Submarine Power Cable Systems
Design, Planning, and Implementation Guide

IEEE PES NY Chapter

NYC September 18, 2018

LS Cable America

Your Link To Energy

SUBMARINE CABLE

BASIC METHODOLOGY

“How to plan & execute a successful submarine power cable project”

This Overview Guide is intended provide:

- A broad overview of the specialized engineering and project considerations involved when including submarine cable in the design of a transmission system.

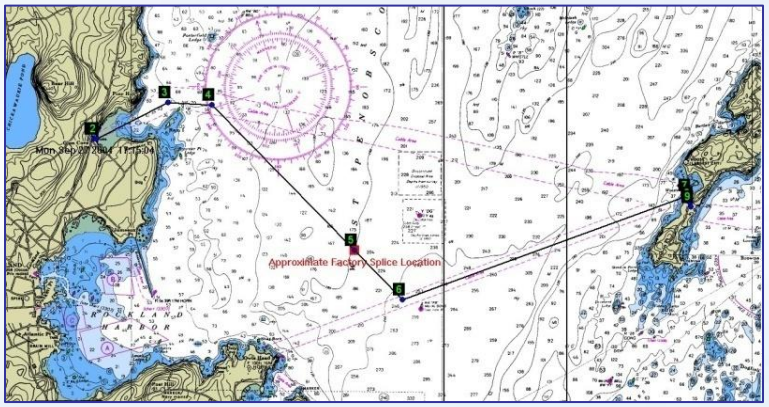
- Highlights of what is involved when preparing to develop or design projects involving submarine power cable installation with an emphasis on submarine cable laying & burial techniques.

Overview Objectives

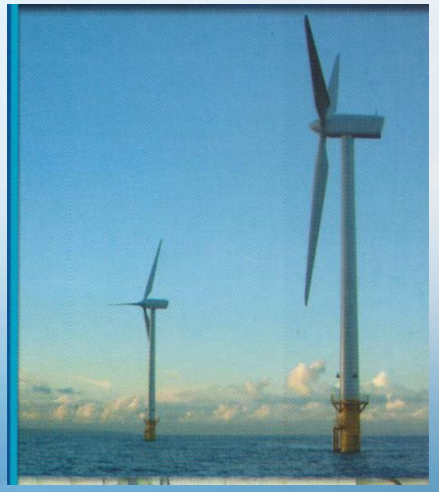
- Objective 1: Identification of Project Needs; Project Design Parameters When Planning Submarine Cable Use
- Objective 2: Project Support Expectations When Designing and Developing Submarine Cable Projects
- Objective 3: A Discussion of Typical Submarine Cable System Sections, from Manufacture to Installation; Freighting, HDDs, Landings, Termination Structures, Planned Joints, and Submarine Cable Laying/Burial techniques.
- Objective 4: Typical Submarine Cable Project Commercial Structure and What to Expect When Preparing a Tender, RFI or RFP

Objective 1: Identification of Project Needs

- Project Needs: Design Parameters Warranting Submarine Cable Use
  - Is the cable route best served by a water body crossing, or is a water crossing unavoidable?



- Very large lakes, rivers
- Mainland to Island Systems
- Inter Island Systems
- **Offshore Wind Farms**
- Offshore Transmission
- Bay crossings
- Transmission or Distribution



Objective 1: Identification of Project Needs

- Customer Needs: Minimum Design Parameters to Move from “Concept” to RFI
  - Defining the minimum project parameters by the system owner in developing the initial RFI?
    - Power System Requirements
      - System Voltage, Nominal and Peak Current Expectations
      - Minimum Cable Design
    - System Depth of Burial Requirements
      - Help define anticipated ampacity calculations
      - Give a “first glimpse” of the possible installation methods
    - New Terminal Station vs. Existing Substation
      - Helps define logical site layout
      - Further defines anticipated cable routing plan
    - Conceptual Cable Route
      - Required at the earliest stages of permitting
      - Required to define both electrical and logistical parameters

Objective 1: Identification of Customer Needs

TYPICAL SUBMARINE CABLE TYPES OR CONFIGURATIONS

AC DESIGNS

MVAC 3C XLPE

HVAC 3C XLPE

HVAC 1C XLPE

HVDC DESIGNS

HVDC XLPE

HVDC MI

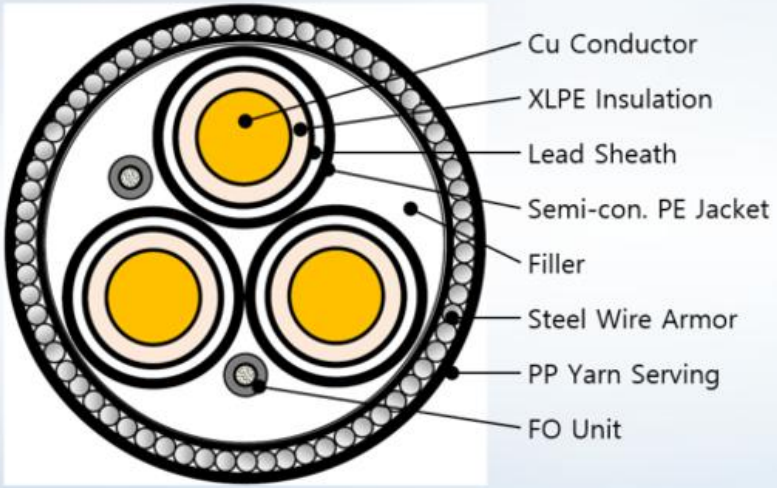
Objective 1: Identification of Customer Needs

- What is the power design specification? Include fibers for SCADA, Coms, or DTS?

- **3-Core AC Cable**
- **Coilable Design??**

■ Submarine Power Cable

- **115kV Cu 3Cx630sqmm** XLPE / Lead Sheath / PE / Steel Armor / PP Yarn



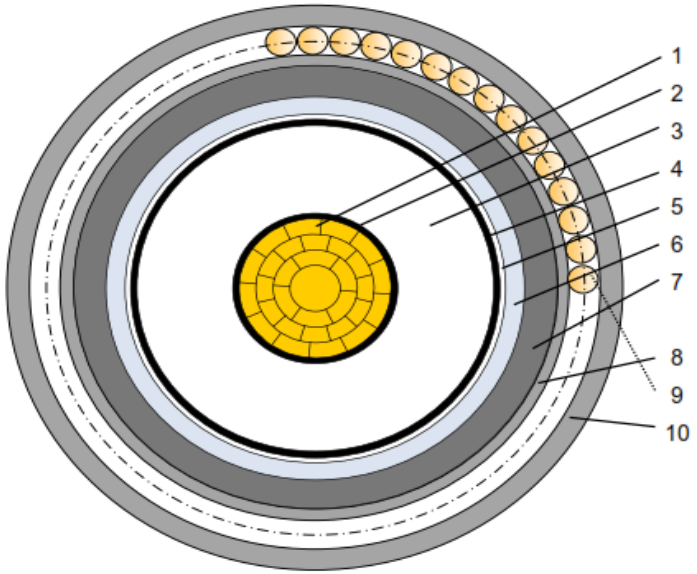
Conductor Type	Copper 3C x 630sqmm
Insulation Type	XLPE
External Diameter	9.07 inches
Min. Bending Radius	181.1 inches
Max. Sidewall Pressure	2150 lbs / ft
Cable Weight (water)	36.9 lbs / ft
Cable Weight (air)	65.6 lbs / ft
Max. Pulling Tension	51808 lbs

Objective 1: Identification of Project Needs

- **Single Core AC Cable**

Rated Voltage (U_o /U/U_m)	132 / 230 / 242 kV	Conductor Size	1C x 1800mm²

Scale: NTS



No.	Item	Material	Thickness (mm/inch)	Indicative Diameter (mm/inch)
1	Conductor	Annealed profiled(keystone shaped) copper	-	49/1.93
2	Conductor shield	Extruded semi-conducting compound	App. 1.5/0.06	-
3	Insulation	Extruded cross-linked polyethylene (XLPE)	Nom. 20.5/0.81	95/3.74
4	Insulation shield	Extruded semi-conducting compound	App. 1.3/0.05	98/3.86
5	Water blocking layer	Semi-conducting swelling tape(s)	-	-
6	Metallic sheath	Extruded lead alloy	Nom. 3.3/0.13	106/4.17
7	Anti-corrosion sheath	Extruded polyethylene	Nom. 2.9/0.11	112/4.41
8	Armor bedding	Polypropylene yarn with bitumen	App. 2.0/0.08	116/4.57
9	Wire armor	Copper wires with bitumen	Nom. 6.0/0.24	128/5.04
10	Serving	Polypropylene yarn with bitumen and black / yellow stripe	App. 4.0/0.16	138/5.43
	Overall diameter	-	-	138/5.43
	Cable weight in air / water (kg/m)		App. 54 / 38	

Objective 1: Identification of Project Needs

- Customer Needs: Minimum Design Parameters to Move from “Concept” to RFI
  - Defining the minimum project parameters by the system owner in developing the initial RFI?

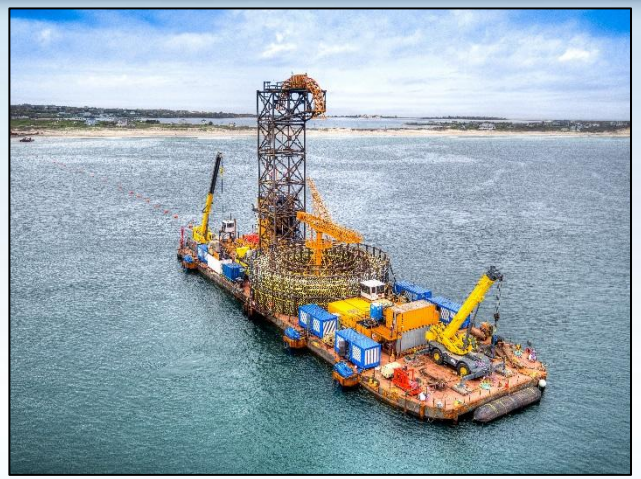
DESK TOP STUDY

- -Proposed Route
- -Route Position List
- -Cartography
- -Bathymetry
- -Geology
- -Oceanography
- -Meteorology
- -Archeology
- -Fishing Activities
- -Restricted areas
- -Permits required
- -Existing utilities
- -Cable Protection Survey
- -Site Visits
- -Survey Analysis
- -Crossing Agreements

Objective 1: Identification of Project Needs

TYPICAL PERMIT CONDITIONS

- BOEM/USACE/State/Local
- Turbidity Control
- Water Quality
- Fauna/Flora Regulations
- Cable Corridor Restrictions
- Working Window Restrictions
- Pollution Controls
- Standard Care & Control
- Diligent EHS Control

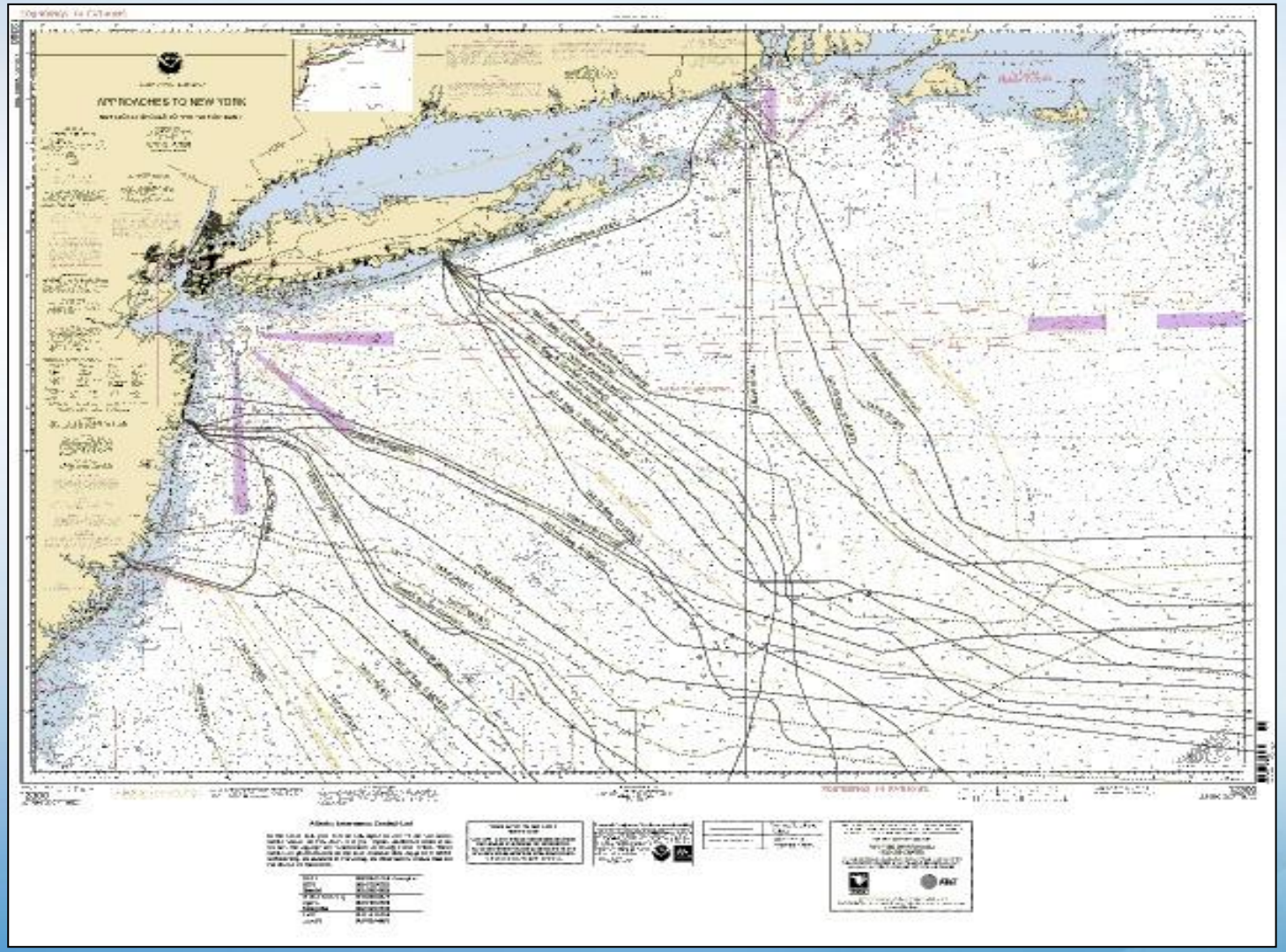


PROJECT RISK ANALYSIS

- Work Site Safety – PPE
- Permit Receipt – Stipulations
- Equipment Failure/Damage - Contingency
- Severe Weather – Local Service
- Material Delivery – Logistics Control
- Regulator Interface
- Marine Traffic – Pre-Job Planning

Objective 1: Identification of Project Needs

Do We Have To Cross Any Existing Utilities??



Objective 1: Identification of Project Needs

Typical Example of an unburied pipeline crossing

Crossing Agreement to be negotiated with the Pipeline owner

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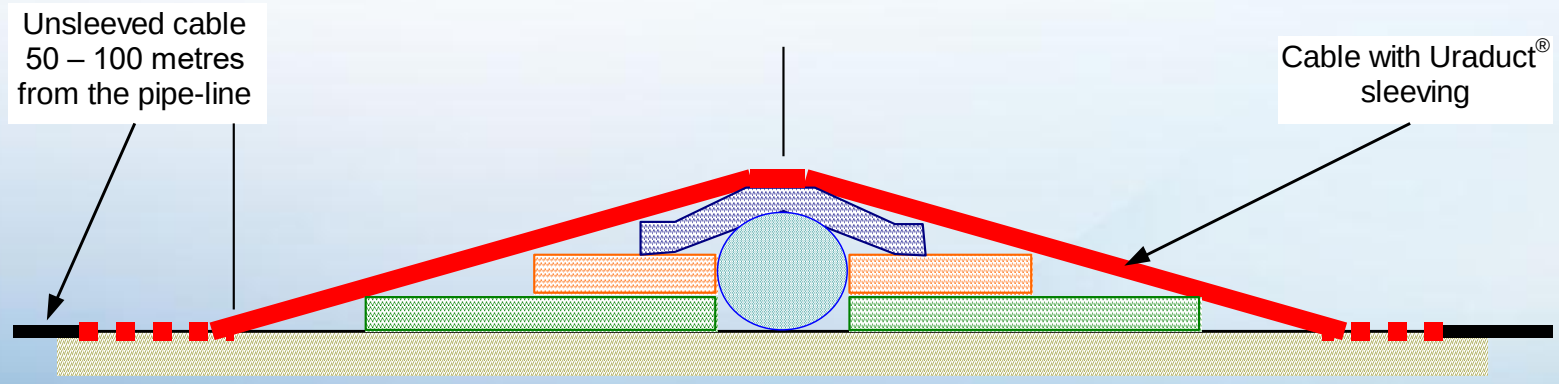
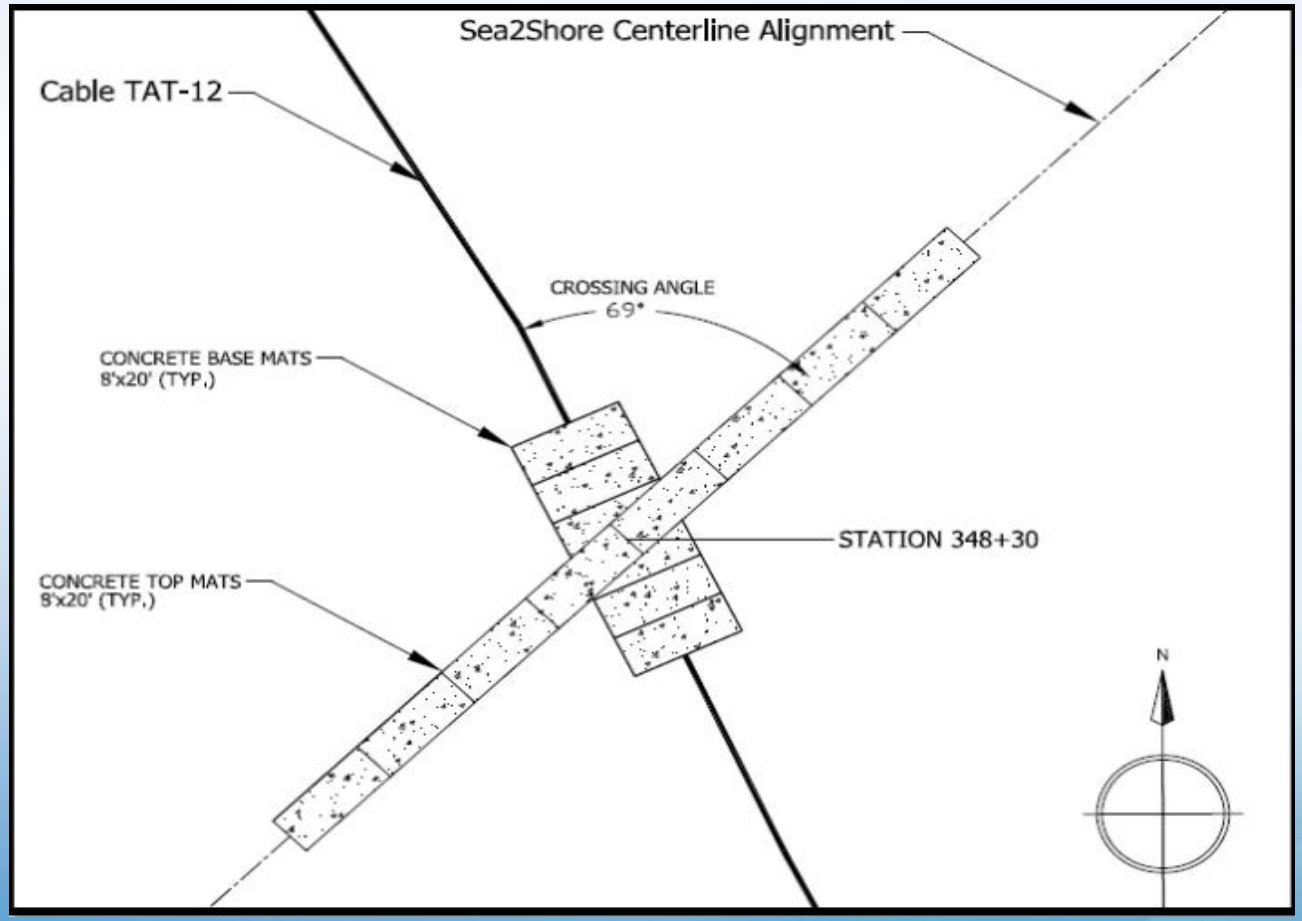


Objective 1: Identification of Project Needs

Typical Example of an unburied or buried cable crossing

Crossing Agreement to be negotiated with the Cable owner.



Objective 2: Project Support Expectations after Concept

- Project Support Expectations: Designing the Marine Route Survey
  - A submarine cable route survey is required very early in the development of the project….. long before the system plan can be finalized. The results of the marine route survey (MRS) will initially be required for the following (at a minimum:)
    - Probable USACE initial approval
    - ISO initial approval (where applicable)
    - BPU initial approval (where applicable)
    - Federal and State DEP initial permit applications
    - Archaeological and Historical Society review and acceptance
    - USCG planning
    - Vessel Traffic Control planning
    - Air traffic control planning (where applicable)
    - Ferry Authority planning (where applicable)
    - Presidential Permit approval for cross-border grid sharing projects
    - BOEM approval for wind-farms – SAP, COP, GAP,FDR & FIR

Objective 2: Project Support Expectations after Concept

- Project Support Expectations: Designing the Marine Route Survey

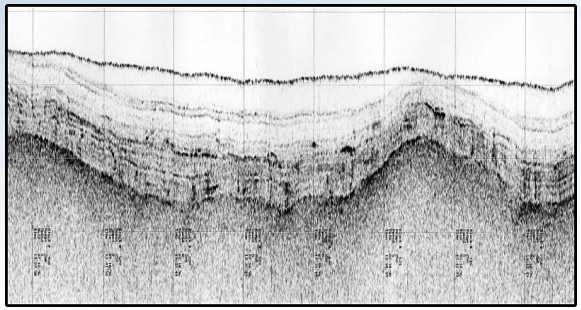
  - The MRS data is then utilized by the marine installation contractors to ascertain general installation conditions and move the submarine cable route design closer to finalization.

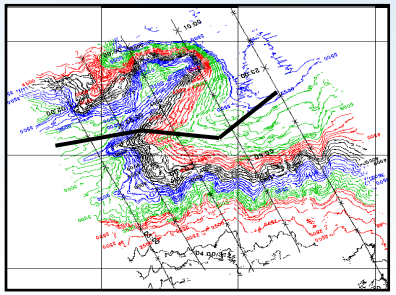
    The critical data used by both Permitting Agencies and the marine installation contractors when responding to a system RFI is as follows (at a minimum):

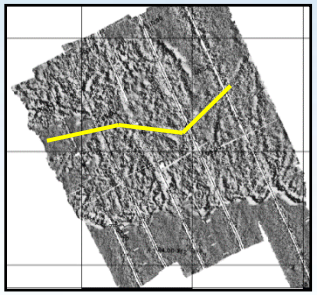
    - ***Side Scan Sonar Data***: Identifies avoidable surface targets and surficial existing utilities
    - ***Magnetometer Data:*** identifies metallic obstruction and anomalous ferrous features; used in conjunction with SSS data, may allow for identification and verification of buried utilities
    - ***Sub Bottom Profile Data***: identifies geomorphology beneath the surface
    - ***Bathymetry Data***: Identifies depth contours along the submarine cable route
    - ***Grab Samples, Vibracore, and gravity core data***: Identifies seafloor/lakebed composition; penetrating methods identify both composition and KPa data.

Objective 2: Project Support Expectations after Concept

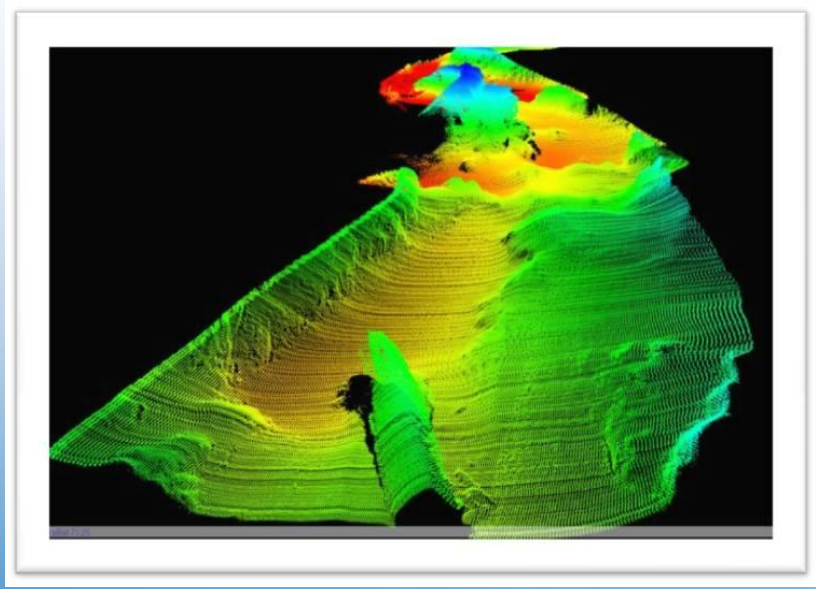
Marine Route Survey







Geophysical & Geotechnical Marine Route Survey



Bathymetry
Side Scan Sonar
Sub-Bottom Profiler
Magnetometer
Burial Assessment Survey
Thermal Resistivity
Archeological Survey
Geotechnical Borings
Finalize Cable Length
Met-Ocean Data

Objective 2: Project Support Expectations after Concept

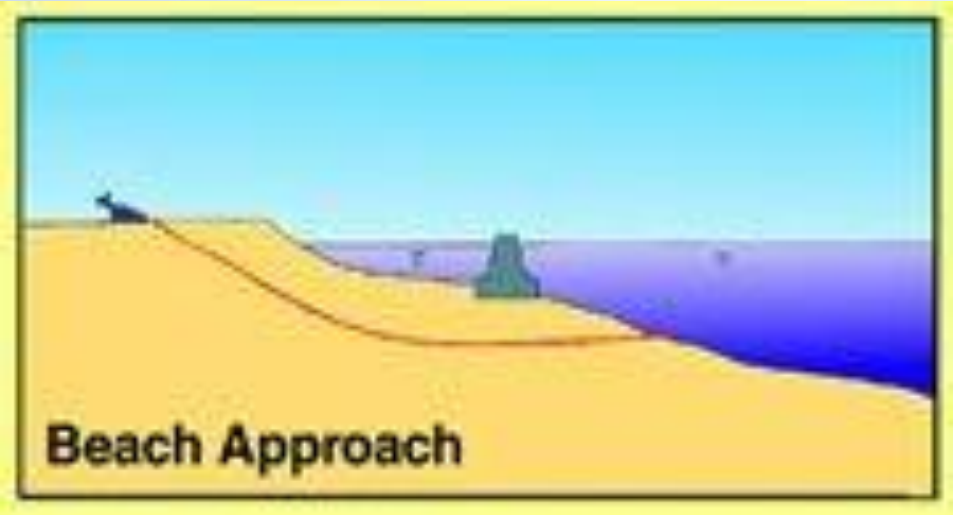
- Project Support Expectations: After the route survey
  - Permitting Support
  - Route Design Finalization (RPL)
  - RFI Coordination and response review support
  - RFQ Coordination and Documentation Generation
  - **System Design Finalization**
  - Vendor Review and Selection Support
  - Installation Monitoring, “11th hour” Engineering Support
  - Project Management, and Provision of Customer Representation at the Engineering Level

Objective 3: Understanding Submarine Project Sections

- The following “Parts and Pieces” commonly constitute the major tasks and sections of a submarine power cable system
  - HDDs / Open Cut Trench at the Landings
  - Pull-In configuration at the turbine
  - Termination at the turbine
  - Beach Manholes (BMH) and transition vaults
  - Terminal Stations, new or existing
  - Pothead Structures and Substation Interface Structures
  - Duct Bank to the Terminal
  - Land Cable Pulling
  - Cable Manufacturing and Factory Acceptance Testing
  - Cable Freighting to the Project Area
  - Cable Trans-spooling Operations and Testing
  - Jointing Operations
  - Submarine Cable Installation
  - Terminating & Commissioning

Objective 3: Understanding Submarine Project Sections

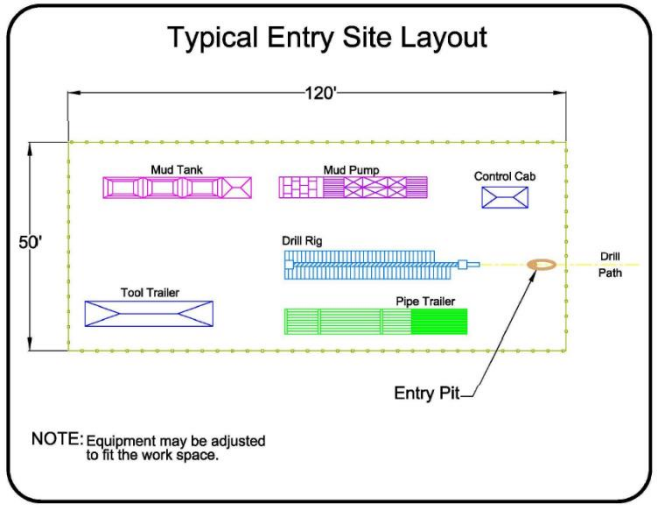
- **HDDs / Open Cut Trench at the Landings**



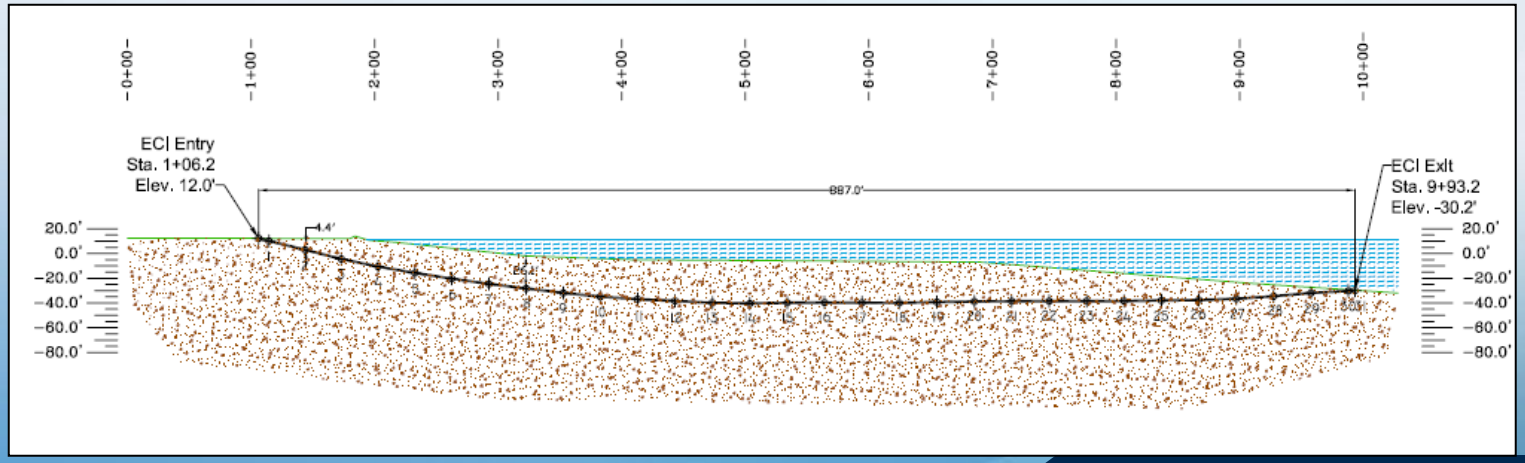
- **Geo-Tech Bores?**

Objective 3: Understanding Submarine Project Sections

- **HDD configurations at the Landings are usually preferred by regulators**



Typical conduit profile

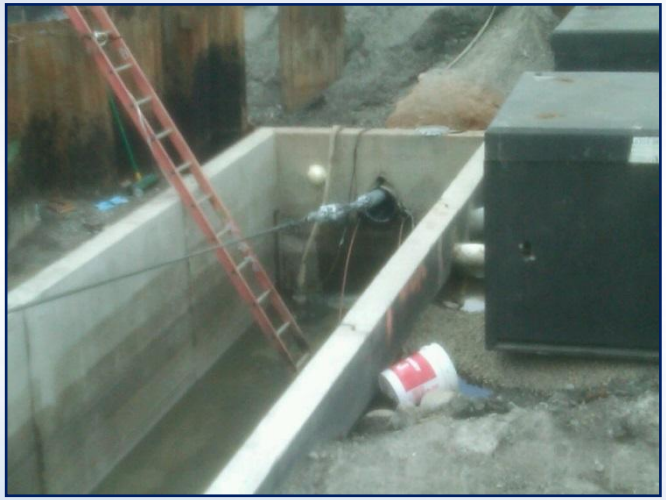


Objective 3: Understanding Submarine Project Sections

- **HDDs / Open Cut Trench at the Landings**

Objective 3: Understanding Submarine Project Sections

- **Beach Manholes (BMH) and transition vaults**

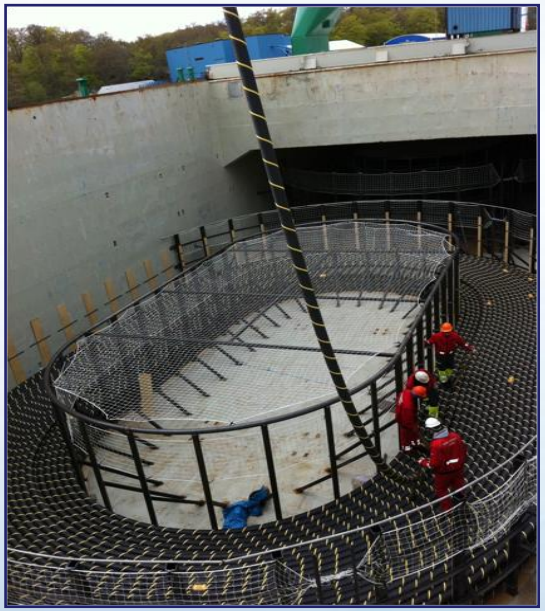


Objective 3: Understanding Submarine Project Sections

- **Terminal Stations, new or existing**
- **Pothead Structures and Substation Interface Structures**

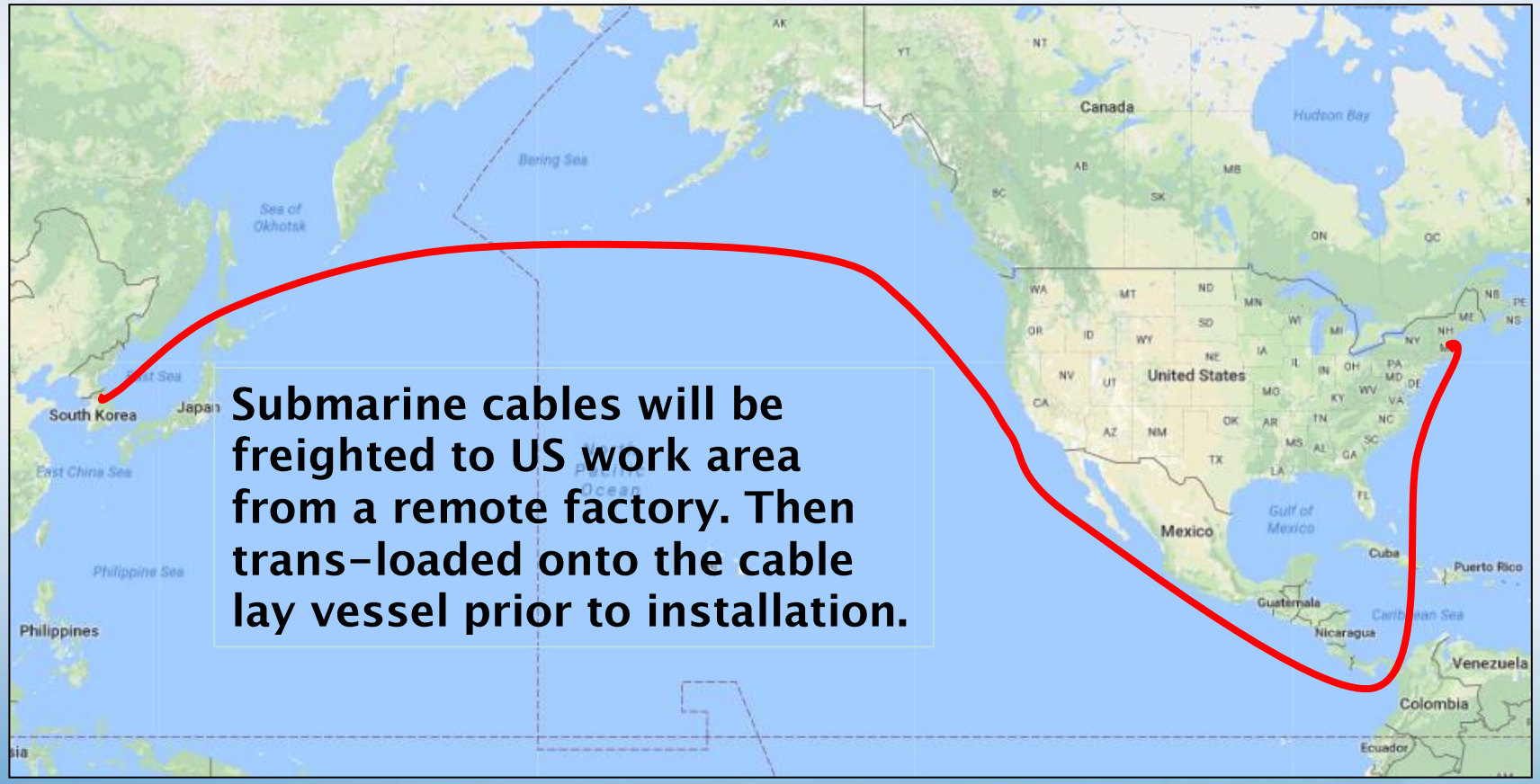
Objective 3: Understanding Submarine Project Sections

- **Cable Manufacturing and Testing**
- **Cable Freighting to the Project Area**



Objective 3: Understanding Submarine Project Sections

- **Cable Freighting to the Project Area**



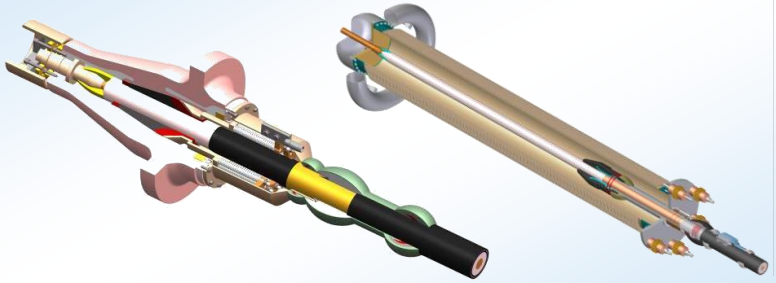
Objective 3: Understanding Submarine Project Sections

- Jointing & Termination Operations

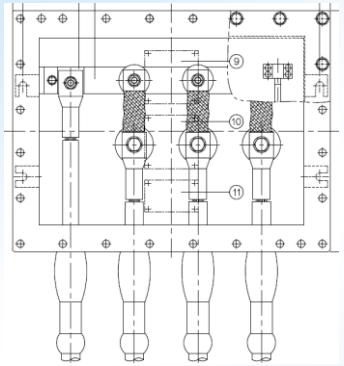
Offshore Repair Joints

Transition Joints (Sea-Land)

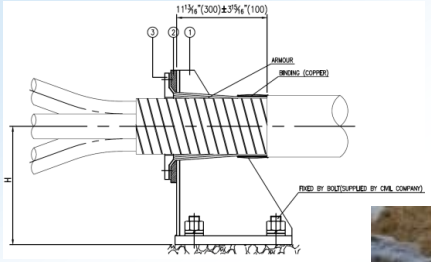
Terminations (Indoor / Outdoor)



Link Box



Armour Clamp



Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation: Typical tasks addressed before barge operations**
  - Marine Route Survey
  - Pre-lay Grapnel Run (PLGR)
  - Route Clearance (RC)(abandoned utilities)
  - Jet Sled Pre-pass (Pre-Rip)
  - Rock and Overburden Removal
  - Shore End Trench Preparation / HDD Installed and Pre-strung
  - Separation Mattresses placed as agreed with 3rd party utility owners (all crossing agreements in place)

Objective 3: Understanding Submarine Project Sections

- **Pre-Lay Route Preparation**

- **Pre Lay Grapnel Run (PLGR) & Route Clearance (RC)**

Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Cable Lay Barges – Shallow Water**

- **Cable Lay Barges can be anchored (4-Point Moor) or use DP**

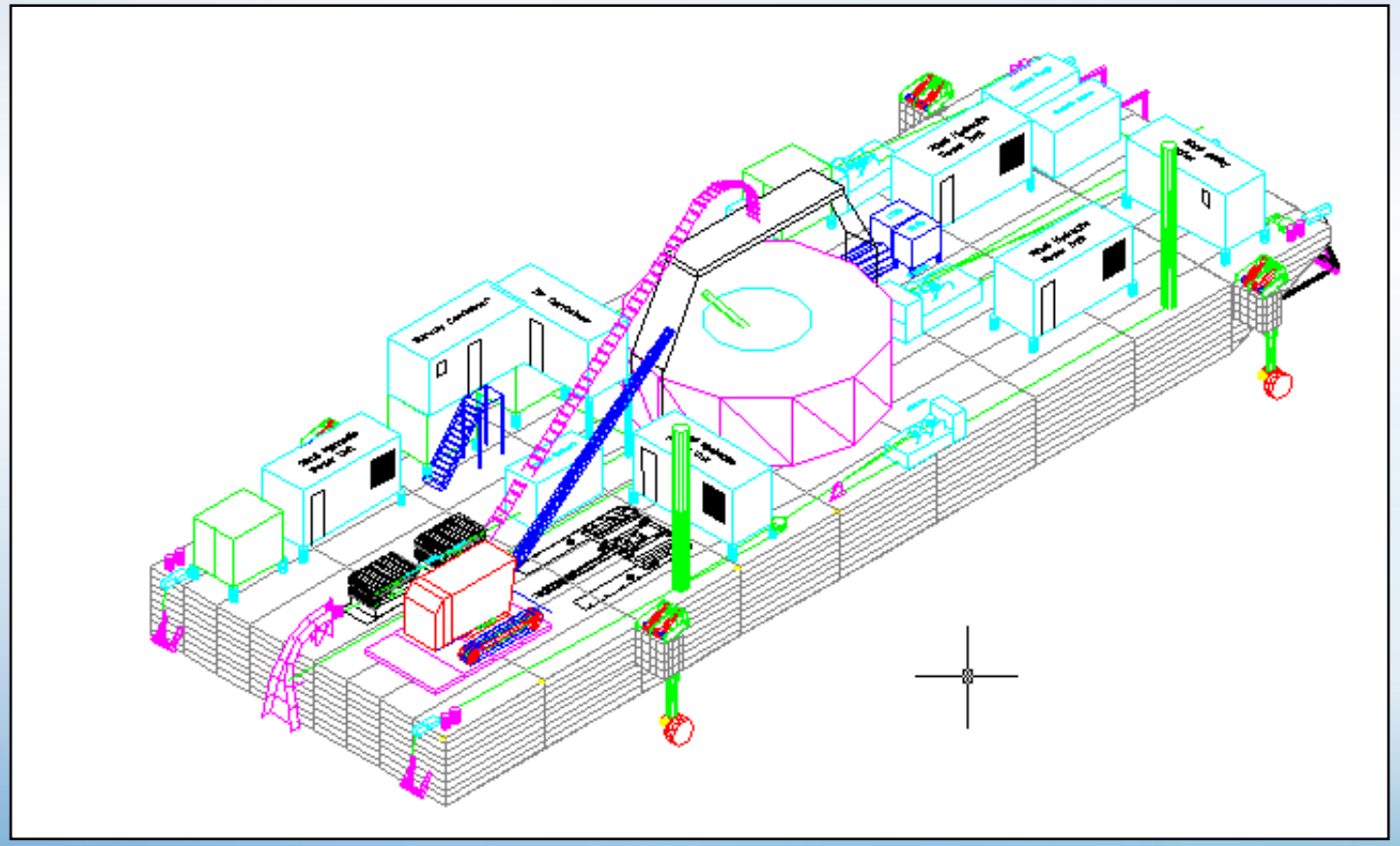
Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Static Tank Vs Turntable (Carousel)**

- **Cable is Coilable? Coiling Test? Do we need a Turntable?**

Objective 3: Understanding Submarine Project Sections

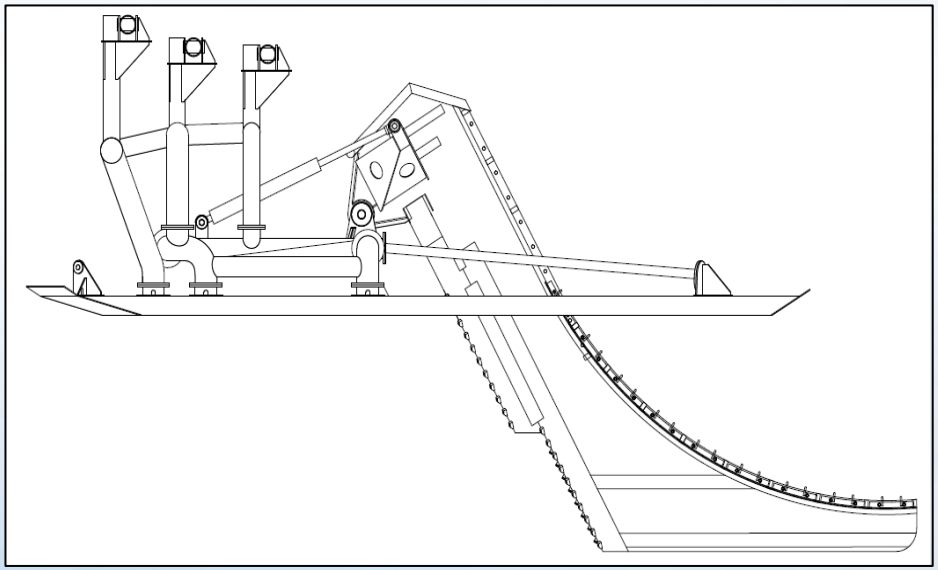
- **Submarine Cable Installation Engineering: Marine Warranty Surveyor for WetCar Insurance Coverage**



- **Cable Weight & Volume Calculations For Barge Stability Check**

Objective 3: Understanding Submarine Project Sections

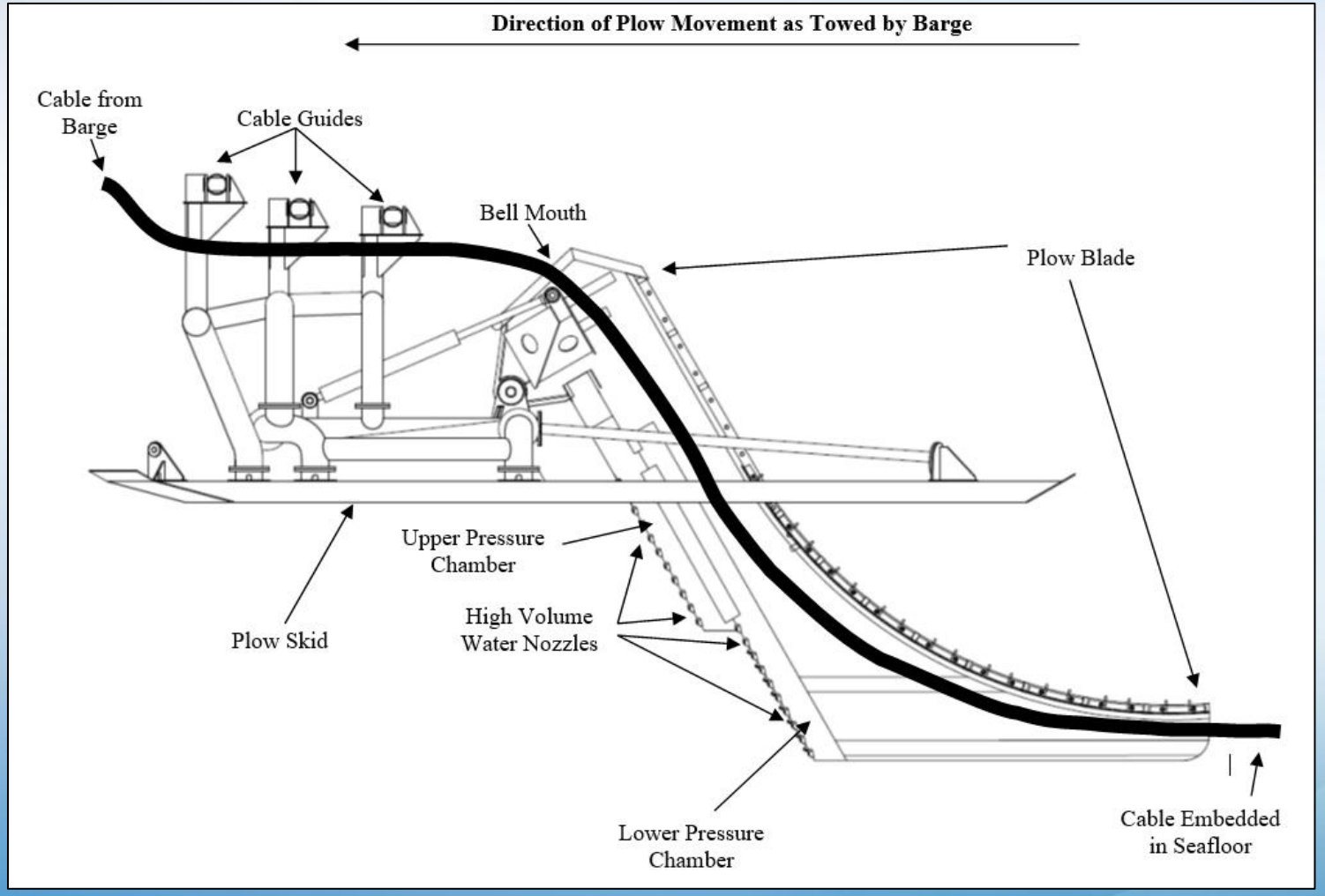
- **Submarine Cable Installation Methodology: Jet Plow Technology for Cable Burial**



- **Simultaneous Lay & Burial**

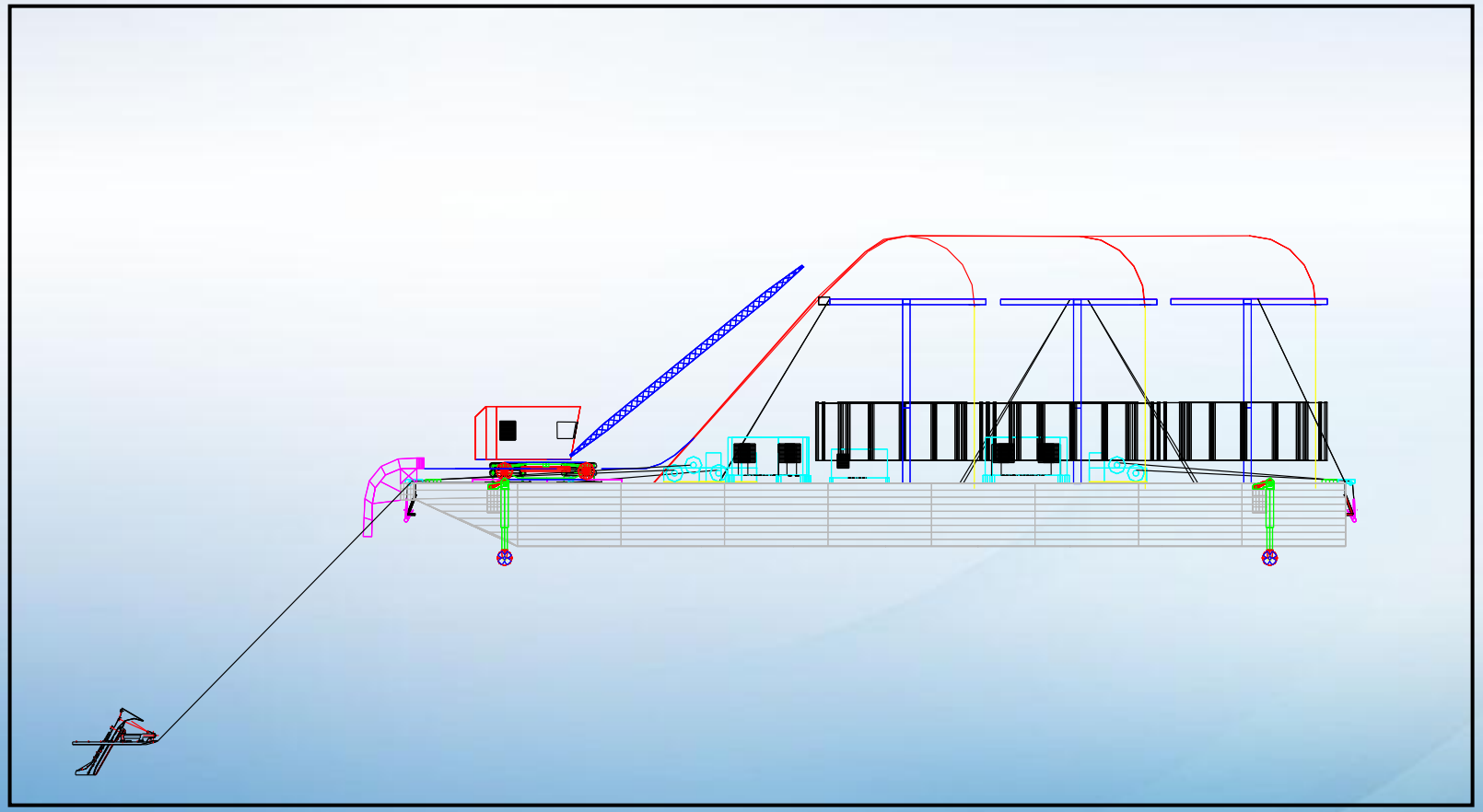
Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Jet Plow Technology**



Objective 3: Understanding Submarine Project Sections

- **Simultaneous Lay & Burial Configuration from a DP Barge**



Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Jet Plow Technology**

SUBMARINE CABLE PLOW

- Adjustable Burial Depth
- Full Electronic Telemetry
- Video & Sonar
- Adjustable Water Flow
- Full Navigation Integration
- Tracked from Barge with USBL

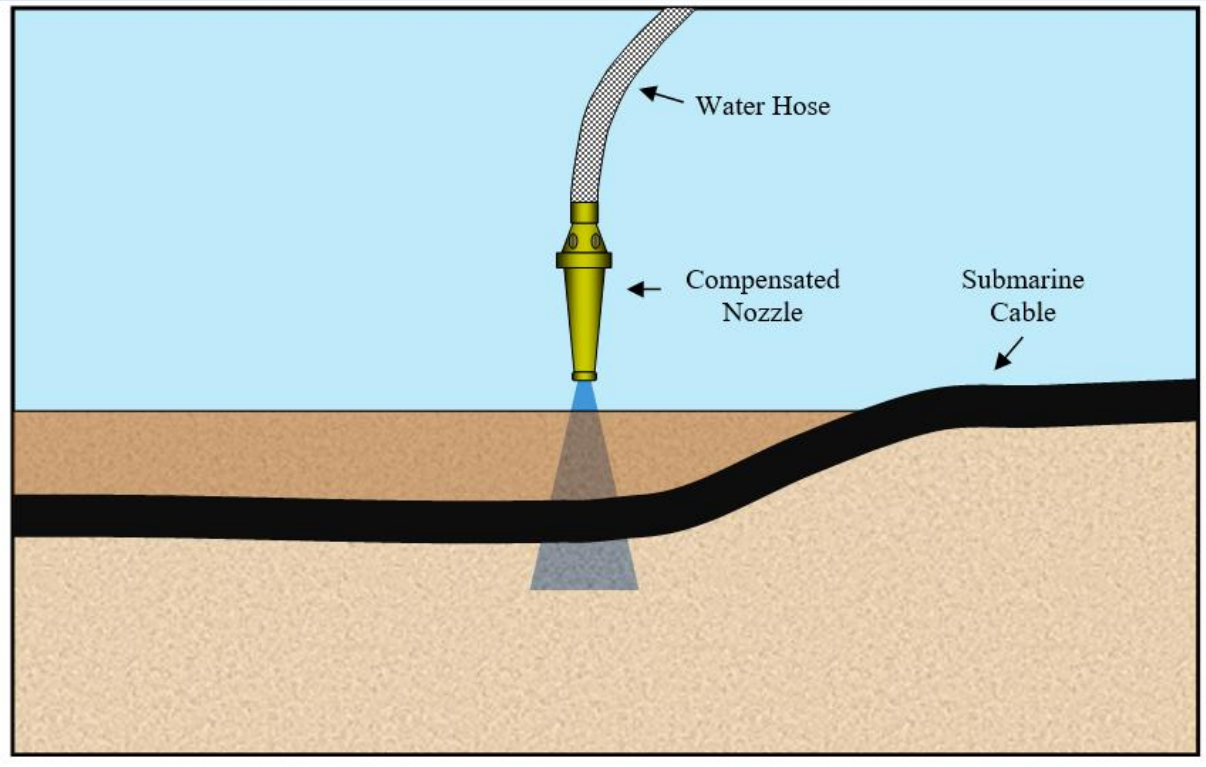
Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Cable Lay Vessels or Cableships for Deeper Water Operations.**

- **ROV or Trencher for Post Lay Burial Operations (PLBO)**

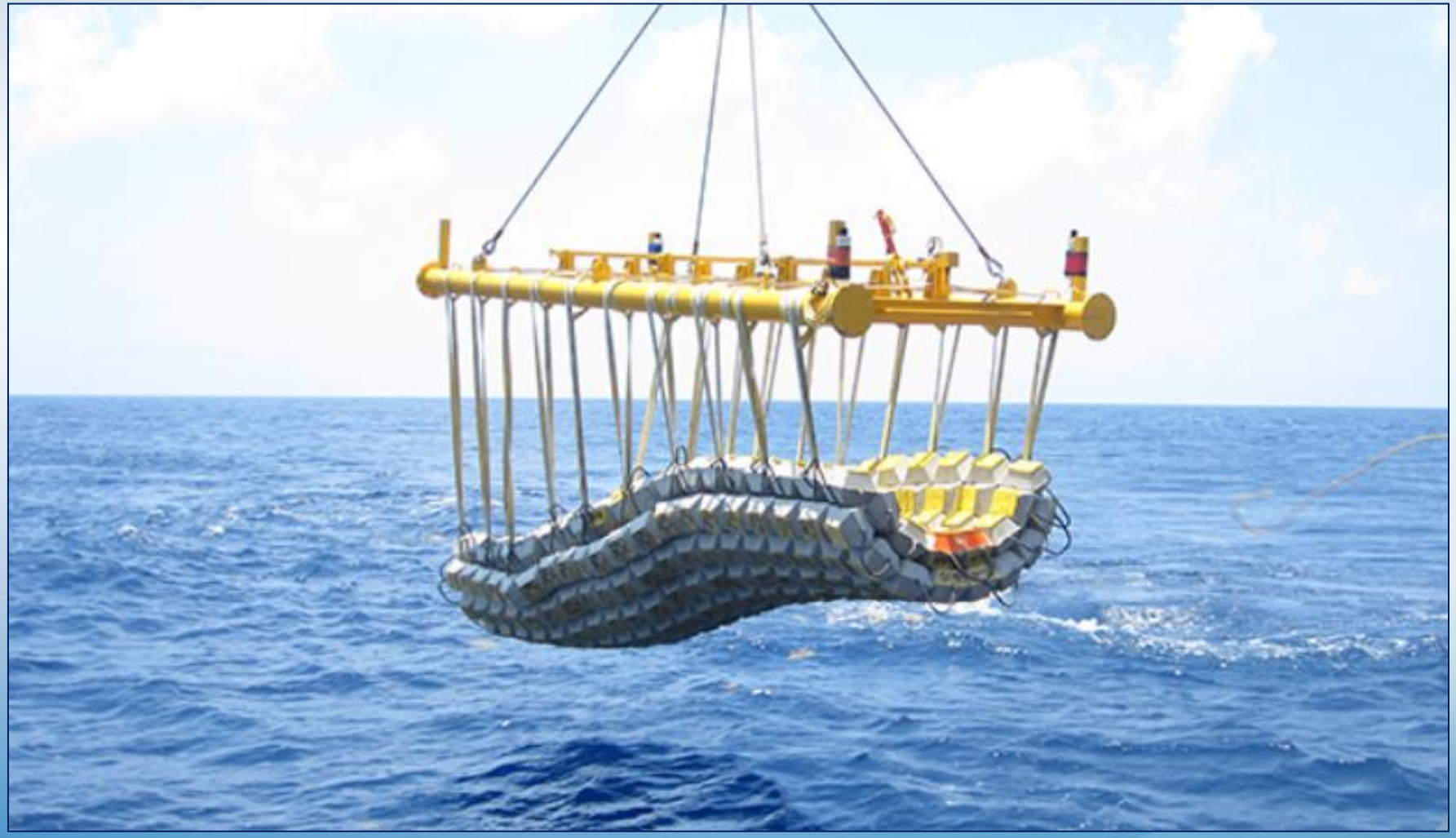
Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Installation Methodology: Diver Burial**



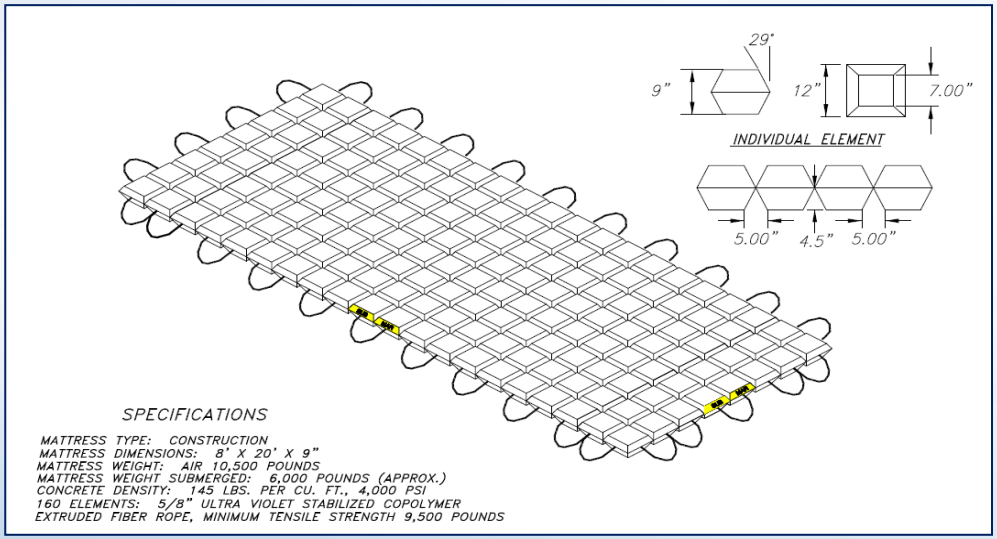
Objective 3: Understanding Submarine Project Sections

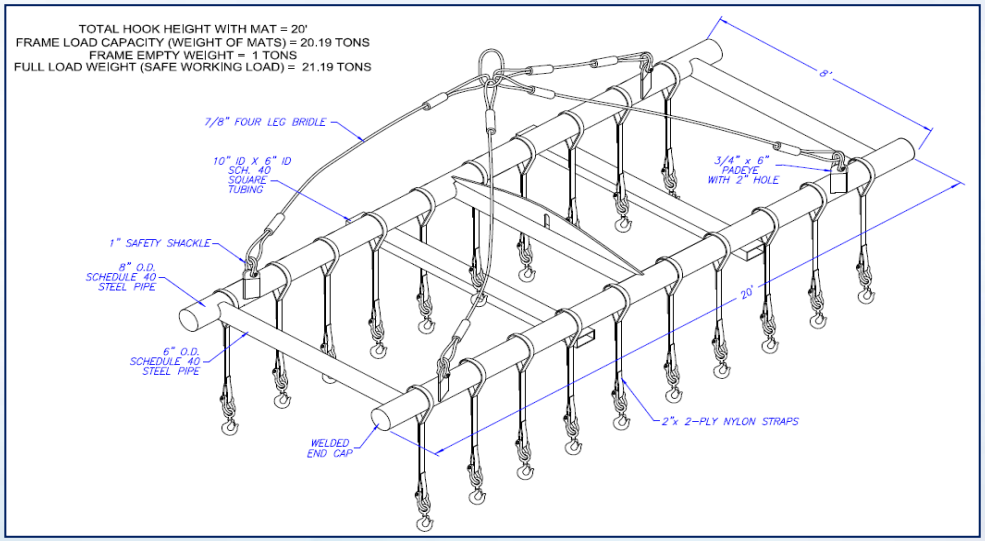
- **Submarine Cable Additional Protective Measures: Articulated Mattresses**



Objective 3: Understanding Submarine Project Sections

- **Submarine Cable Additional Protective Measures: Articulated Mattresses**





Objective 3: Understanding Submarine Project Sections

- **Post-Lay Testing and System Commissioning**
  - Phase Check, IR test & TDR Signature
  - Jacket Integrity Test for Underground Power Cable
  - Single End OTDR for FO Cable
  - AC Hi-POT and Partial Discharge testing
  - On site witness of 24hr soak test prior to in-service

IR Test

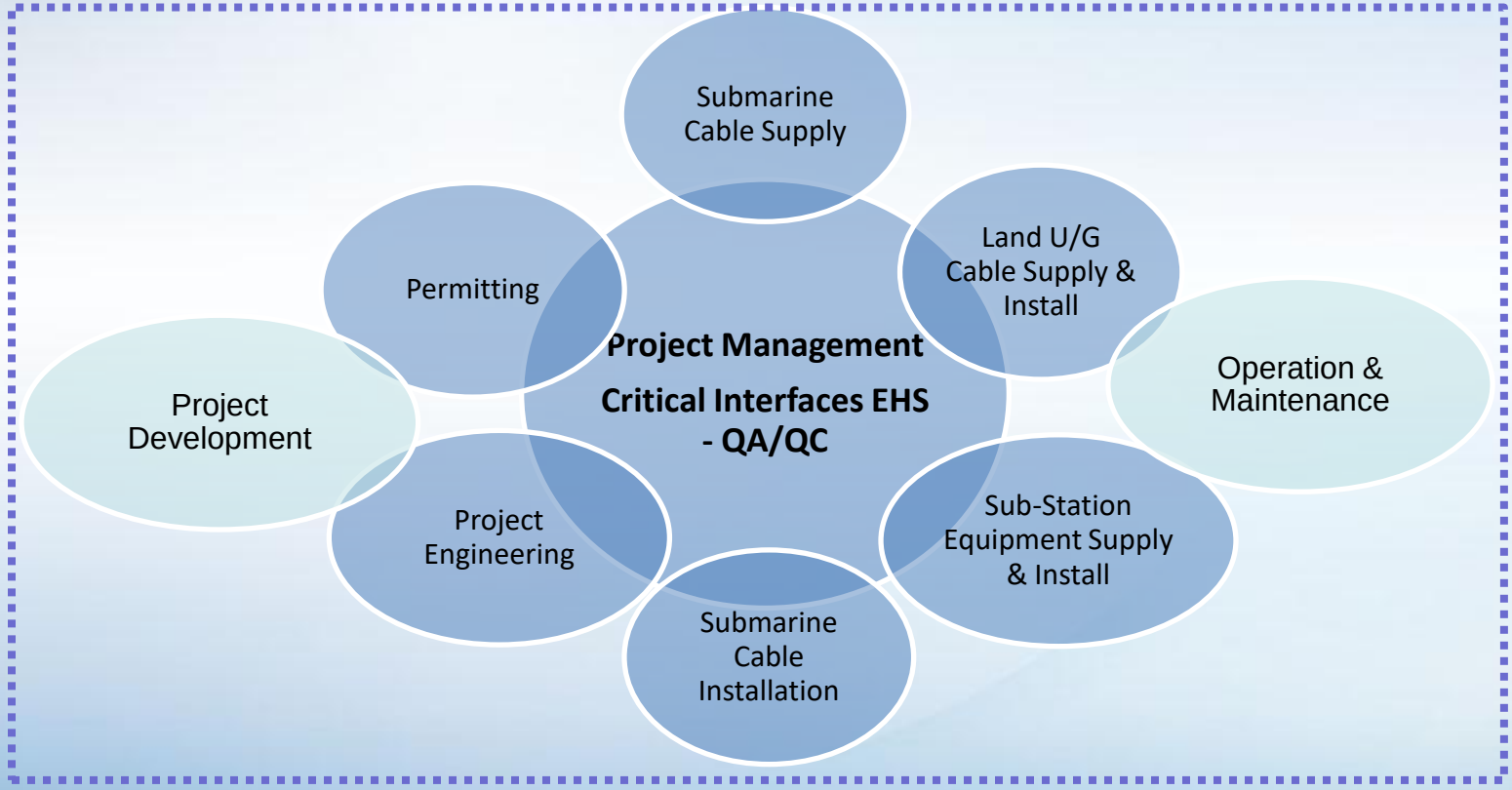
Jacket Integrity Test

Objective 4: Submarine Cable Project Commercial Structure

- **Unique Commercial Structures / What to Expect**
  - Unlike other infrastructure projects, submarine cable manufacturers tend to act as the Prime Contractor for submarine cable projects.
    - Manufacturer's Bonding Capacity tends to be the highest
    - Warranty Issues with the Submarine Cable when transferred to Installation Contractors for transport, handling, and installation operations
    - Component guarantees can be difficult to capture in the head contract Unless the Manufacturer directly carries this item
  - Utilities may prefer EPC Contracts over Design / Build Contracts to simplify their administrative commitment for large projects AND transfer some risk to a single sub scoped with a "turnkey" project plan.
  - Generally speaking, Engineering Companies should be approached VERY early in the project concept phase to act as the Owner's Engineer for the entire project life.

Objective 4: Submarine Cable Project Commercial Structure

- **Multi-Contract or EPC?**



Typical Contracting/Supply Methodologies:

1. Furnish FOB Factory, 2. Furnish CIF Project Site, 3. Furnish & Install, 4. EPC

Objective 4: Submarine Cable Project Commercial Structure

- **Typical Submarine Cable Task Breakout for a submarine cable project**

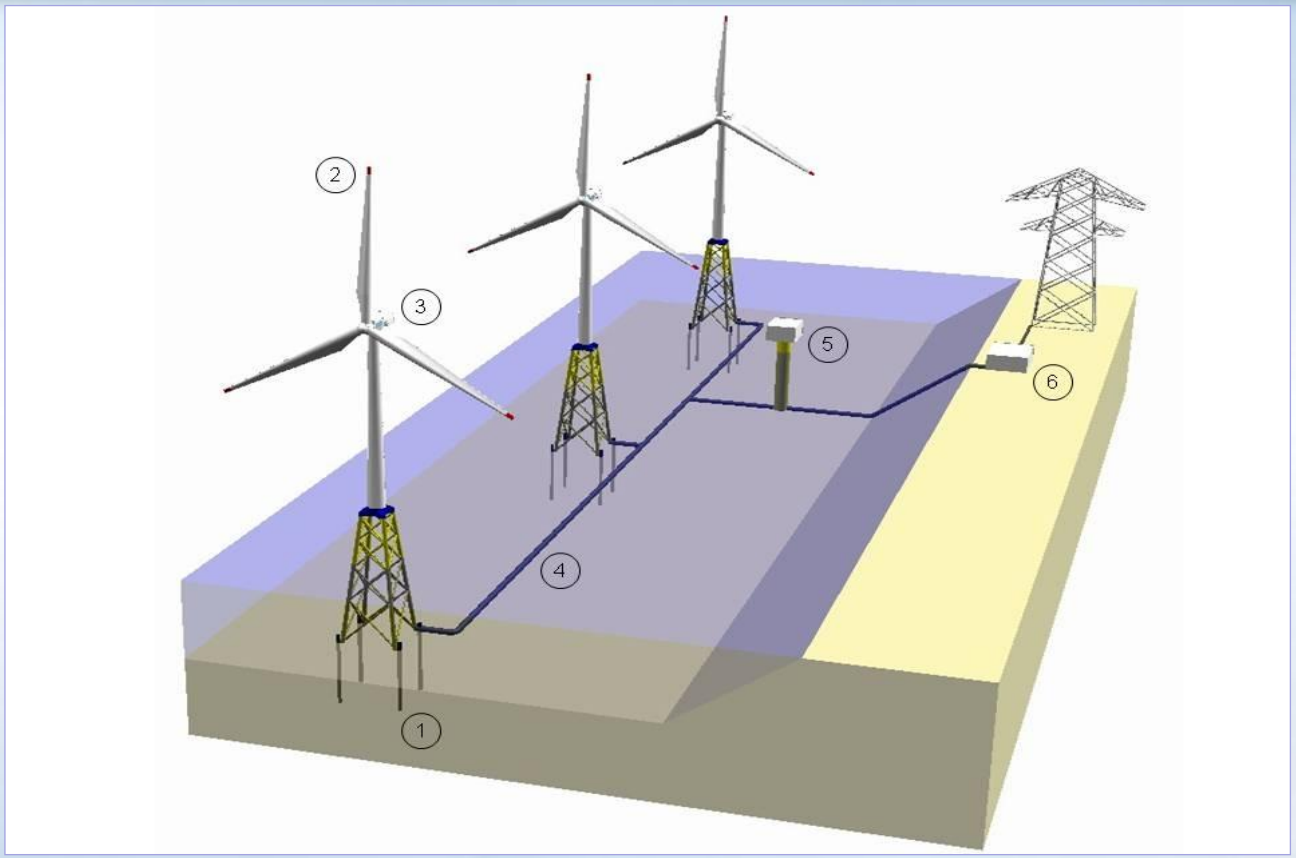
1. Cable Manufacturer. (Prime Contractor)
- Design & Engineering for Power Cables
- Supply of Power Cables with 2 FO units & Accessories
- Supervision of Cable Laying
- Jointing & Termination of Power Cables
- Commissioning Test

2. Marine Installer (Sub Contractor)
- Engineering for Submarine Cable Installation
- Marine (Route) Survey and Clearance
- Removal of existing cable & rock, if requested
- Installation of Submarine Power Cable (Laying & Burial)

3. Underground Installer (Sub Contractor)
- Installation of Underground Power & FO Cable
- Support for Jointing & Termination of Power Cable
- FO splicing work and Installation of cable support structure

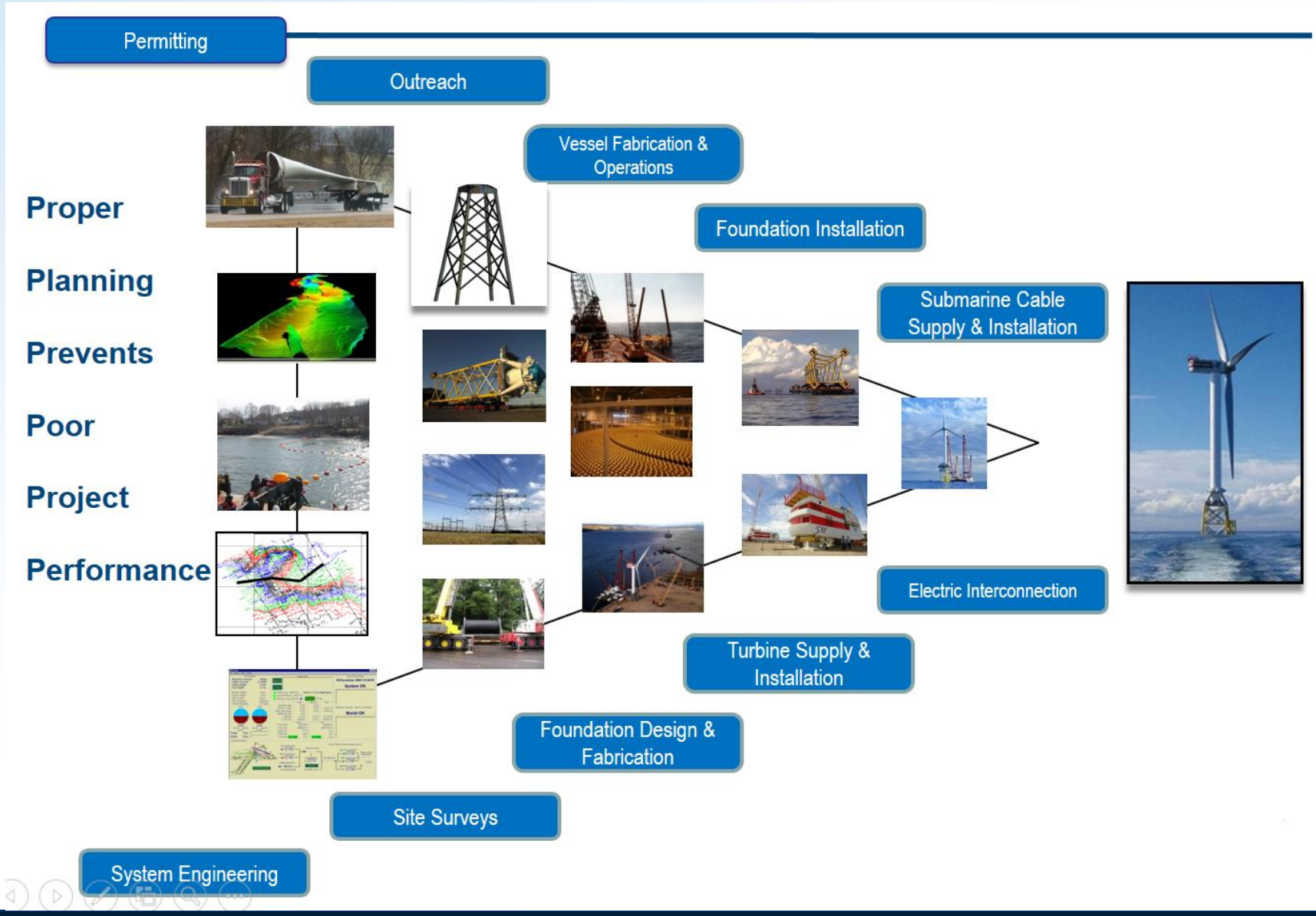
** <u>Not included in Contractor's scope of work</u> **
1) Environmental Permits
2) Substations, Manholes and Duct Banks
3) HDD works at landfall area (Optional)

Offshore Wind Basics



1. *Foundation*
2. *Wind Turbine Generator (WTG)*
3. *Nacelle*
4. *Inter-Turbine (Array) Submarine Cables*
5. *Offshore Sub-Station & Export Submarine Cable*
6. *On-Shore Grid Connection*

Logistics, Logistics, Logistics……



Thank You

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