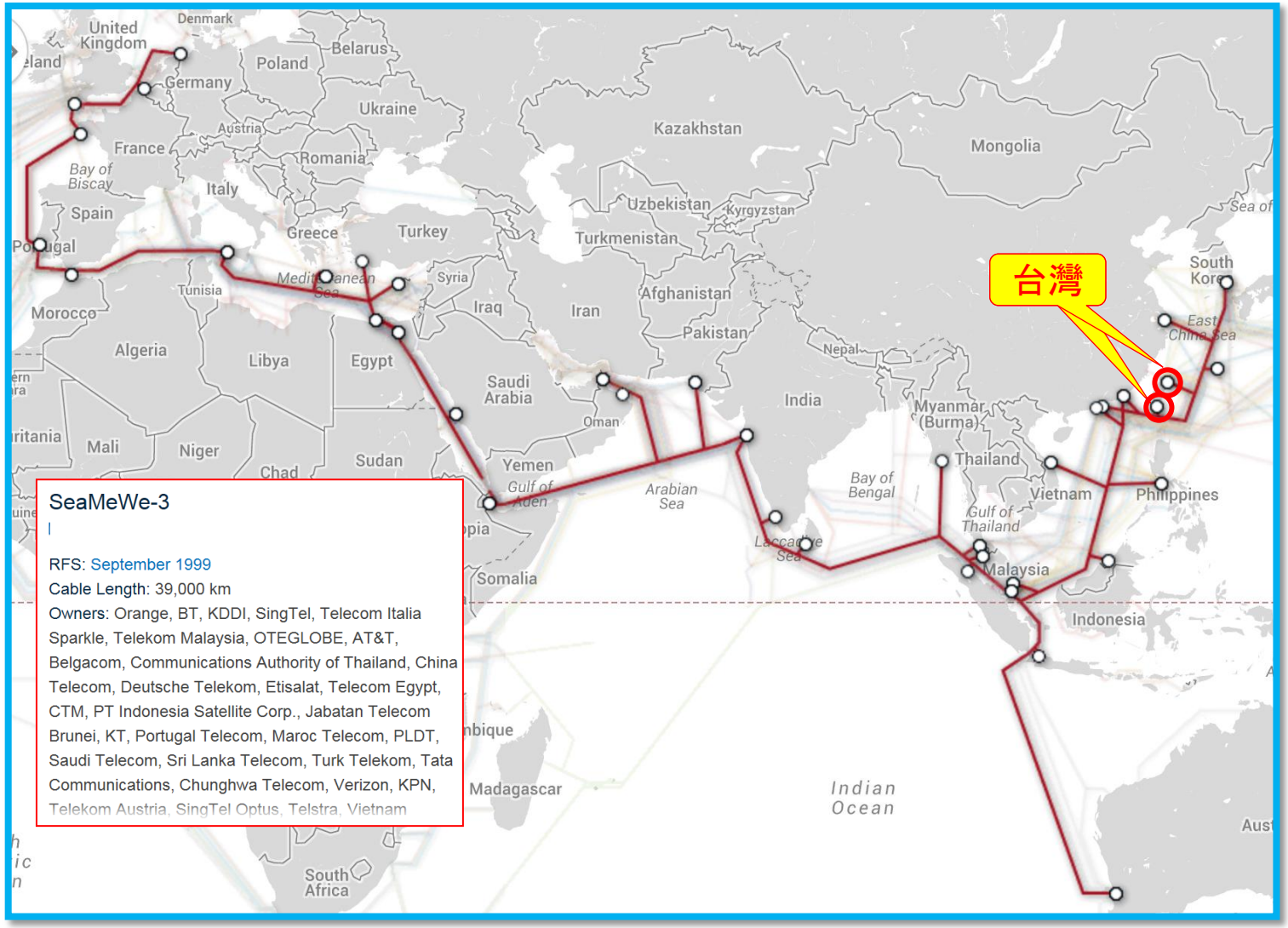
+ 深海撈起電纜是困難的
+ 復收工序是非常複雜的

連接台灣之光纖海纜

參 考 資 料 Reference Information

連接台灣之光纖海纜 (1) – South East Asia–Middle East–Western Europe - 3 (SMW -3)

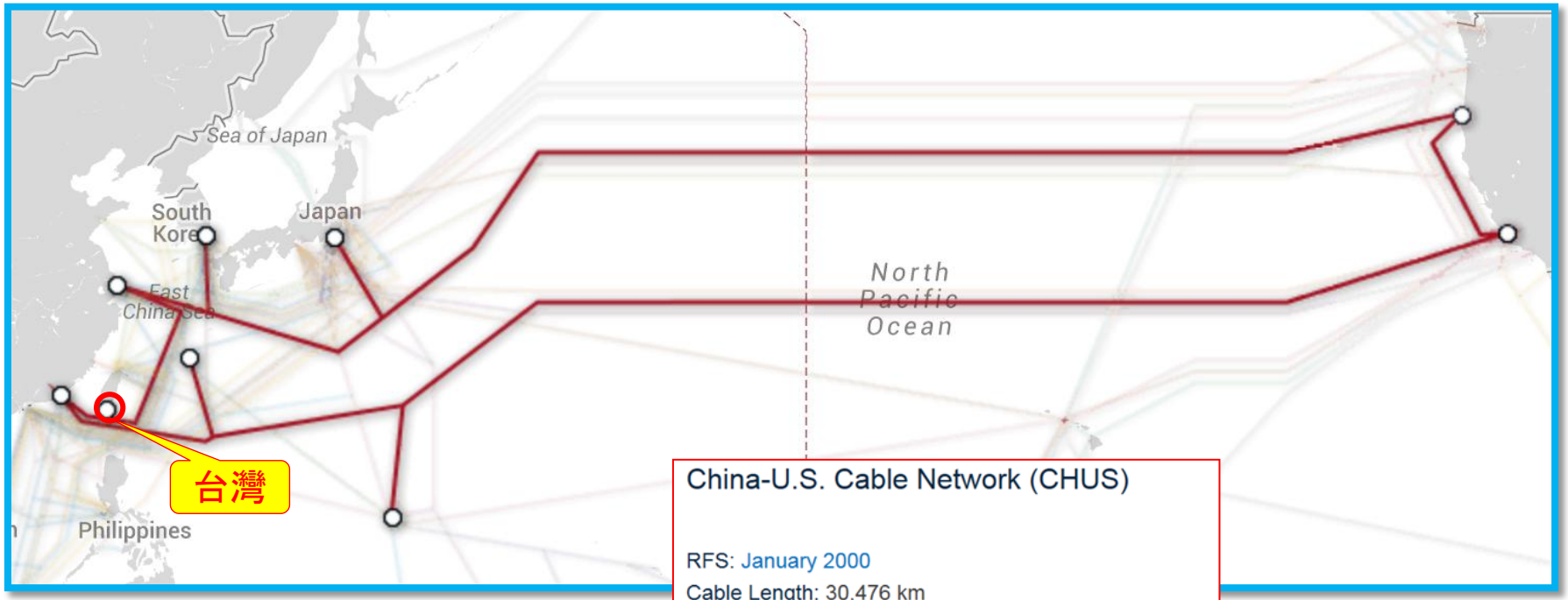
(Reference Materials)
(參考资料)



Source: TeleGeography

連接台灣之光纖海纜 (2) – China-US Cable Network (CHUS)

(Reference Materials)
(参考资料)



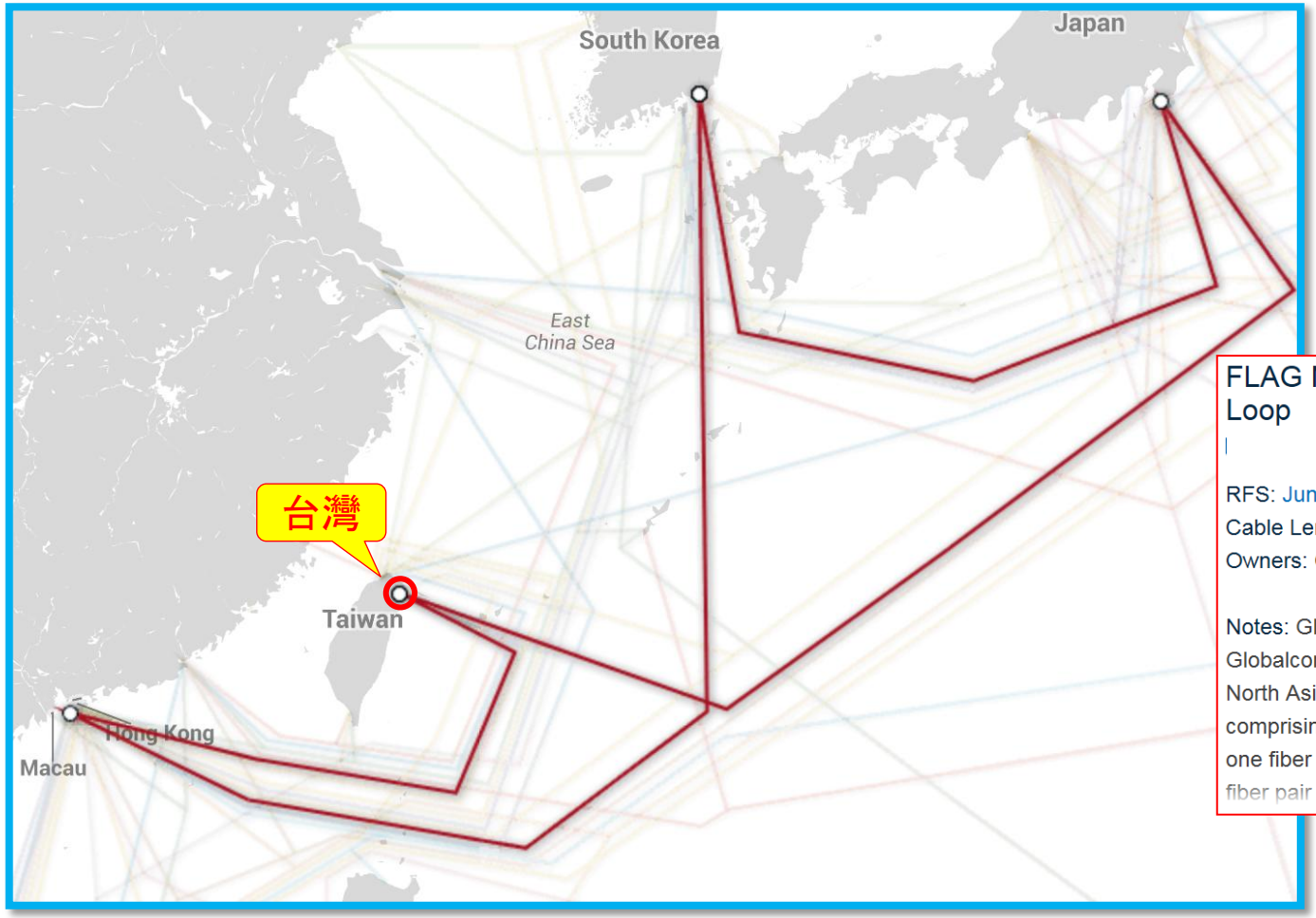
China-U.S. Cable Network (CHUS)

RFS: January 2000
Cable Length: 30,476 km
Owners: Verizon, AT&T, KDDI, Tata Communications, China Telecom, Chunghwa Telecom, KT, NTT, Level 3, SingTel, Sprint, Telekom Malaysia, Telecom New Zealand, Telstra, PCCW, LG Uplus, Softbank Telecom, Rostelecom, SingTel Optus, Orange

Source: TeleGeography

連接台灣之光纖海纜 (3) – Flag North Asia Loop

(Reference Materials)
(參考资料)



FLAG North Asia Loop/REACH North Asia Loop

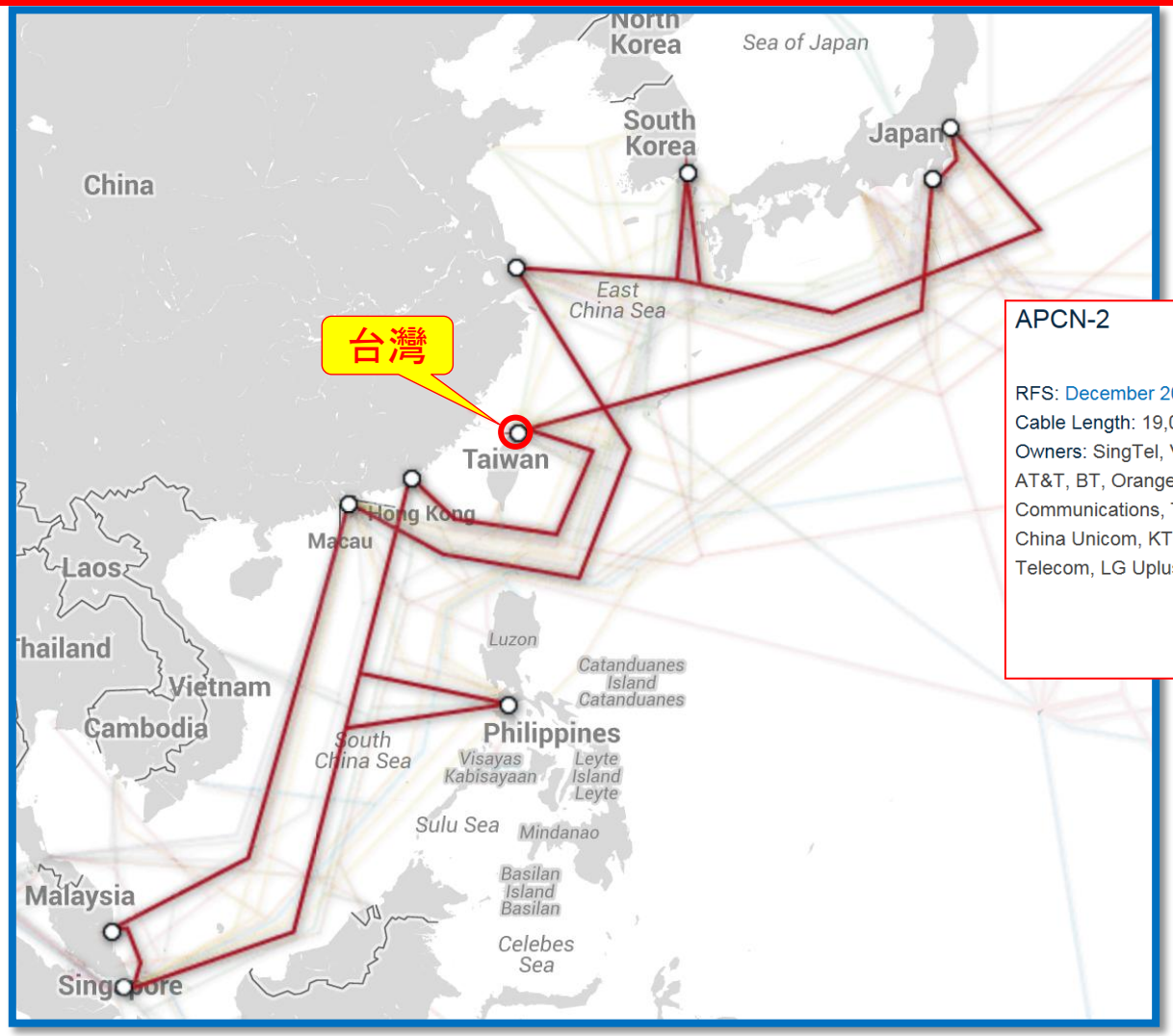
RFS: June 2001
Cable Length: 9,504 km
Owners: Global Cloud Xchange, PCCW, Telstra

Notes: Global Cloud Xchange, formerly Reliance Globalcom, owns 3 fiber pairs which it refers to as FLAG North Asia Loop. Of the three remaining fiber pairs comprising the REACH North Asia Loop, Telstra owns one fiber pair, PCCW owns one fiber pair, with the final fiber pair is jointly owned by Telstra and PCCW

Source: TeleGeography

連接台灣之光纖海纜 (4) – Asia Pacific Cable Network 2 (APCN-2)

(Reference Materials)
(參考资料)



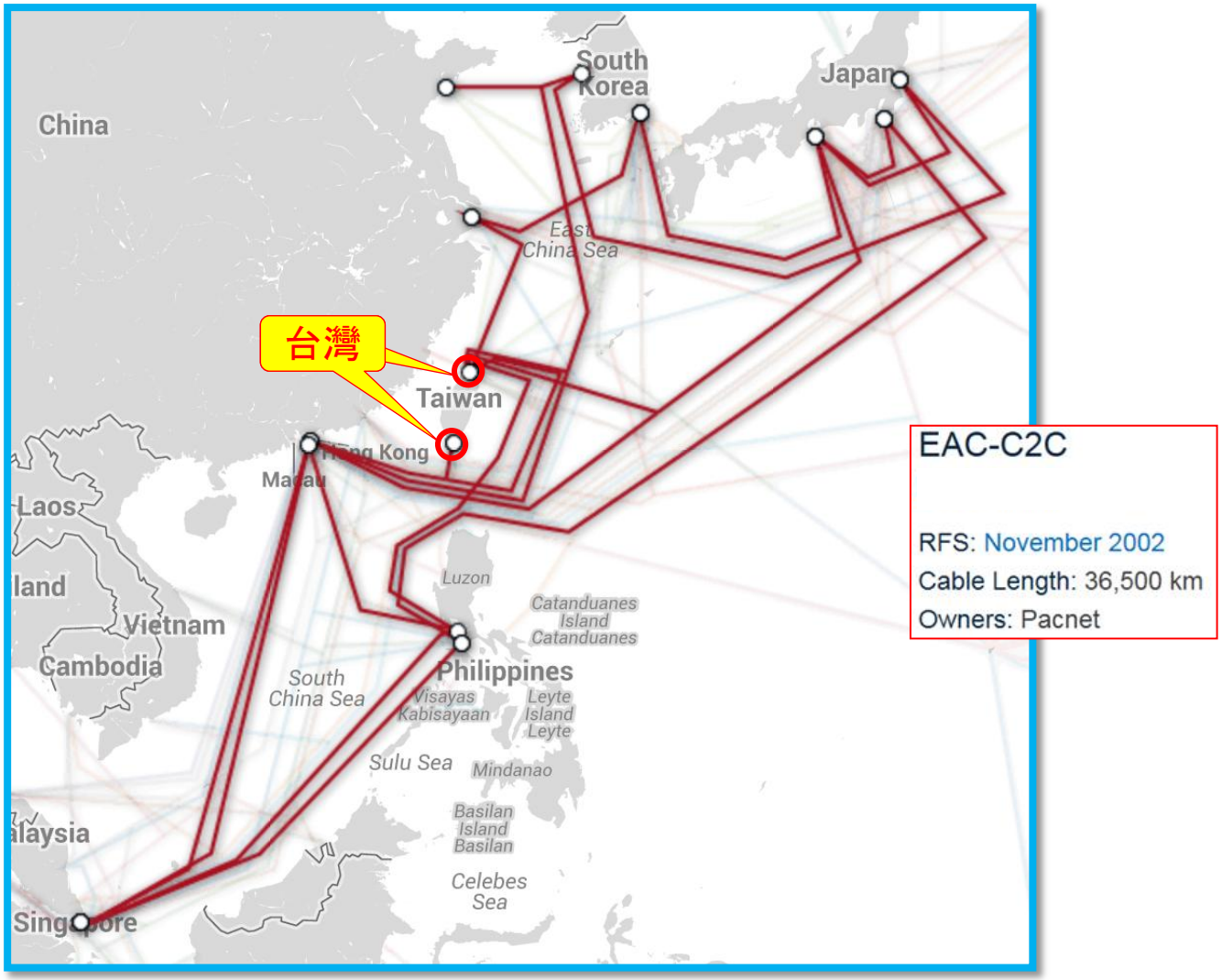
APCN-2

RFS: December 2001
Cable Length: 19,000 km
Owners: SingTel, Verizon, KDDI, Chunghwa Telecom, AT&T, BT, Orange, Softbank Telecom, NTT, Tata Communications, Telekom Malaysia, Starhub, PLDT, China Unicom, KT, SingTel Optus, Telstra, PCCW, China Telecom, LG Uplus, New World Telecom, Vodafone

Source: TeleGeography

連接台灣之光纖海纜 (5) – Asia Pacific Crossing (EAC) – City to City (C2C)

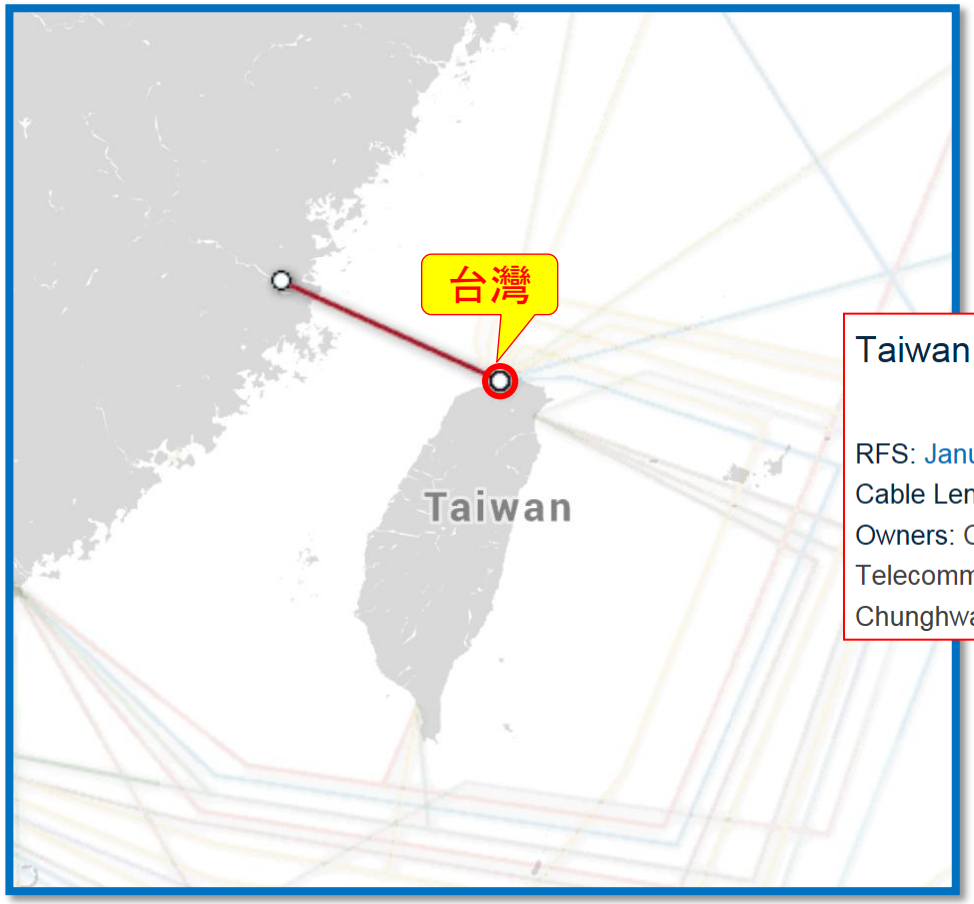
(Reference Materials)
(参考资料)



Source: TeleGeography

連接台灣之光纖海纜 (6) – Taiwan Strait Express (TSE-1)

(Reference Materials)
(參考資料)



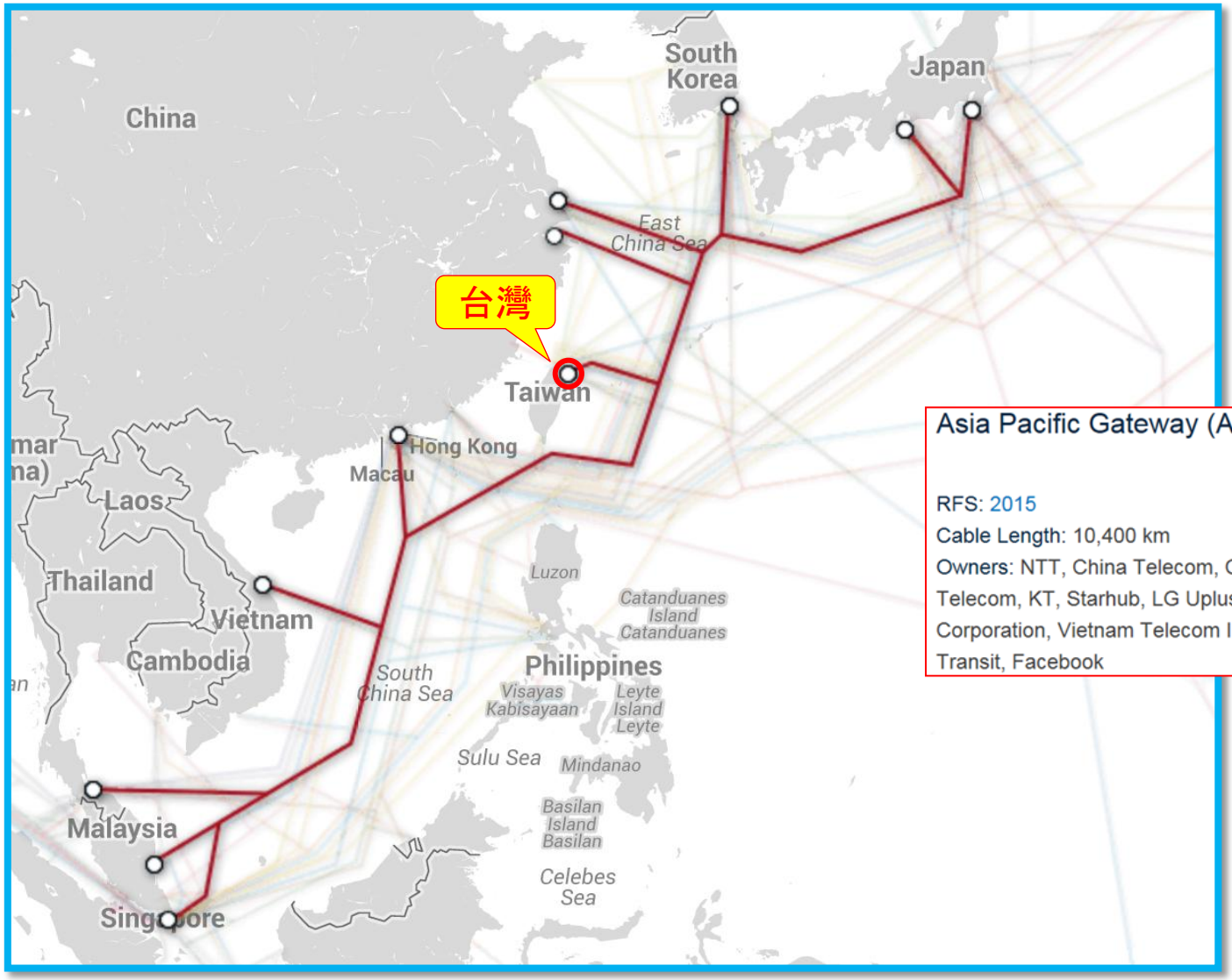
Taiwan Strait Express-1 (TSE)-1

RFS: January 2013
Cable Length: 260 km
Owners: China Unicom, Far Eastone Telecommunications, Taiwan Mobile, China Telecom, Chunghwa Telecom, China Mobile

Source: TeleGeography

連接台灣之光纖海纜 (7) – Asia Pacific Gateway (APG)

(Reference Materials)
(參考资料)



Asia Pacific Gateway (APG)

RFS: 2015
Cable Length: 10,400 km
Owners: NTT, China Telecom, China Unicom, Chunghwa Telecom, KT, Starhub, LG Uplus, China Mobile, Viettel Corporation, Vietnam Telecom International, Global Transit, Facebook

Source: TeleGeography

(For Academic Reference Only)

i.e. with no direct or indirect business implications

第一條連接台灣與香港之光纖海纜 (HONTAI - 2) 歷史照片

First Fiber Optic Submarine Cable connecting Taiwan and Hong Kong (HONTAI - 2)

(Reference Materials)
(參考资料)

講者與子 Speaker & son

海纜船 Cable ship

與中華電信同行討論
Discussion with colleague in Chunghwa Telecom.

第一條連接台灣與香港之光纖海纜

First Fiber Optic Submarine Cable connecting Taiwan and Hong Kong

連接：台灣枋山香港鶴咀海纜站

Connect: Fang Shan and Cape Daguilar Cable stations

全長：735 km.

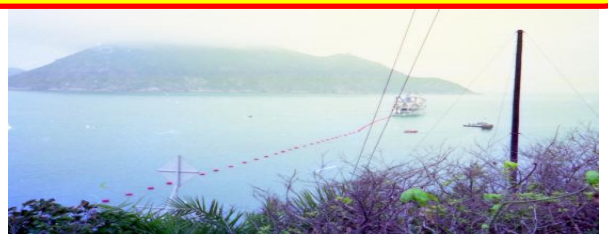
Total Length: 735 km.

速度：420 Mb/s

Speed : 420 Mb/s

投產日期： 1990

Ready for Service date: 1990



海纜在香港登岸 Cable Landing in Hong Kong

海纜在香港登岸 Cable Landing in Hong Kong

最後請看一段短錄像

Contact: (for further information and discussion)

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peterkc.yu@cityu.edu.hk