ABS Seminar on Floating Production Installations and Facilities

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- FPSO Functionality, Risk and Availability
  - *FPSO's provide similar functionality as existing FPS systems in GoM plus storage and offloading facilities which allow direct export to both local and foreign markets [...except dry trees and drilling, for now…]*
  - *Risks associated with FPSO systems are no greater than for existing platforms: TLP, Spar, Semi [preliminary result of MMS CRA Study]*
  - *"...FPSO based systems have higher 'availability' than any other FPS+Pipeline based systems…" [Petrobras].*
    - *If FPSO process facilities or production well has a fault, reserve storage can still be delivered to a shuttle tanker*
    - *If FPSO shuttle tankers are late or WOW, production can continue when excess storage capacity is available*
    - *If an FPS or well or pipeline has a fault, delivery to export line stops.*

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Likely Characteristics of the First FPSO for the Gulf: *(my predictions)*
  - Large depth because of vast pipeline infrastructure in shallower water
  - > 1,000,000 bbl capacity: large field more economic in deep water
  - Internal turret because of large number of risers and harsh environment
  - Permanent system most economic for many risers / large field
  - Taut polyester anchor legs: rapidly gaining acceptance (e.g., Brazil)
  - Extensive use of steel pipe in riser system: presently the norm in GoM
  - Thermal insulation via Pipe-in-Pipe
  - Riser configuration that de-couples steel pipe from vessel wave motions

Early production system waiting on export pipeline may be exception

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Turret Systems: Elegant Solution, Highly Functional

  Provides Station Keeping

  - primary method for station keeping (thruster assist can be added)
  - restricts offsets to maintain riser system integrity

  Allows 360 degree weathervaning capability

  - reduces loads on mooring system
  - reduces motions for riser system and process (roll)
  - passive system can be unmanned during hurricanes

  Platform for mooring and riser systems pull-in equipment

  - Self contained pull-in systems require no additional support vessels after anchor leg/riser handoff to FPSO

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Turret System: Elegant Solution, Highly Functional

Provides product transfer system

  - Accommodates liquid and gas swivels and pig launching/receiving
  - Turret manifold system can replace or augment subsea manifolding

Includes well safety, control and maintenance systems

  - Contains emergency shutdown valves/controls
  - Wellhead control umbilicals (electric/hydraulic/fiber optic)
  - Gas lift and water injection for low pressure formations
  - Chemical injection for wax/hydrate control
  - Provides spare risers for well testing and round trip pigging

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Turret Systems: Elegant Solution, Highly Functional

  Drilling and work-over operations ⇒ future

  - Specialized turret design allows simultaneous drilling, production and storage: FPDSO. Non-conventional vessel, conventional components.

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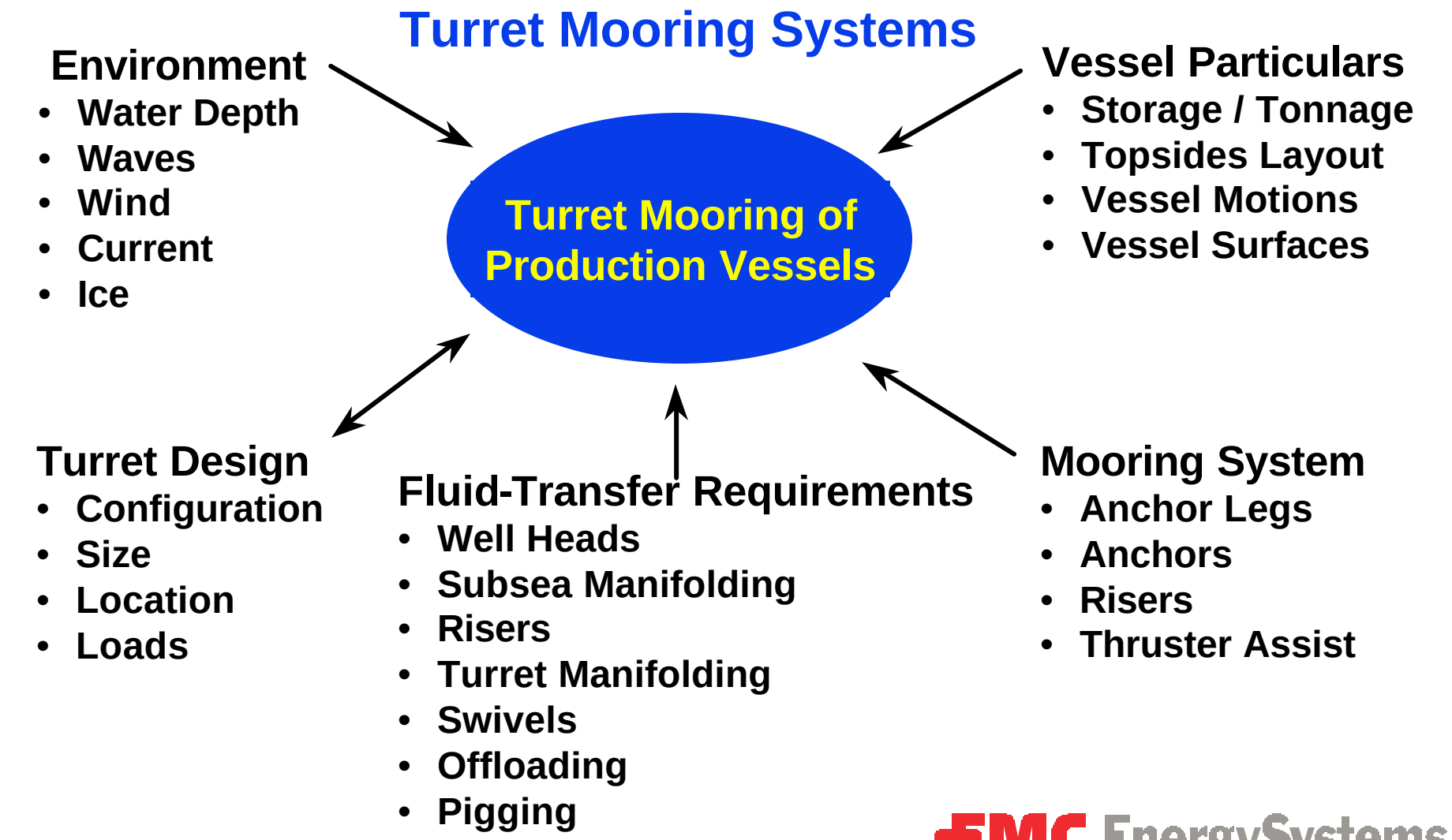
Design Considerations



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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Internal Vs. External Turret Systems

  External Cantilevered Turret Systems

  ⇒ Applications in mild to moderate environments:
  West Africa, Southeast Asia, Middle East, South Pacific

  ⇒ Permanent systems (generally)

  ⇒ Small number of risers

  ⇒ Shallow to moderate water depth applications

  Generally less costly than internal turrets

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External Turret Systems


Yepco Red Sea, Yemen
World's Largest FSO
436,000DWT=2,900,000BBL


Petronas (MASA), Malaysia


Amoseas Anoa, Indonesia


Shell Todd Maui B, New Zealand


PEMEX Cantarell, Gulf of Mexico
World's 2nd Largest FSO
352,000DWT=2,300,000BBL


Chevron Escravos, Nigeria

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Existing External Turret Mooring System in Gulf of Mexico

PEMEX Campeche Bay FSO: 1998, MODEC Intl LLC

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Internal Vs. External Turret Systems

  Internal Turret Systems

  ⇒ Applications in moderate to harsh environments:
  Brazil, North Sea, North Atlantic, South China Sea, Gulf of Mexico

  ⇒ Large number of risers (generally)

  ⇒ Moderate to deep water applications

  ⇒ Permanent and disconnectable systems

Internal turret anchor legs easier to design: no interference with bow

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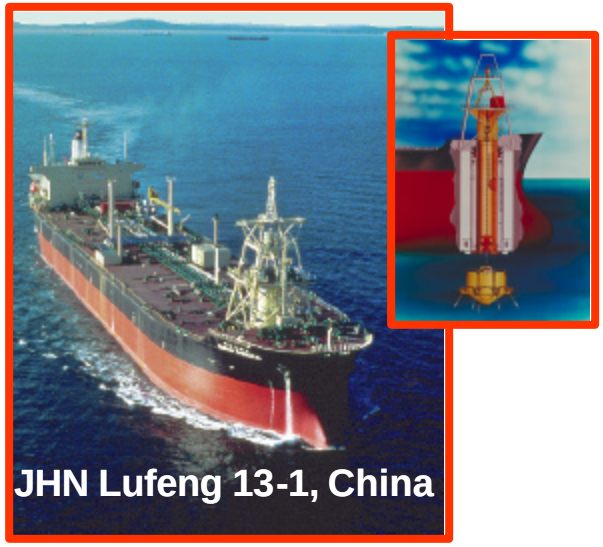
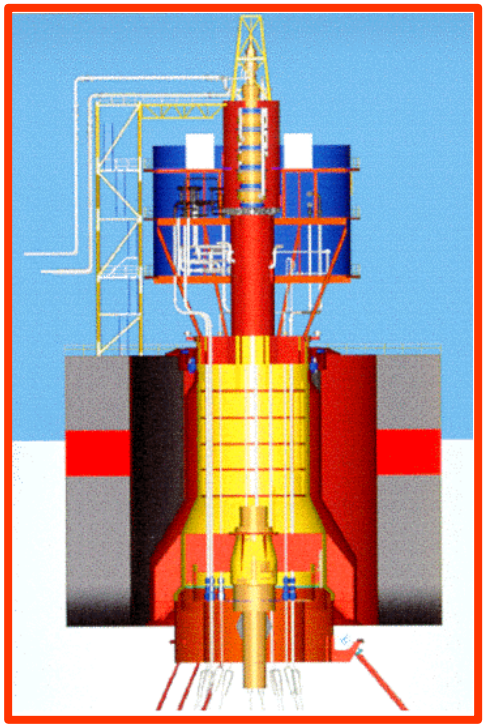
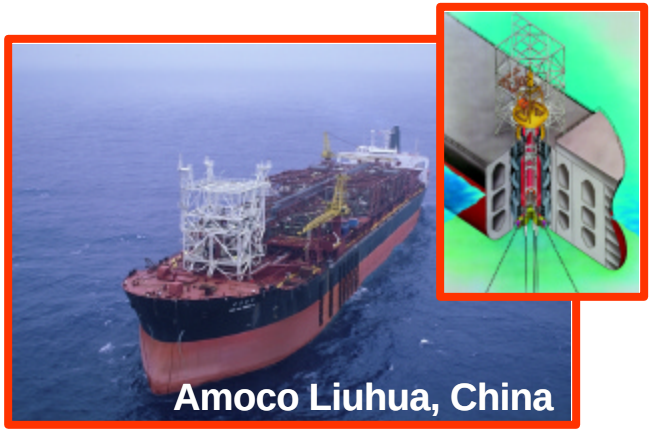
Internal Turret Systems: Permanent or Disconnectable


JHN Lufeng 13-1, China


PetroCanada - Terra Nova
Newfoundland, Canada


Petrobras - Albacora, Brazil


Petrobras - Barracuda, Brazil


Amoco Liuhua, China

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Permanent Vs. Disconnectable Turret Systems

  Which is the best solution?

  - Either approach could be acceptable depending on:
    - Regulatory requirements
    - Owner Company's approach to Risk
    - Environment
  - Each approach has different:
    - CAPEX
    - OPEX
    - Availability
    - Risks

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Permanent Vs. Disconnectable Turret Systems

  Permanent Turret Systems

  ⇒ Higher production up-time: don't necessarily shutdown because of hurricane "threat", only if direct hit is immanent

  ⇒ Evacuation decision based on operator preference, not environment

  ⇒ Lower long-term OPEX

  ⇒ Less complex mechanical systems

  ⇒ Must withstand 100-yr hurricane environment

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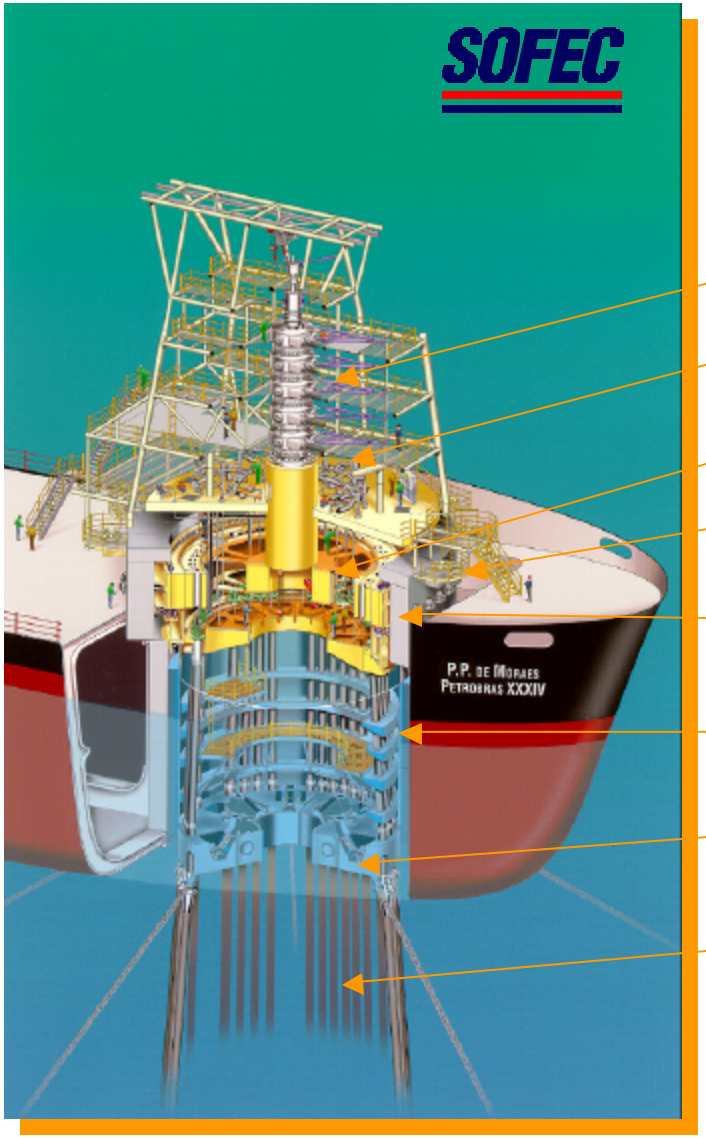
Typical Permanent Internal Turret System



Barracuda FPSO: Campos Basin
834m (2,700ft), 34 Risers

- Swivel Stack (Product/Lift/Controls)
- Manifolds + Pig Launching/Receiving
- Emergency Shutdown Valves
- Anchor Leg + Riser Pull-In Equipment
- Bearing (only upper in this case)
- Turret Shaft / Riser Guide Tubes
- Chain Table (Hawse Pipes/Chain Supports)
- 6 Anchor Legs + 34 Risers

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Permanent Vs. Disconnectable Turret Systems

Disconnectable Turret Systems

⇒ Potentially lower risk of hurricane damage

⇒ Requires full time marine certified crew

⇒ Requires maintenance of self propulsion system

⇒ More complex fluid transfer system and control / instrumentation for disconnect / reconnect

⇒ Not necessarily lower CAPEX than permanent turret system: depends on number of risers, required disconnect/reconnect times, safety features, etc.

Example: Terra Nova FPSO disconnects for icebergs, not 100-yr storm.
In GOM, one might design a disconnectable system to withstand up to 100-yr storm, but disconnect for > 100-yr.

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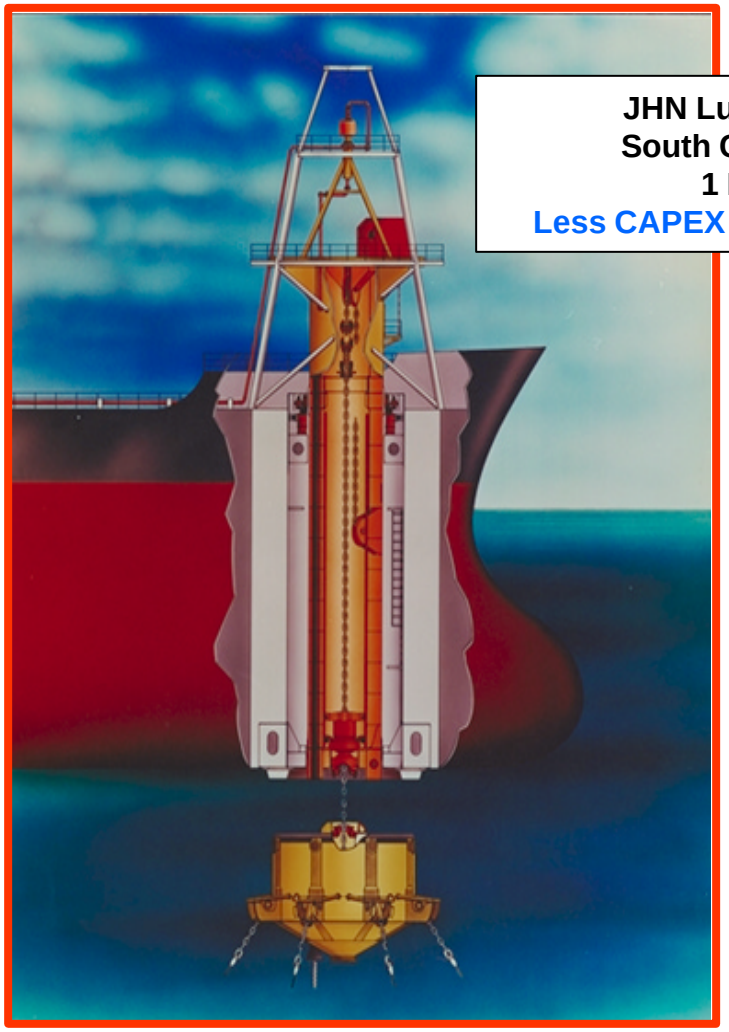
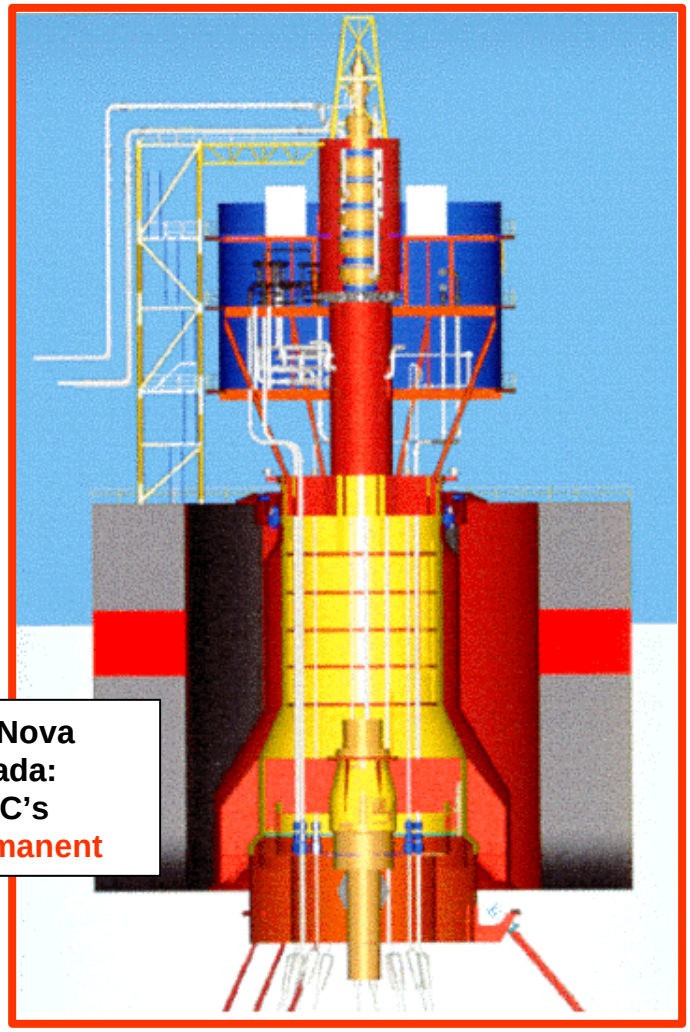
Disconnectable Turret Systems



JHN Lufeng 13-1,
South China Sea:
1 Riser
Less CAPEX than Permanent



PetroCanada - Terra Nova
Newfoundland, Canada:
19 Risers with QCDC's
More CAPEX than Permanent

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Mooring and Riser System Design

Shallow water design

⇒ Vessel offsets = 30% to 40% of water depth: riser design challenge

⇒ Riser loads nearly insignificant for turret design

⇒ Anchor leg / riser interference is key design issue

Deep water design

⇒ Offsets = 10% to 20% of water depth: helps simplify riser design

⇒ Riser loads significant for turret design and total restoring force

⇒ Surge-drift damping contribution from anchor legs and risers is large

⇒ Current loads on anchor legs and risers can be large

⇒ VIV induced motions/loads on risers must be considered for fatigue

∴ *Coupled analysis of mooring & risers is critical for deepwater*

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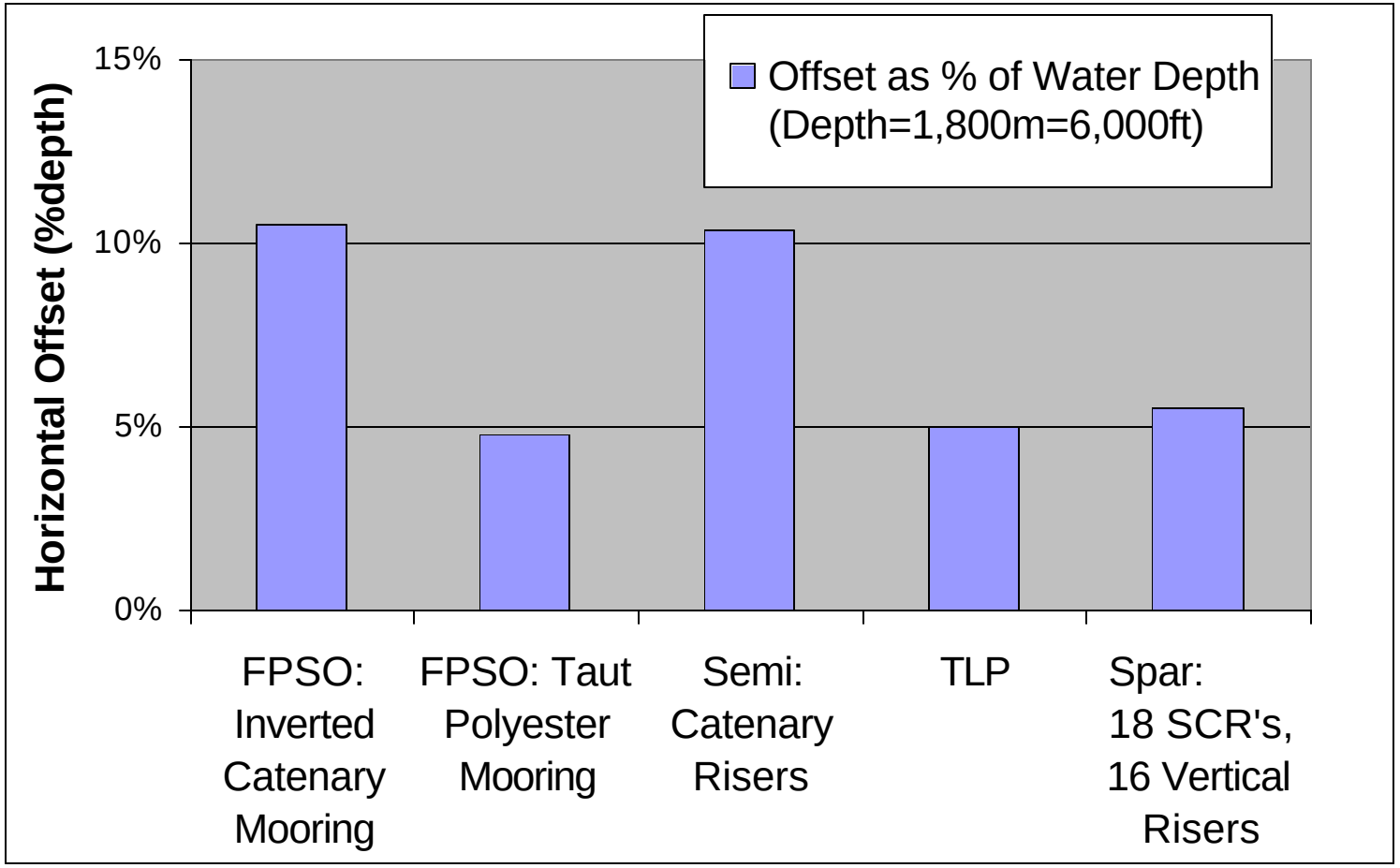
Comparison of FPSO Motions to Existing Platforms in the Gulf of Mexico

- Comparison of Maximum Total Horizontal Offset



Non-FPSO Motions courtesy Shell and Deepstar

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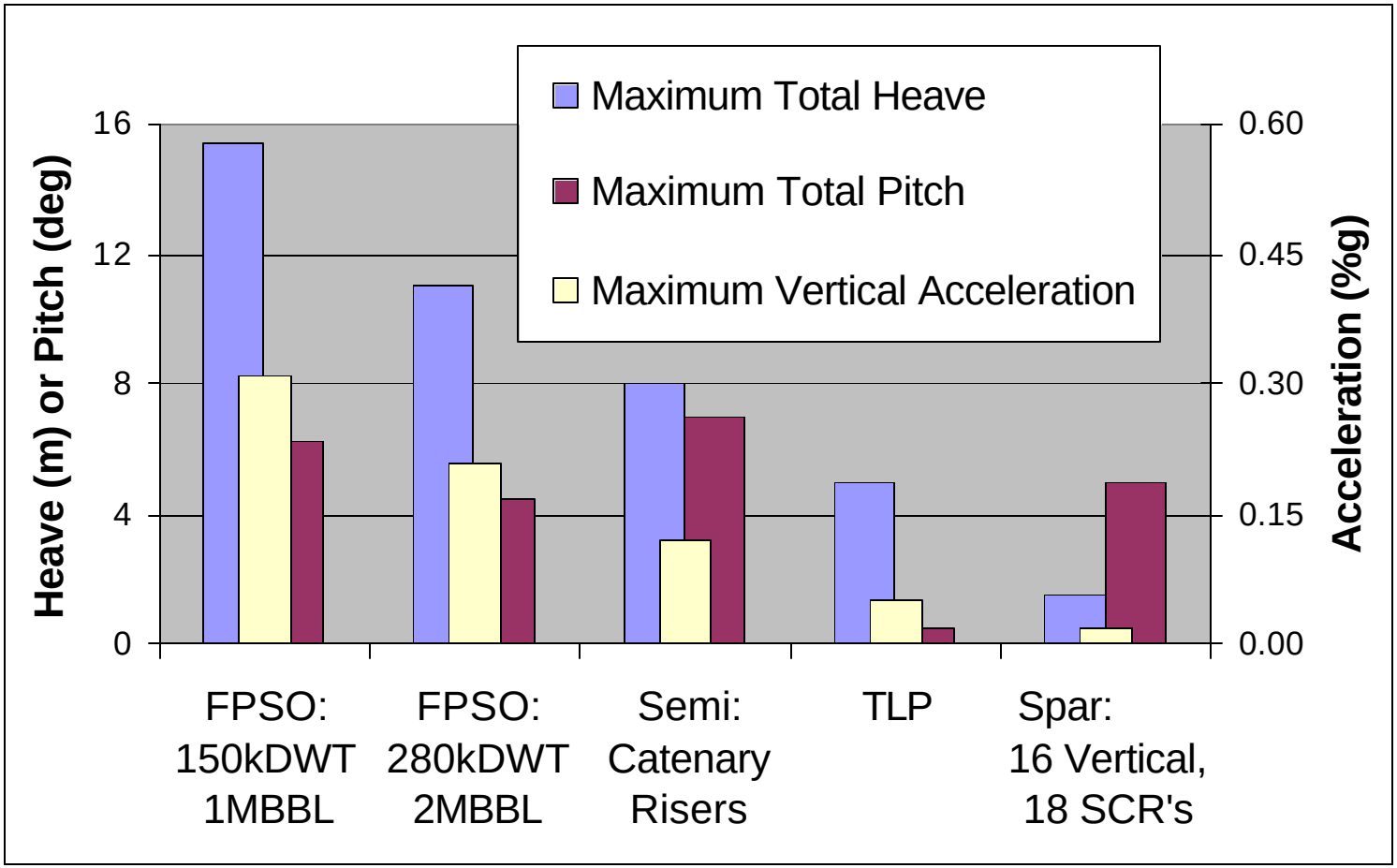
Comparison of FPSO Motions to Existing Platforms in the Gulf of Mexico

- Comparison of Maximum Total *Heave, Pitch, Vert. Accel.*



Non-FPSO Motions courtesy Shell and Deepstar

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Semi, Spar and TLP motions are “De-Tuned” from Waves (small waterplane area hull forms compared to FPSO)
  - Wave Periods: 4 to 20 seconds (95% energy)
  - Semi-Sub Natural Periods: 20 to 50 seconds (heave & pitch)
  - Spar/TLP Natural Periods: 30 to 150 seconds (heave & pitch)
  - Therefore dynamics are generally less severe than for FPSO
- Heave & Pitch Natural Periods for tanker: 8 to 12 seconds
- In GOM, FPSO will likely require a more “compliant” or “de-coupled” riser configuration compared to simple catenary or top tensioned vertical risers

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- FPSO Motion Reduction & Motion-Tolerant Riser Systems
  - Hull Form Optimization: ⇒ minimize wave motions
  - Utilize Oversized Hull: ⇒ reduce wave motions
  - Thruster-Assisted Mooring: ⇒ smaller wave/vessel heading reduces motions & offsets, ⇒ turret closer to midships reduces wave motions
    (may require manned platform for Hurricane)
  - Taut Polyester Mooring: ⇒ reduce vessel offsets
  - Compliant Riser Configurations: ⇒ e.g., Steel Lazy Wave
  - Decoupled Riser Configurations: ⇒ e.g., TLR, FTB, Hybrid Tower

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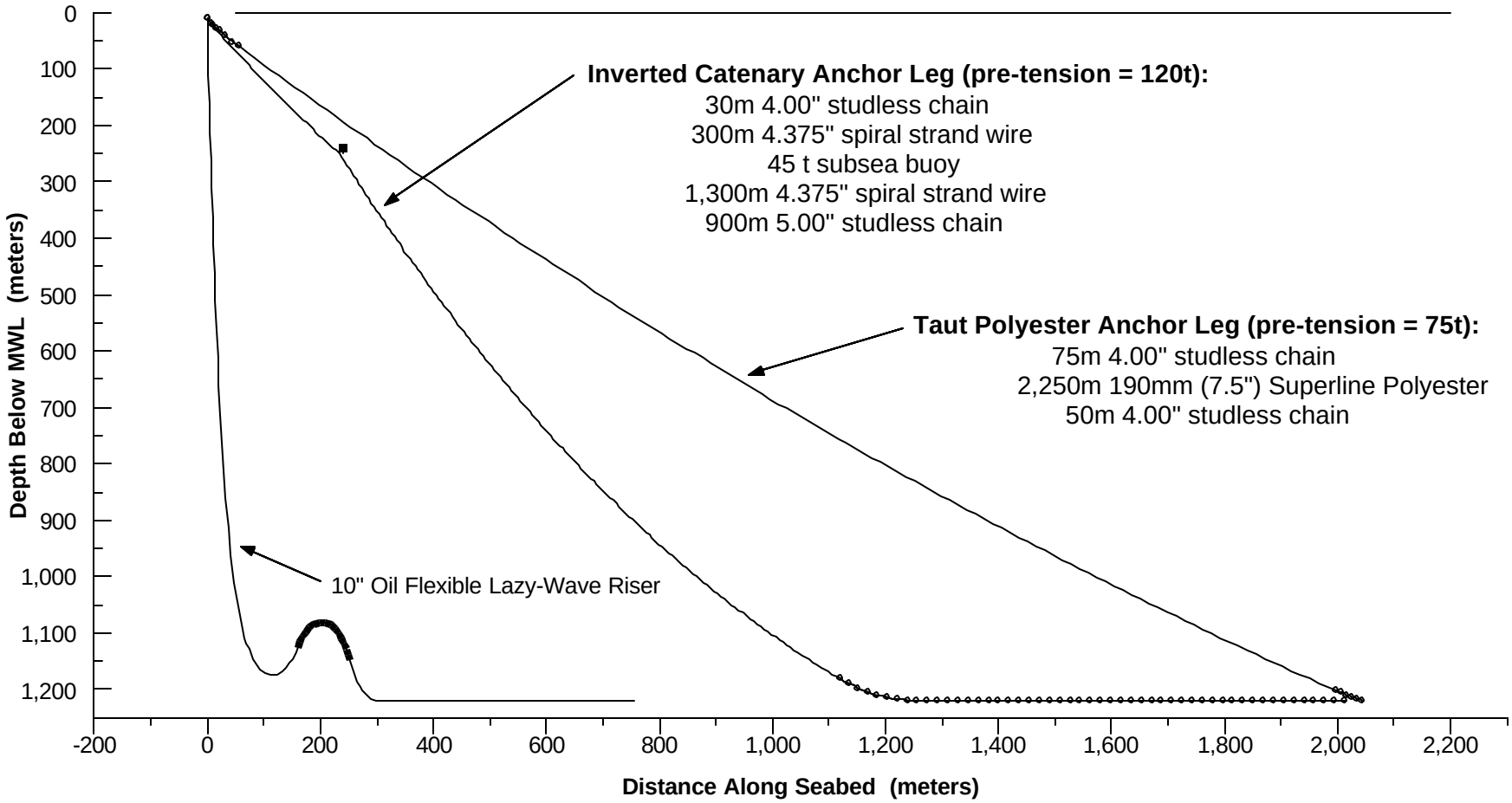
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Offset Reduction Via Taut Polyester Mooring: 10% to 5%



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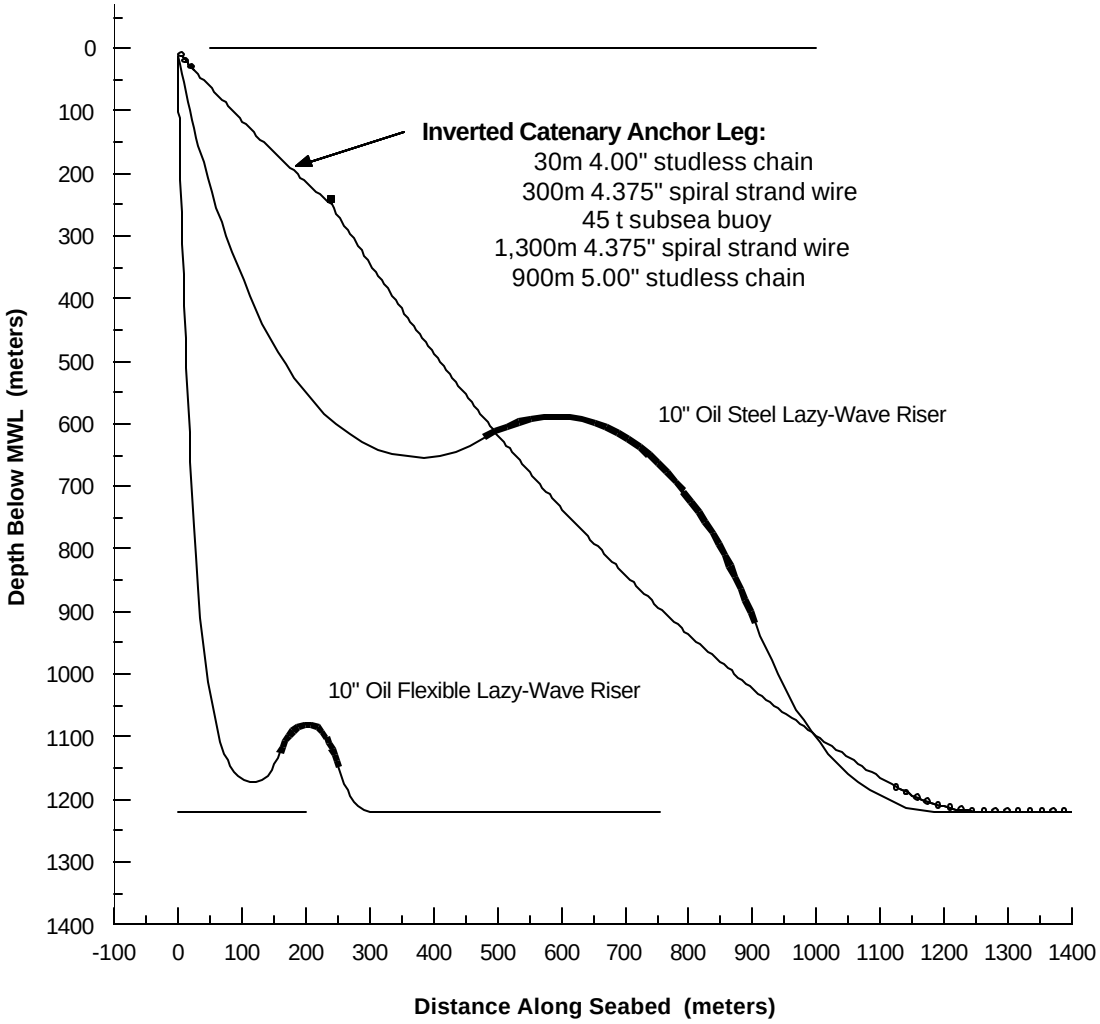
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Steel Lazy Wave Riser (compliant)



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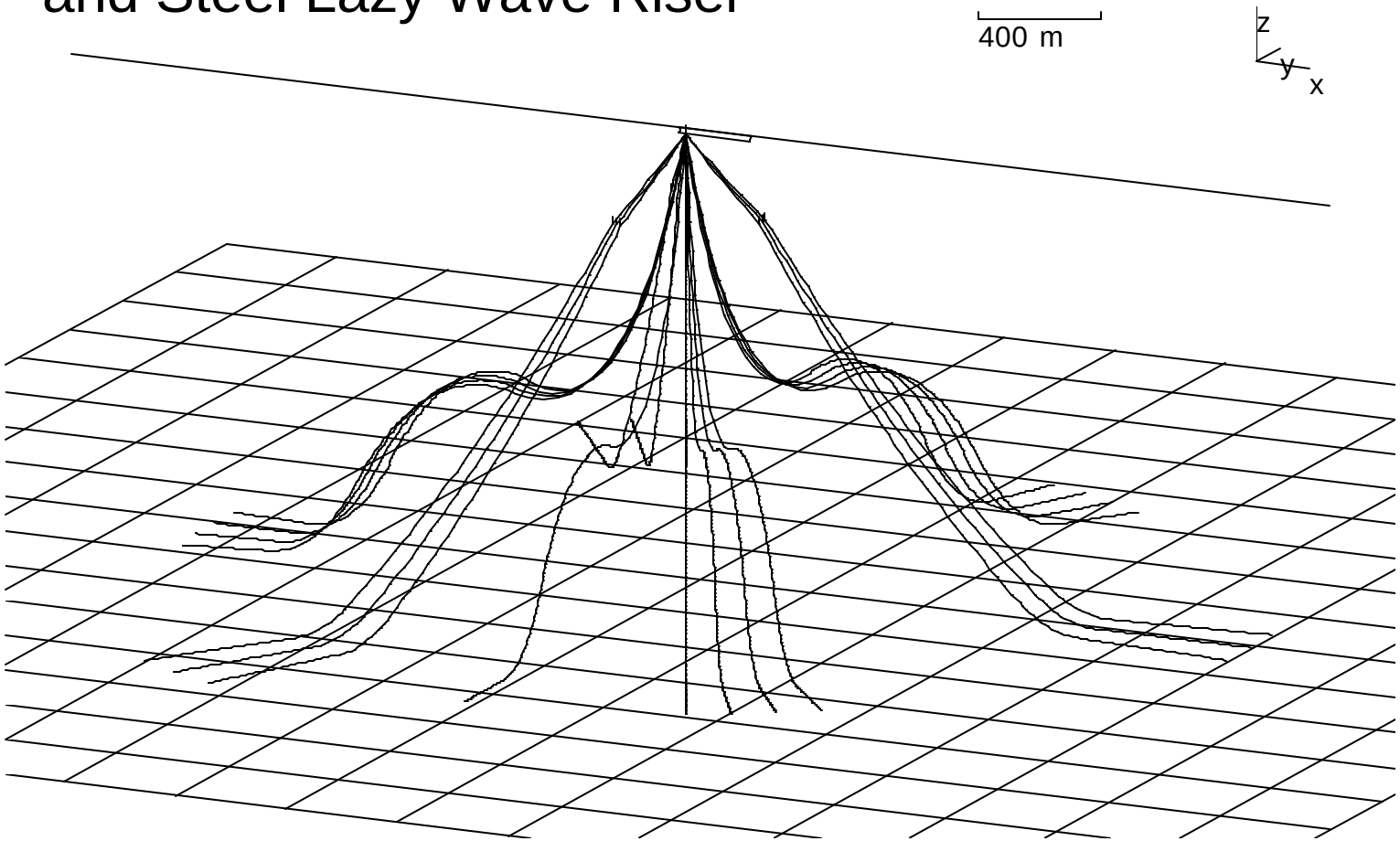
Typical Deepwater GoM FPSO Mooring & Riser System

- 3x3 Inverted Catenary Chain & Wire Mooring and Steel Lazy Wave Riser



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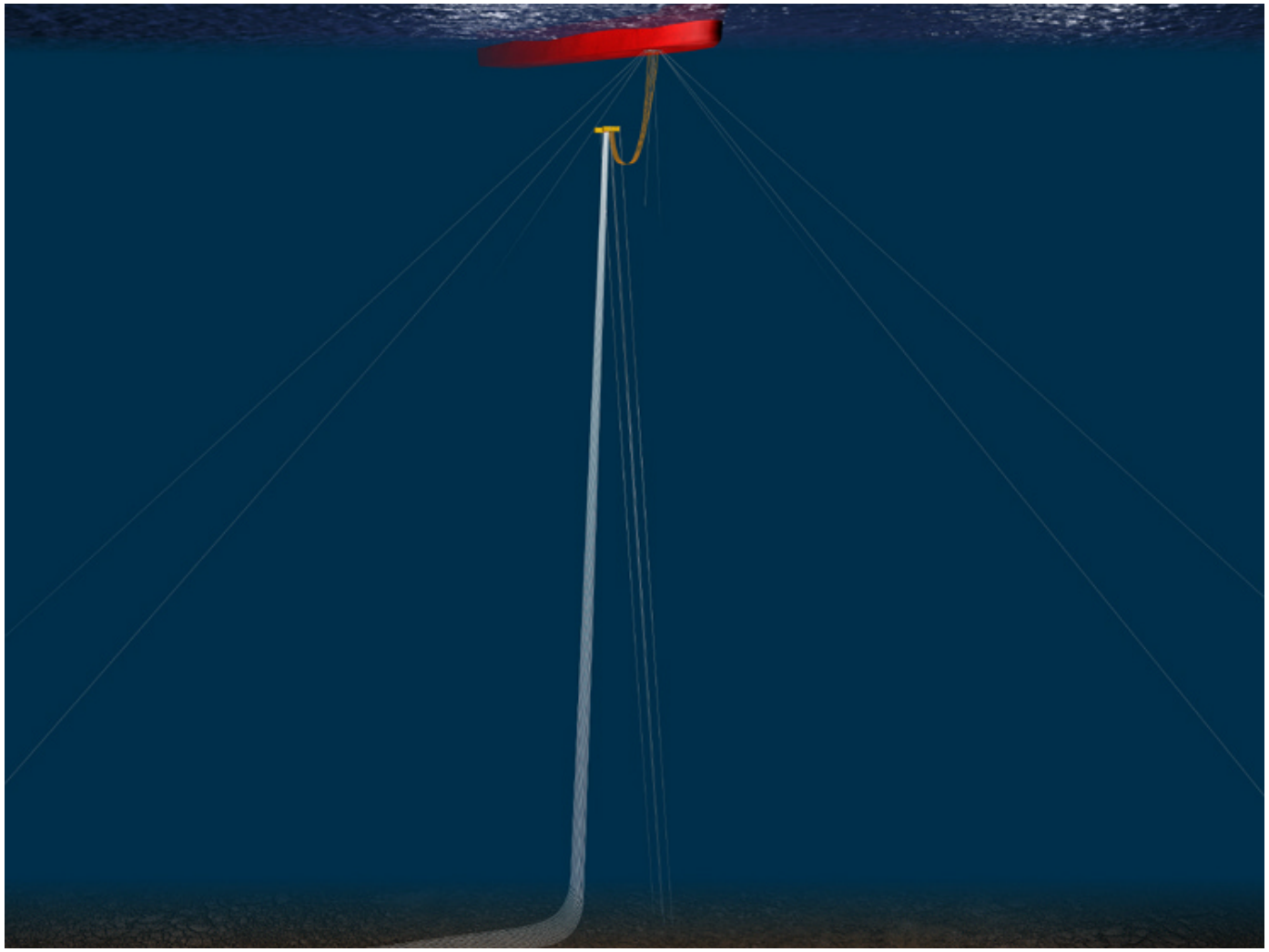
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions



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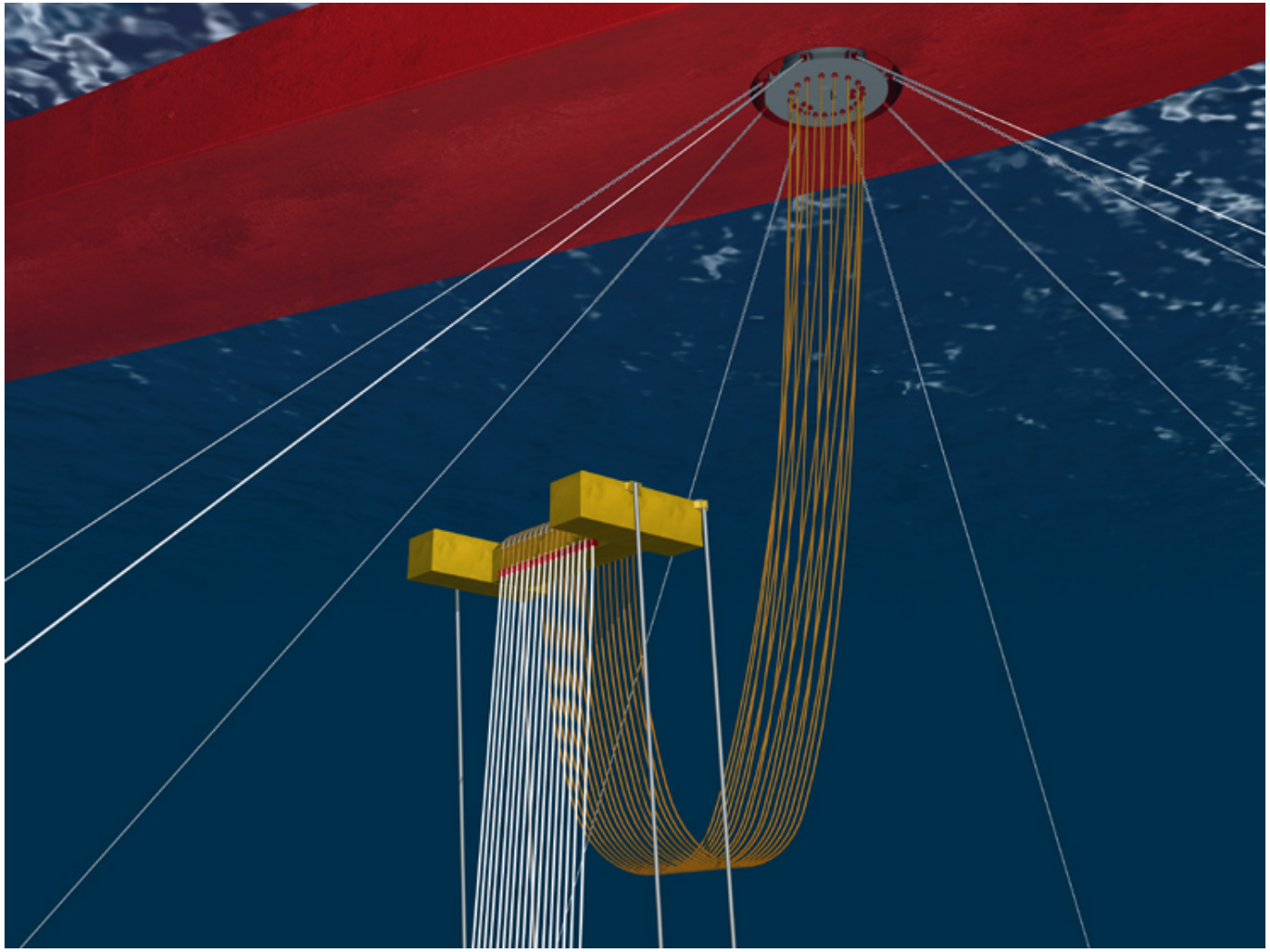
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions

Drastically
Reduces
Turret
Loads



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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- TLR Riser System:
  - FPSO motions de-coupled using a submerged steel buoy supporting SCRs and flexible jumpers to the turret
  - Can accommodate a large number of risers
  - De-coupling effective ⇒ buoy motions are small
  - SCR's not affected by the 100-year hurricane or fatigue environments
  - Proven technology, with standard fabrication/installation procedures
  - Recent DeepStar study concluded that TLR system is feasible in 3,000m depth and less costly than Steel Lazy Wave or Hybrid Riser Towers:

COST COMPARISON:	TLR	100%
(based on large, multi-	Lazy Wave	120%
riser field development)	Hybrid Tower	145%

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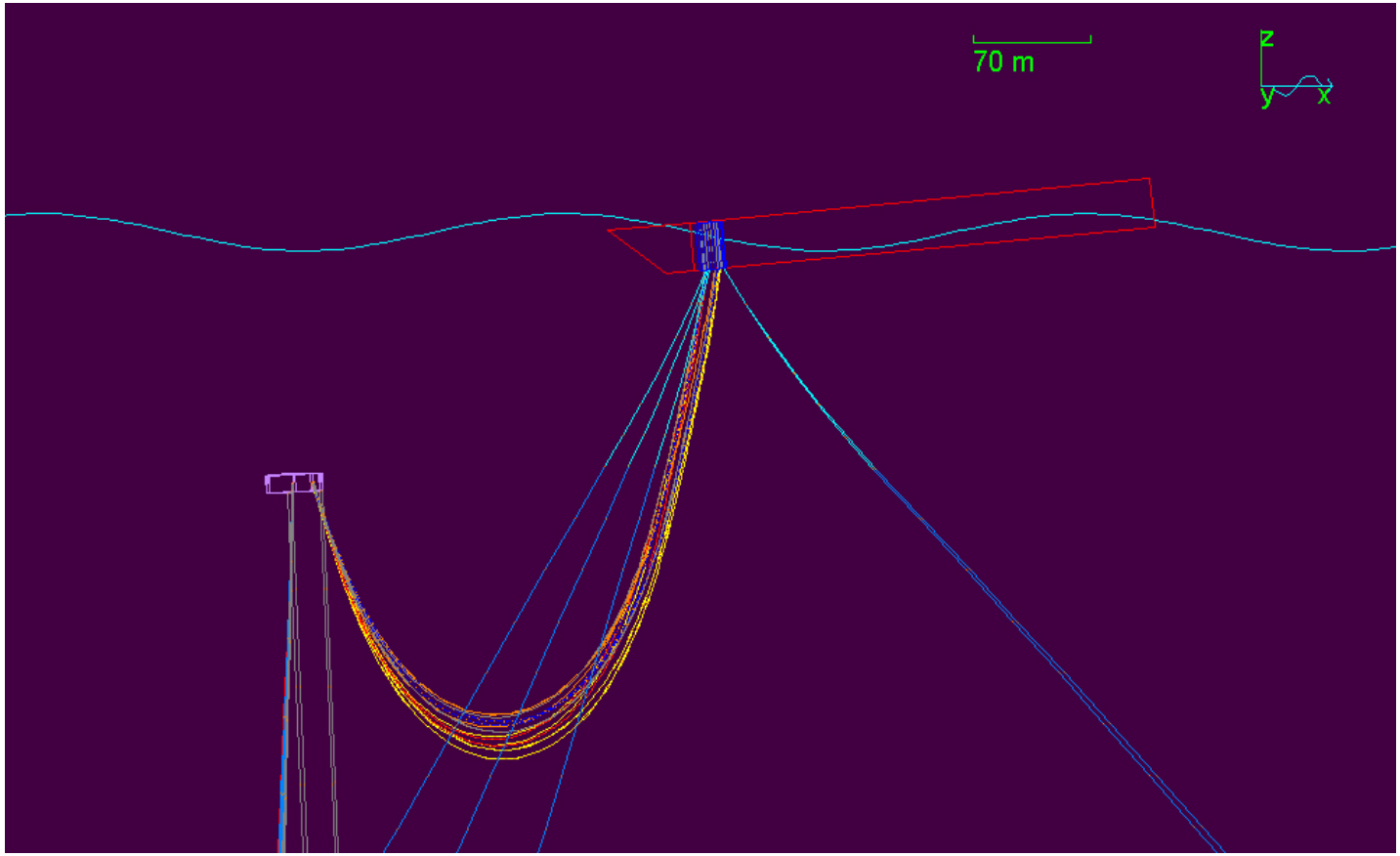
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR Riser System

Steel Lines De-Coupled from FPSO Motions



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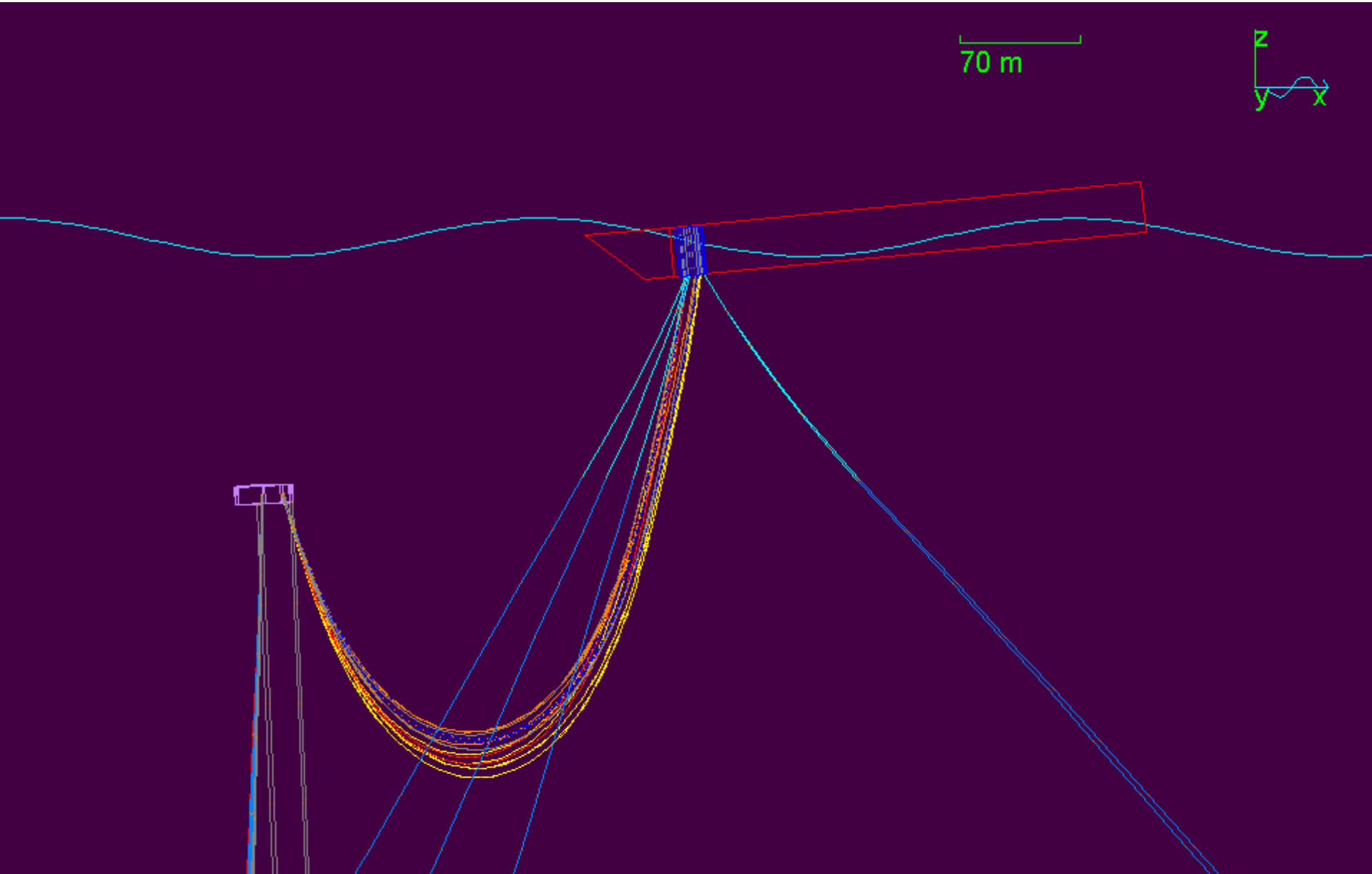

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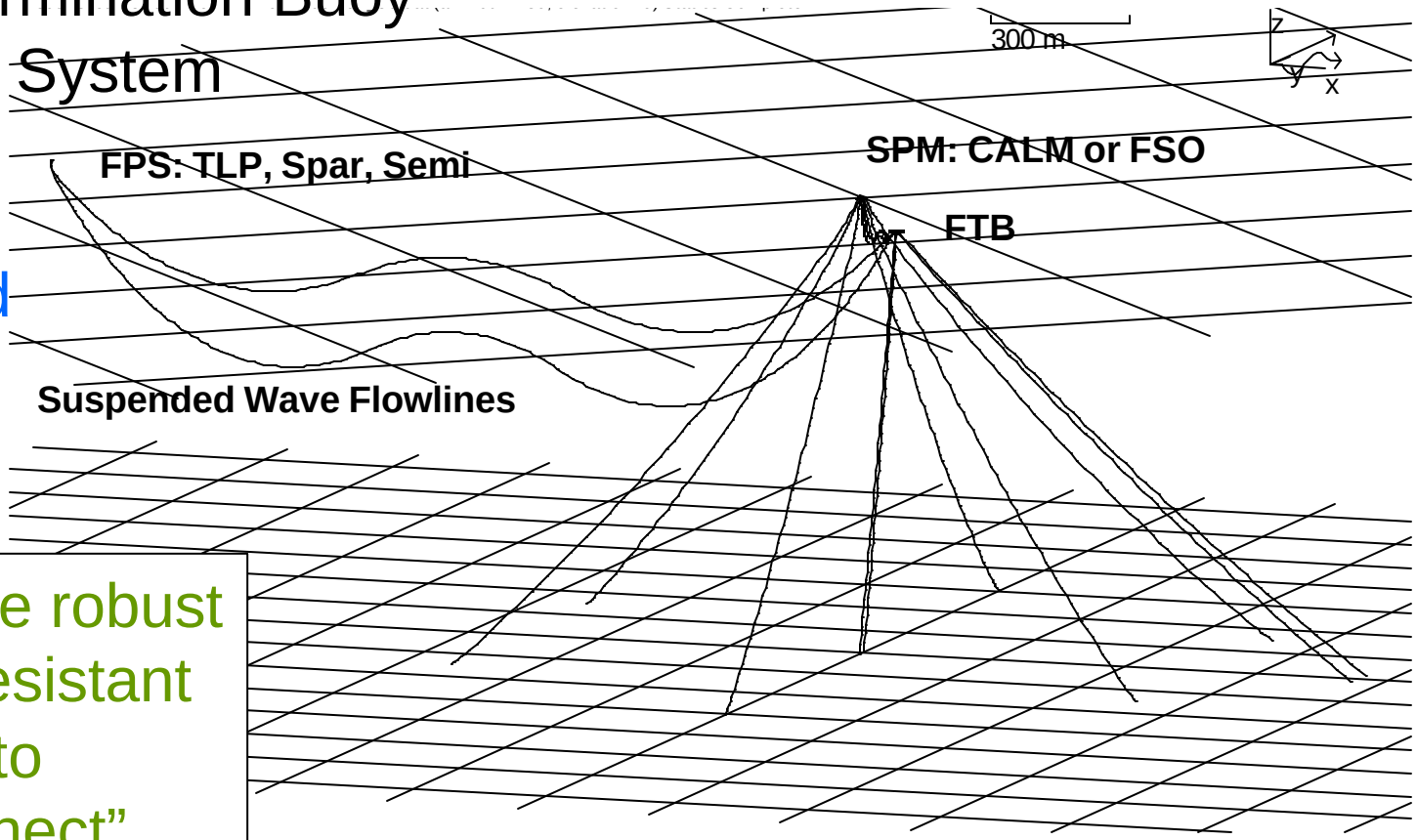
Flowline Termination Buoy (FTB) Riser System

Steel Lines De-Coupled from FPSO



FTB is more robust & fatigue resistant compared to "direct-connect" riser systems

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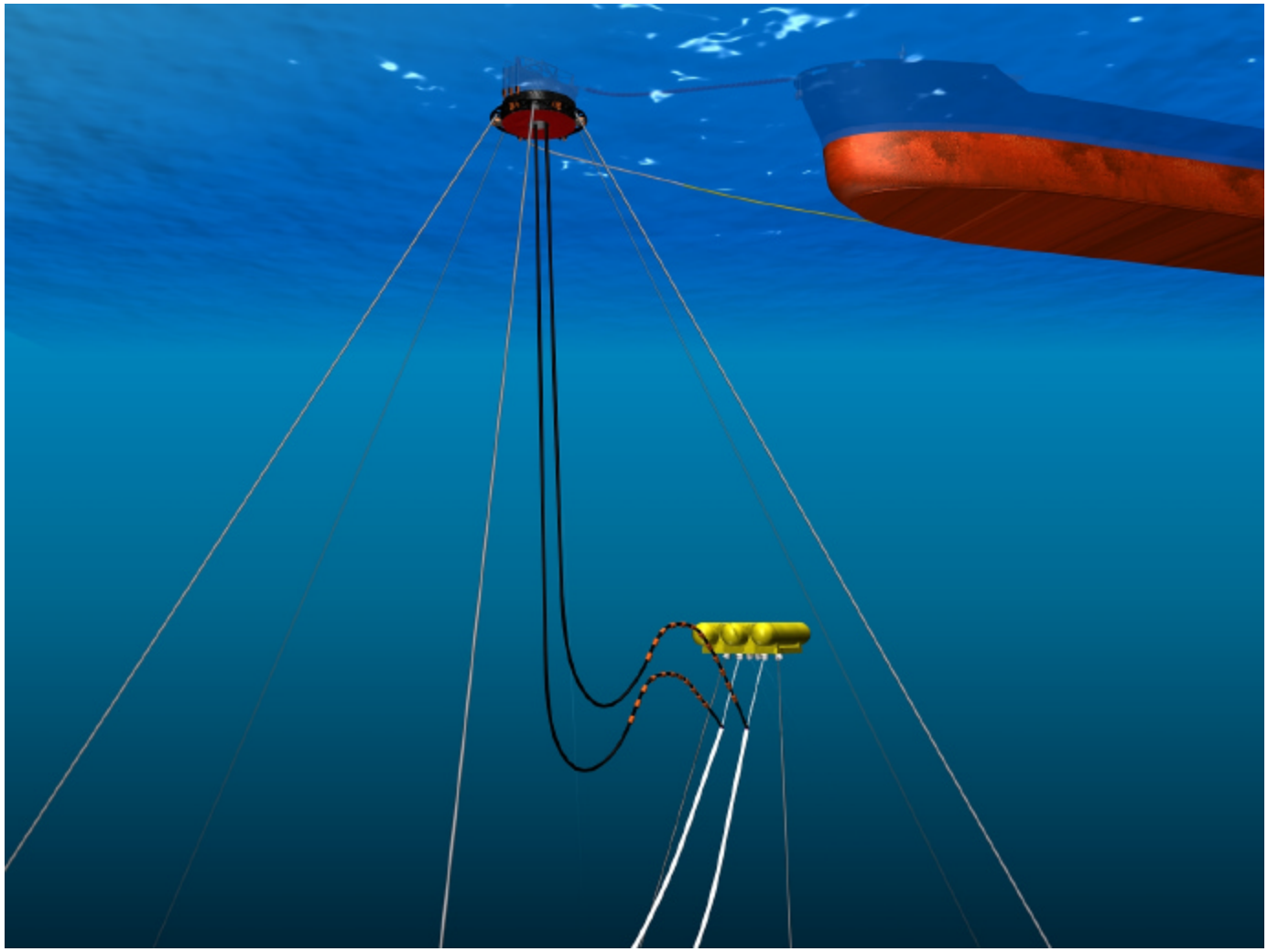
SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

SPM can be CALM or FPSO



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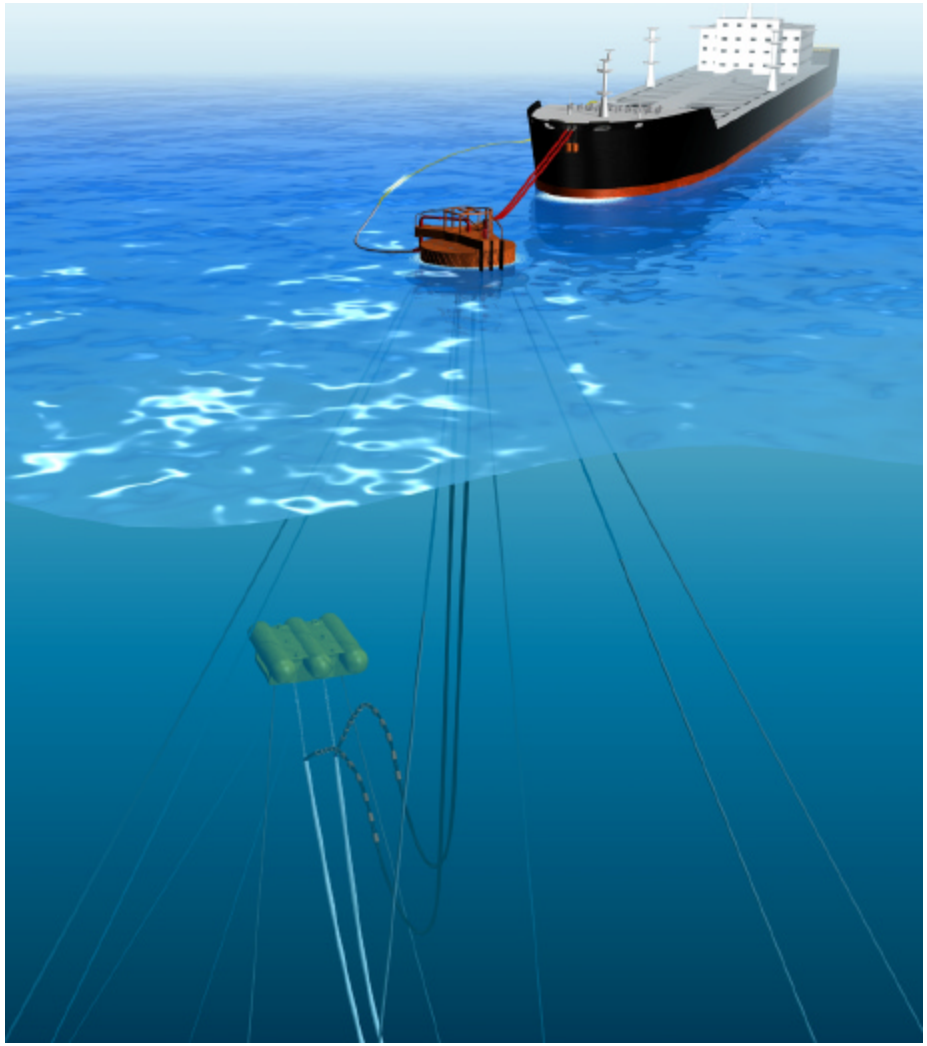
SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Fluid Swivels Above Water



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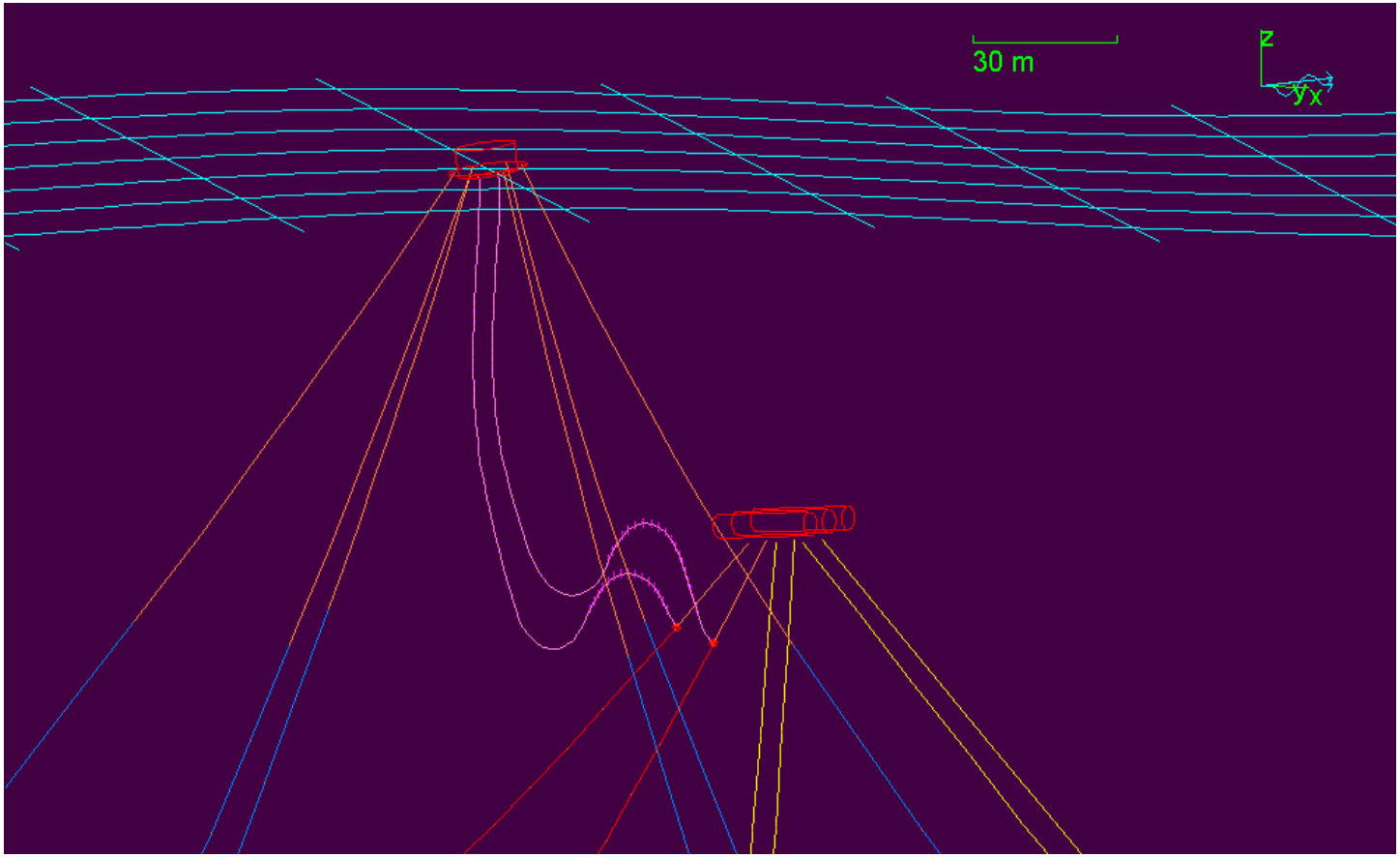
SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Product Swivels Above Water



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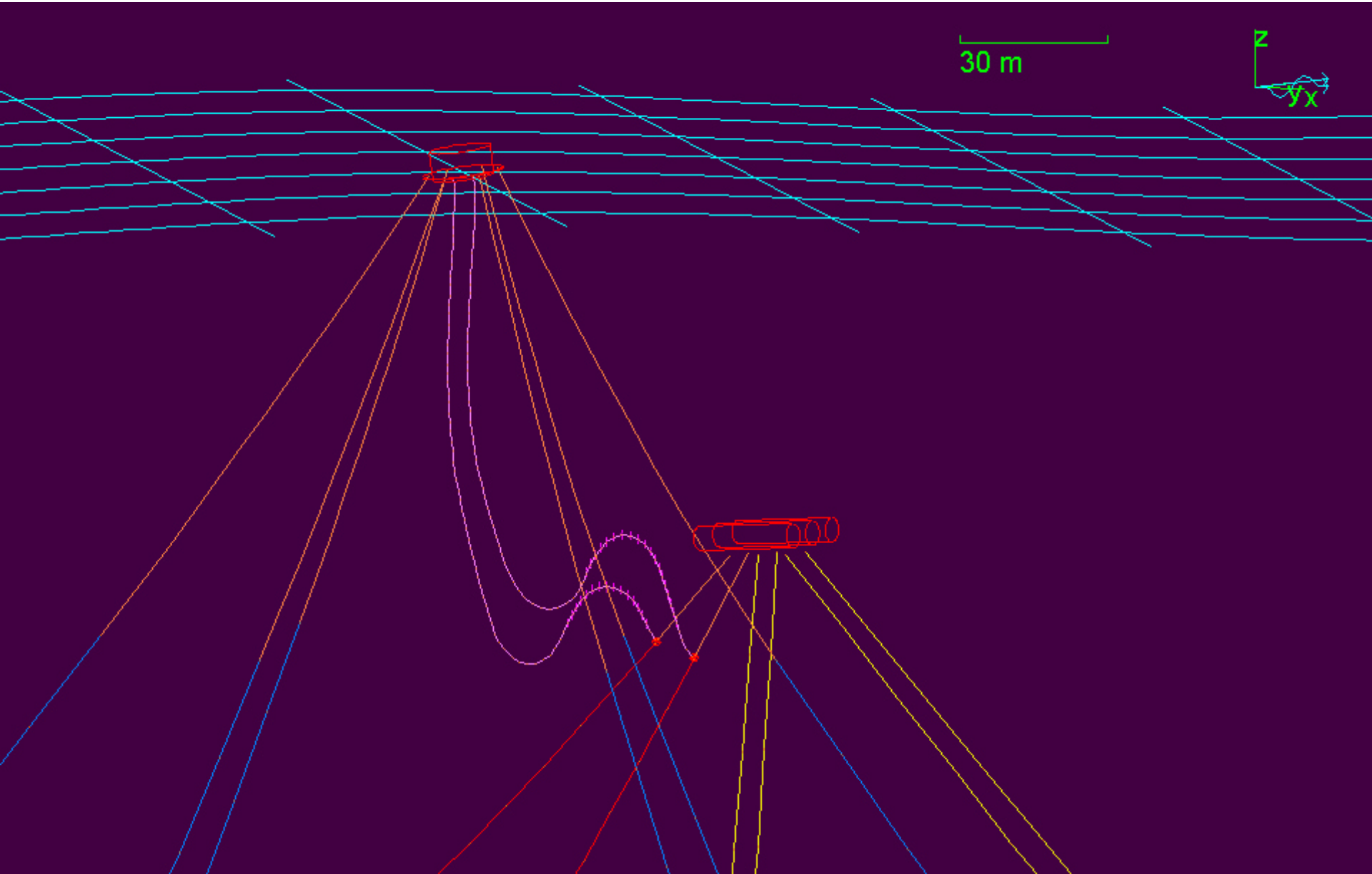
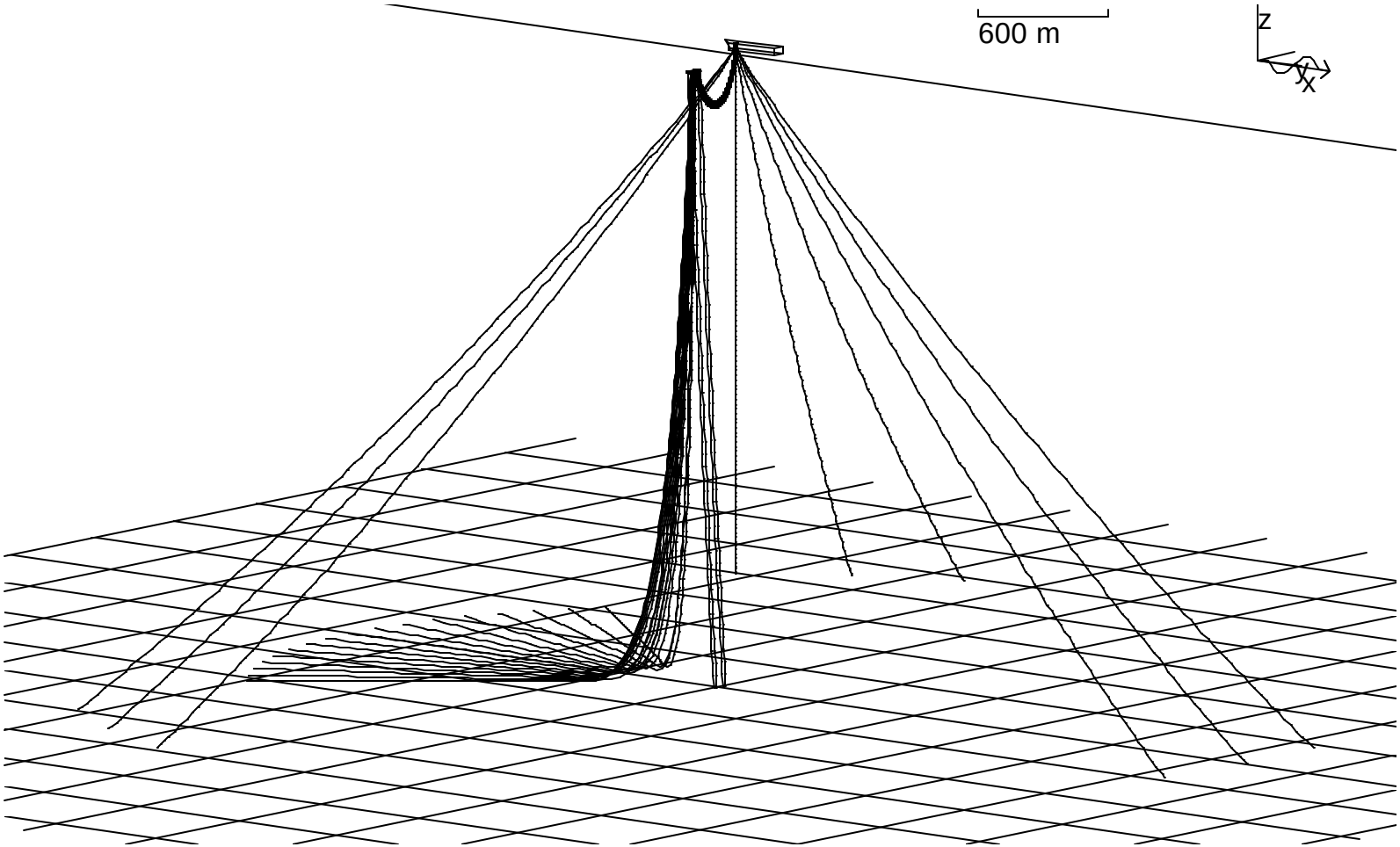
SPM to FTB Riser System



Typical Deepwater GoM FPSO Mooring & Riser System

- 3x3 Taut Polyester Mooring and TLR Riser



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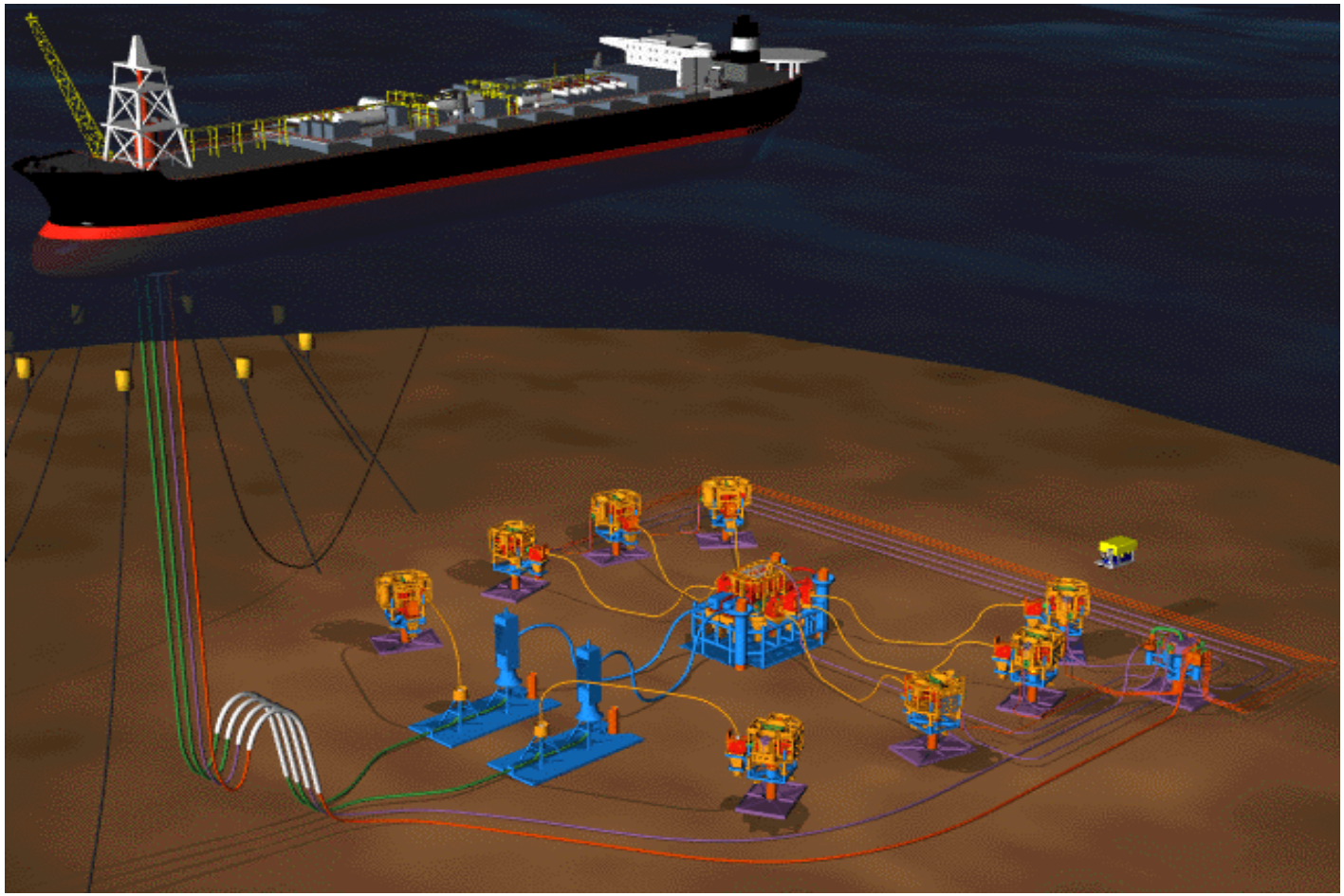
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- FPSO-Based Field Development: present and future...



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