Dynamic Power Cable Layout Solutions

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Organized by QFWE Quest Offshore

Acteon and 2H Offshore Introduction

ACTEON claxton
DRILLING AND DECOMMISSIONING

ACTEON MENCK
FOUNDATIONS AND CABLES

ACTEON INTERMOOR
MOORINGS AND ANCHORS

ACTEON 2H offshore
OFFSHORE ENGINEERING

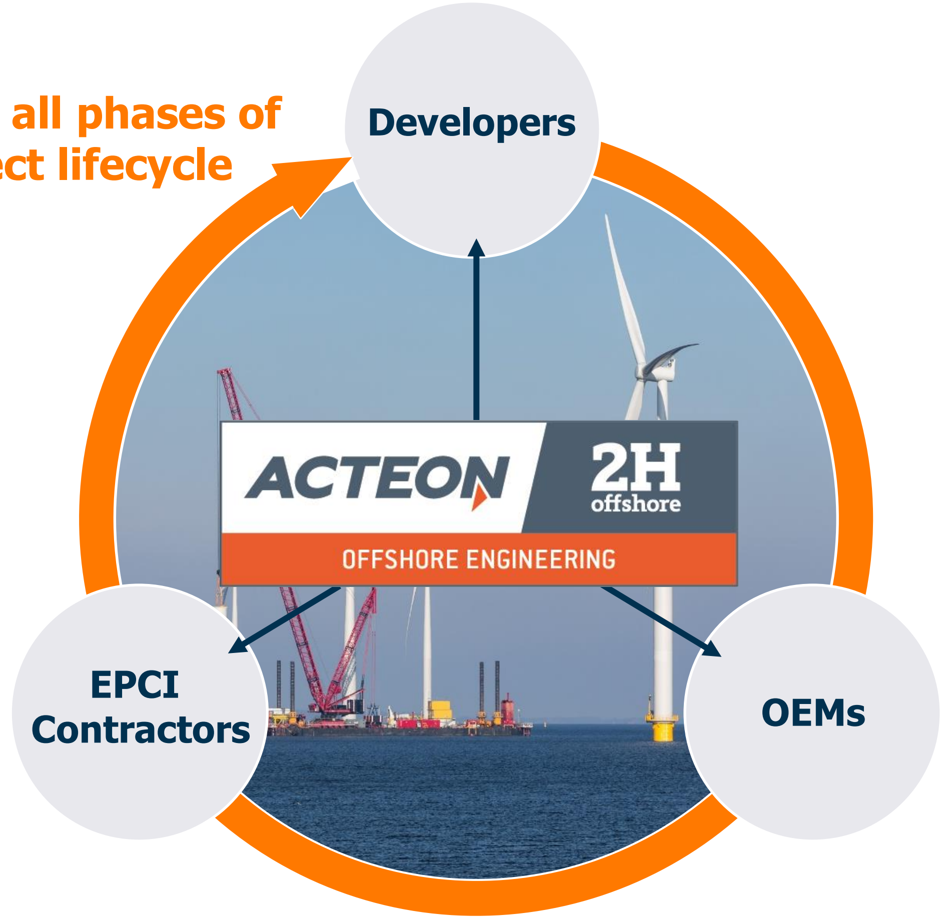
ACTEON PULSE Structural Monitoring
ASSET INTEGRITY AND MONITORING

ACTEON UTEC
GEO-SERVICES

ACTEON seatronics
ELECTRONICS AND TOOLING

ACTEON TEAM Energy Resources
ENERGY RESOURCING

Supporting all phases of the project lifecycle



PRE-DEVELOPMENT → DEVELOPMENT → OPERATIONS → LATE LIFE → DECOM & POST-ABANDONMENT

Challenges of FOW Dynamic Cable Configuration

- Requires reliability in extreme environments while remaining economical
  - Relatively shallow water
  - High sustained winds
  - Large seastates (likely very directional, large % of WD)
  - Small, light floaters with dynamic motions (6DOF and large offsets)

- Key design attributes:
  - Functionality/Operations/Reliability
  - Strength
  - Fatigue
  - Environmental impact
  - Cost (materials, installation, maintenance, insurance)
  - Risk (applies to all the above)

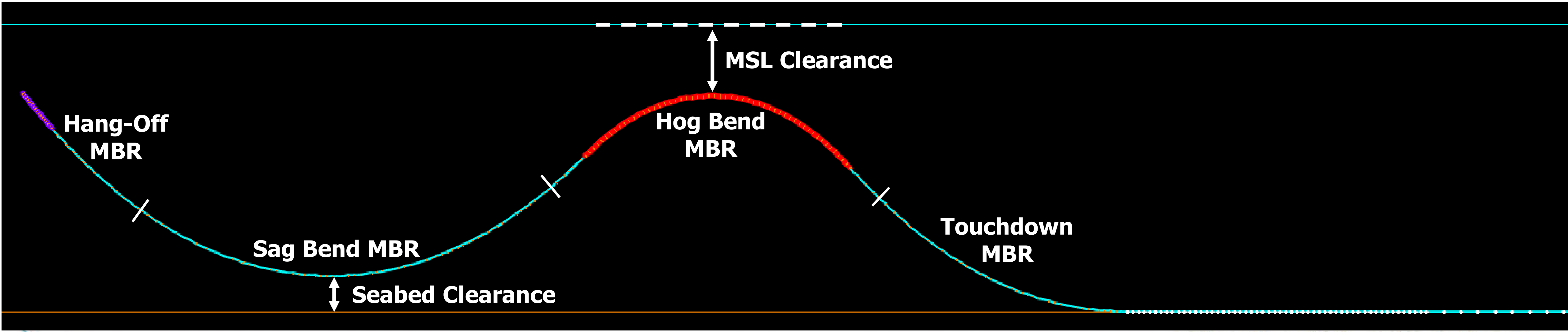
Case Study:
Shallow Water 15MW FOWT in Harsh Environment

Case Study Design Premise

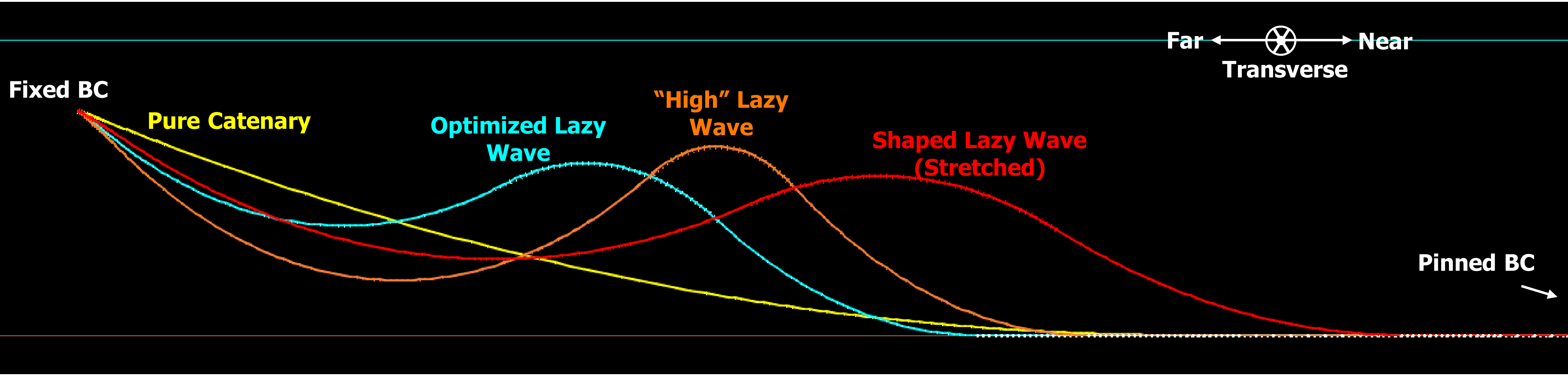
- **Premise:** Develop feasible power cable configuration for 15MW FOWT system in shallow water with harsh environment
- Stiesdal TetraSub semisubmersible floater in parked turbine condition
- Location/Environment:
  - 50m water depth
  - 50-year environmental conditions:
    - Wind: 40m/s (1-hour average, 10m height)
    - Waves: 14m H_s (26m H_{max}), 17s T_p
    - Current: slab and typical sheared current profile considered, 1.3m/s surface reference
- Mooring: taut nylon, spread mooring (~30m extreme floater offsets)
- 3 power cables considered (36kV, 66kV light and 66kV heavy), fixed at base of floater and routed in most onerous weather direction

Case Study
Response Parameters and Design Requirements

- Design Requirements:
  - Min bend radius > dynamic bend radius
  - Max tension < allowable working load
  - Sag bend to remain off seabed
  - Hog bend to maintain sufficient clearance for vessel access
  - Zero compression (or minimal compression)
  - Minimizing seabed movement

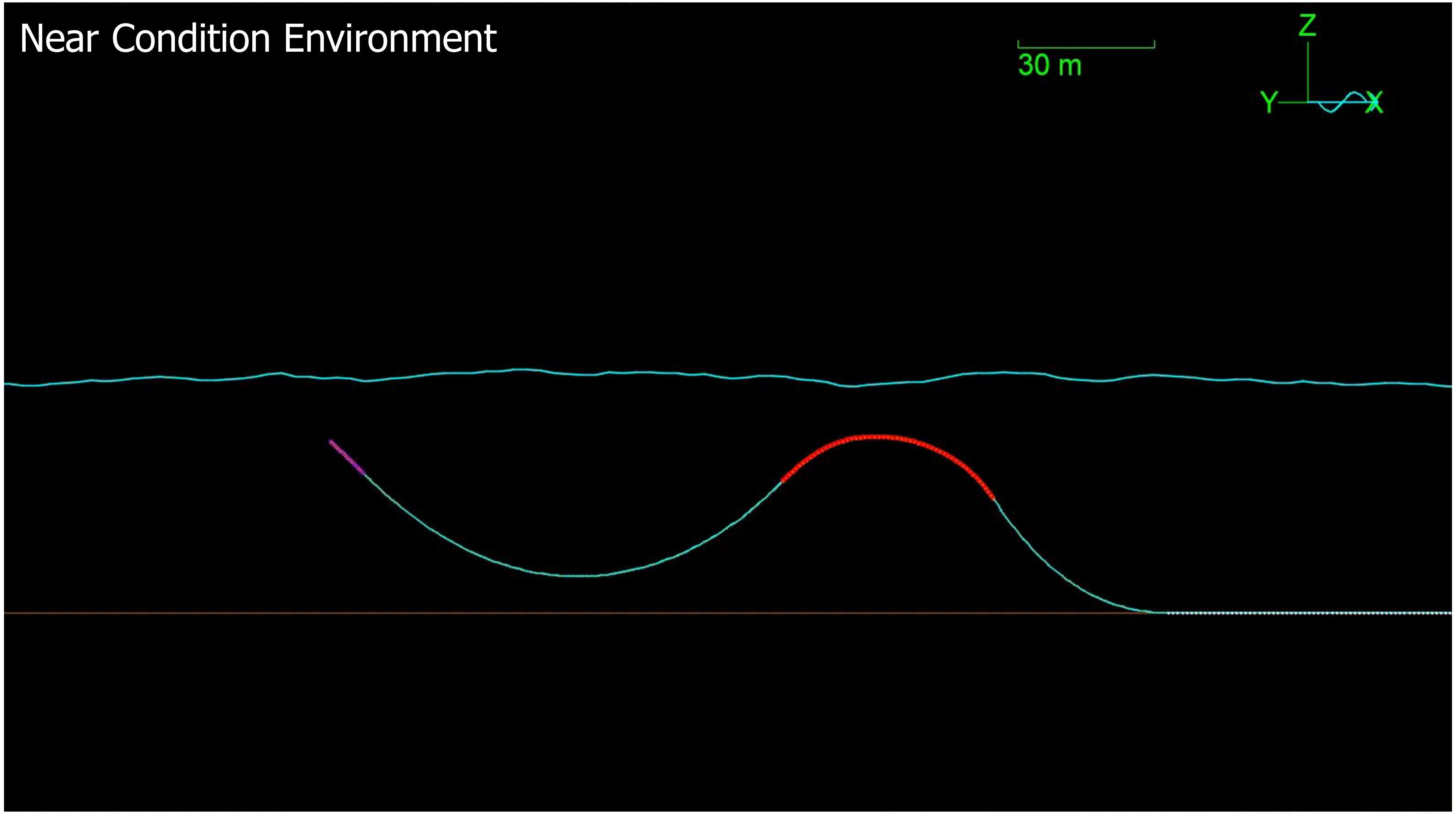


Power Cable Configuration Development



- Many power cable configurations are considered (some shown above)
- **Pure catenary:** configuration can exceed MBR at touchdown, have high compression, and can exceed allowable tension
- **"High" lazy wave (high arch, low sag):** gives good compliance and smaller footprint but can compromise MBR (particularly in near conditions)
- **Shaped lazy wave (stretched):** gives good response with near conditions, but can compromise tension and has larger footprint
- Selected configuration is based on time traces of FOWT motions for controlling environments and later evaluated with full extreme storm matrix and coupled with FOWT system (floater, turbine, mooring)

Power Cable Configuration Development
Selected Configuration - FOWT Time Traces



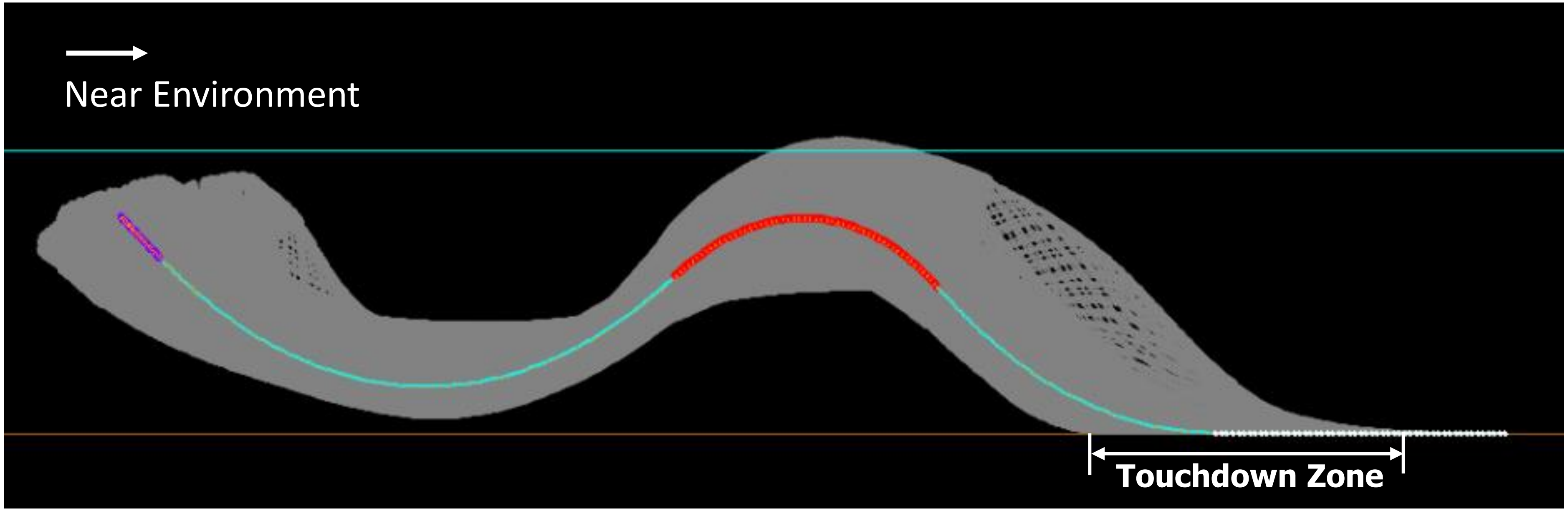
Configuration Development Results

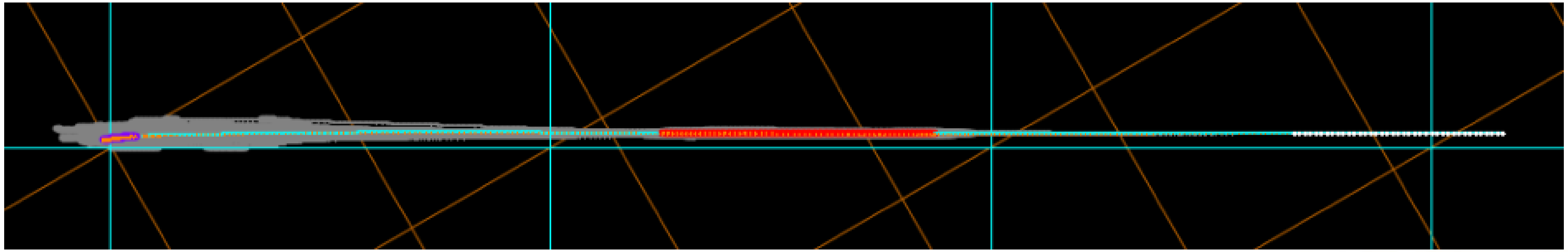
Parameter	36kV	66kV (Light)	66kV (Heavy)
Allowable MBR (m)	2.45	2.11	2.86
Allowable Tension (kN)	263	345	505

	Power Cable	Max Tension (kN)	Min Tension (kN)	Min MBR (m)				Seabed Clearance (m)
				Hang-Off	Sag	Hog	TD	
Typical Current Profile (Sheared)	36k	117	-4	3.32	10.33	3.85	6.05	2.14
	66kV (Light)	131	-20	4.66	8.19	3.83	4.90	2.69
	66kV (Heavy)	211	-19	8.52	10.31	3.42	5.37	1.42
Slab Current	36kV	811	-21	0.59	9.55	3.92	2.16	2.10
	66kV (Light)	995	-34	4.05	8.57	4.02	1.93	2.78
	66kV (Heavy)	883	-27	8.43	11.32	3.67	1.83	1.80

- Feasible lazy wave configurations are developed for various power cables and typical current profile
- Power cable response is sensitive to slab currents due to light weight of cable and high dynamic motions
- Tension and MBR exceed allowable with slab current
- Seabed clearance is maintained for sag bend for all cases
- Minimal compression is expected but likely tolerable by the cable
- Compression is caused by compression wave initiated by floater surge

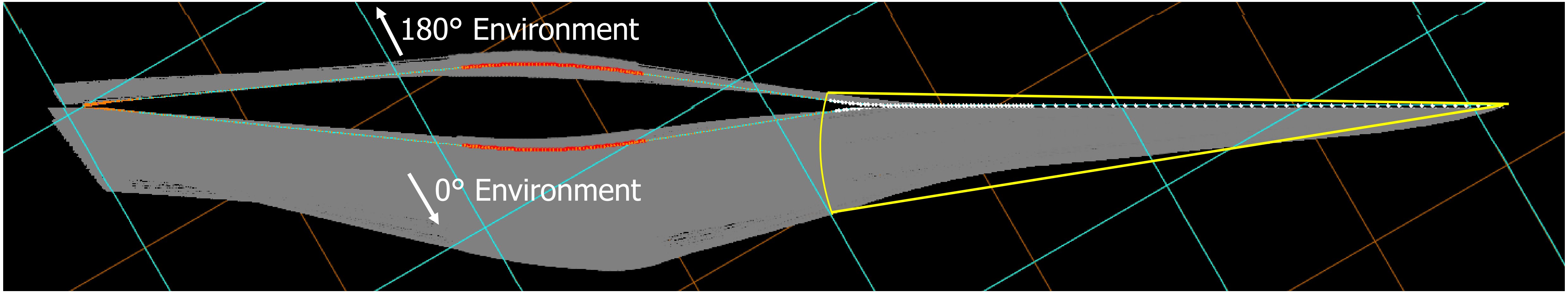
Configuration Development Results
Motion Envelope (Near Environment)

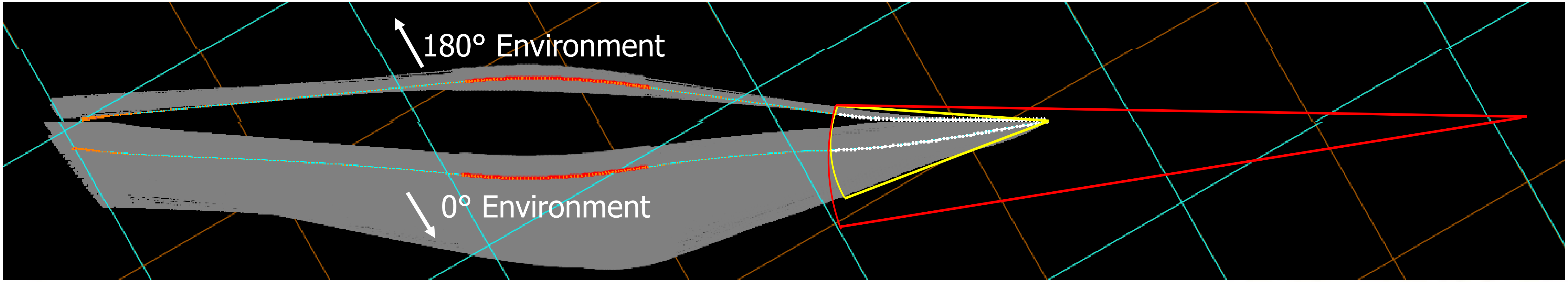




Floating Wind Solutions

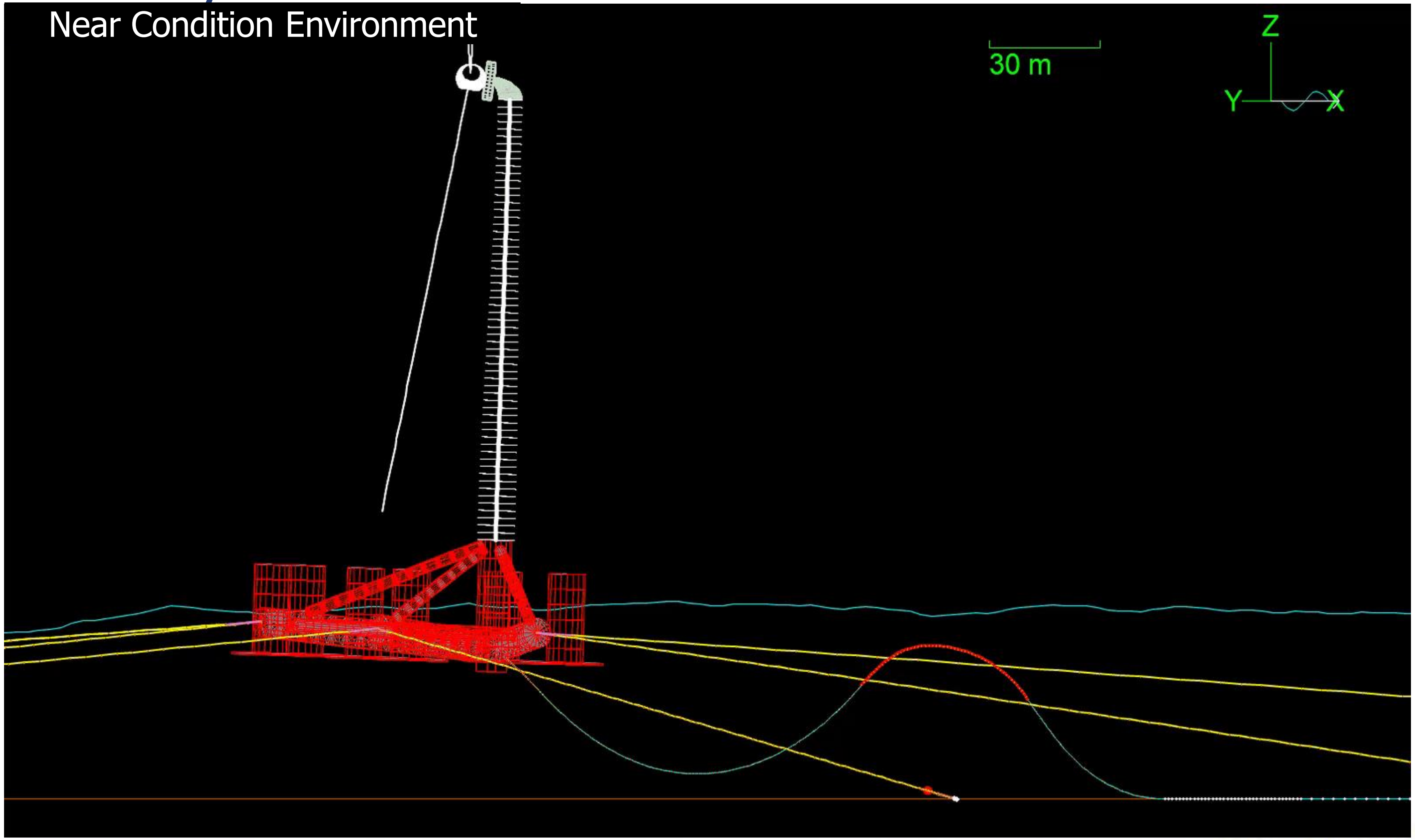
Configuration Development Results
Seabed Impact (Transverse Environments, Typical Current Profile)





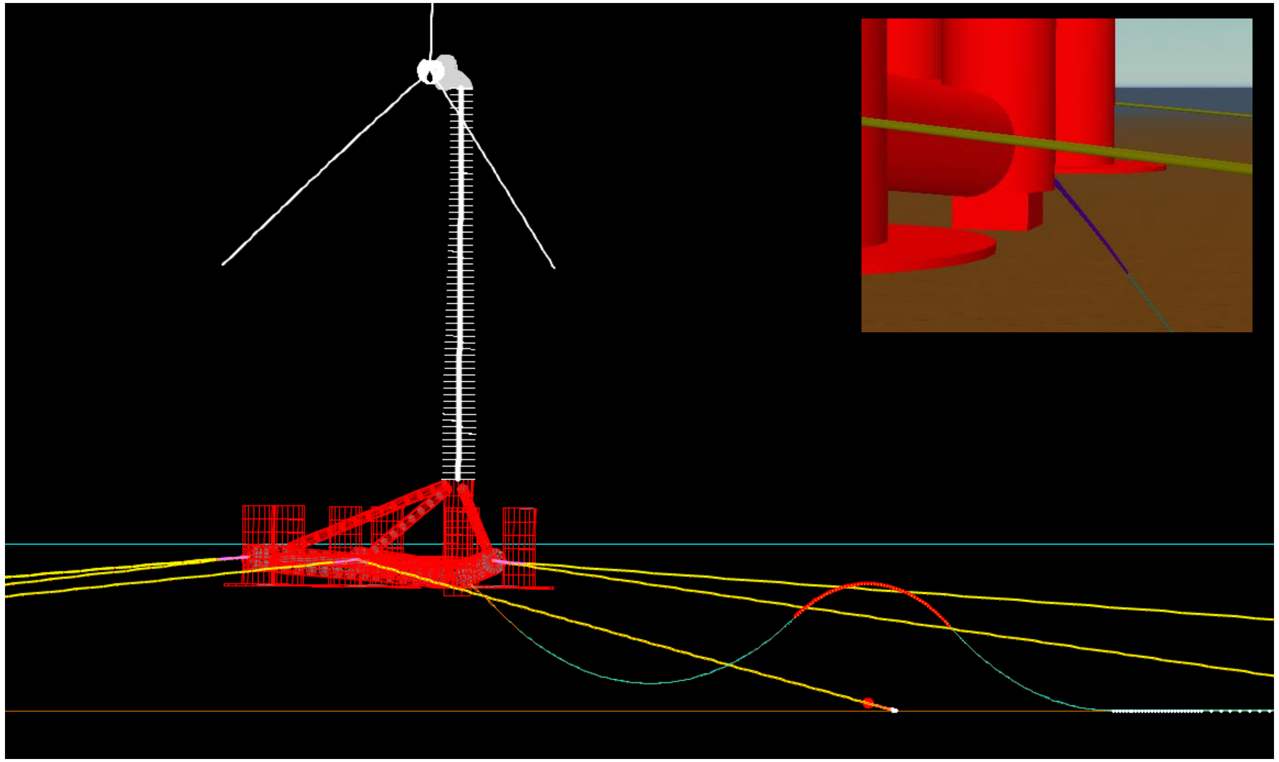
Power Cable Configuration Development

Fully Coupled Analysis



Configuration Development Results
Fully Coupled Analysis

- Improvements in floater motions and mooring line response observed in fully coupled analysis
- All mooring lines saw improved strength response (maximum strength utilization improved by 6.3%)
- Maximum floater offset improved by 5.1%
- It's possible that the dynamic cable is providing a damping response to the system, though requires further evaluation



Case Study Conclusions

- Power cable configuration is developed which meets extreme storm requirements in 50m water depth considering highly dynamic floater motions and large offsets

- LW configurations provide allowable operation in harsh environments

- Due to light power cable, anchoring near TDP is recommended to minimize seabed excursion and allow for earlier routing (well defined current speed and profiles are key factors)

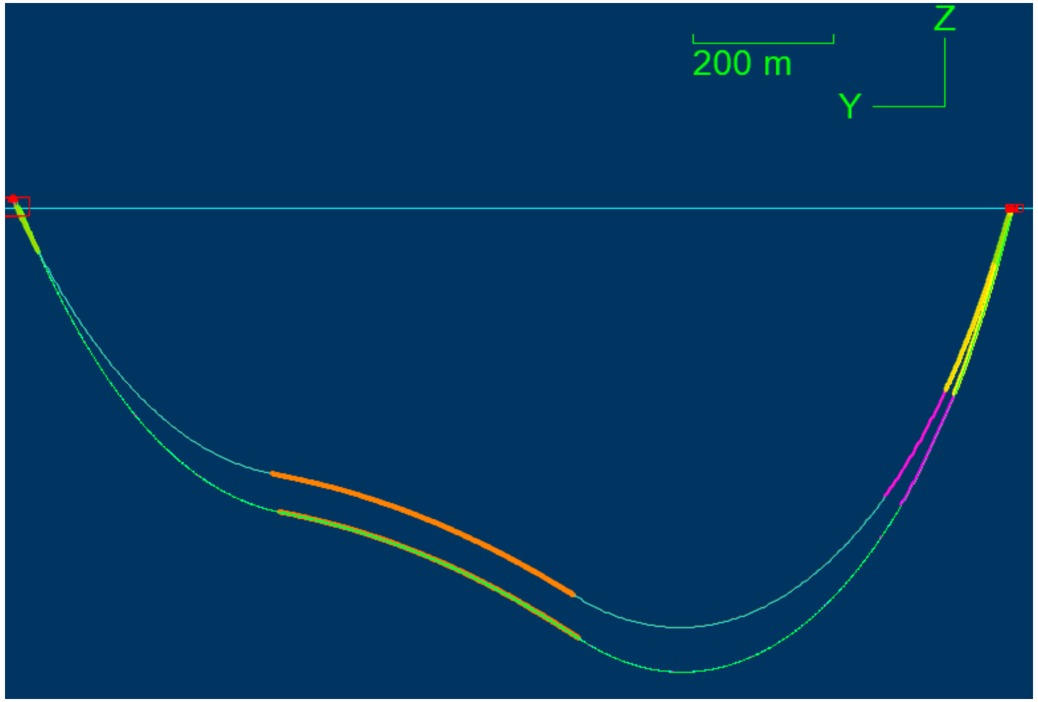
- Fully coupled analysis considering floater, mooring system and power cable may provide improvements in floater motions and mooring response

- Fatigue of power cable and clearance to mooring lines in operational and extreme seastates should be evaluated as environment is highly dynamic

Challenges in Deeper Water

Challenges in Deeper Water (>500m)

- Compliance requirements for vessel motions less of a concern, however maintaining small footprint for compact field may pose challenges
- Deeper water is less economical for seabed cable routing
- Midwater arch configurations (w-shaped) between floating foundations may provide more economical and result in less environmental impact



Wrap Up

- Power cable development in shallow water harsh environments with highly dynamic floaters requires compliant configurations to meet operational requirements

- Optimizing configurations to meet environmental and economical requirements will be key on the road ahead

- FOWT in deeper water will have a different set of challenges than shallow water. Shared mooring lines and midwater dynamic cables may be solutions to remain economical