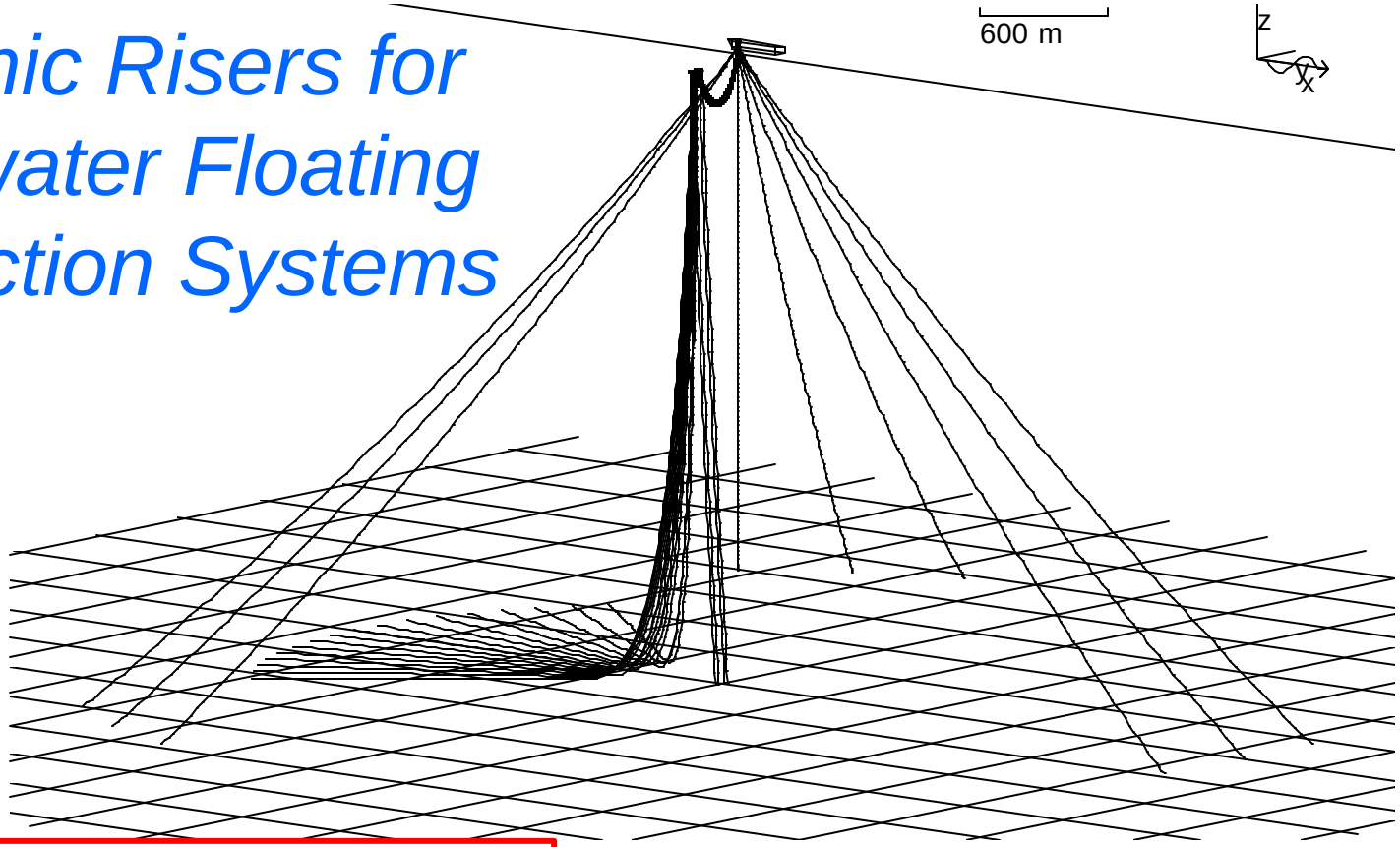
International Conference on Deepwater Exploration and Production

Dynamic Risers for Deepwater Floating Production Systems



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R&D / Hydrodynamics Department

February 22, 2001

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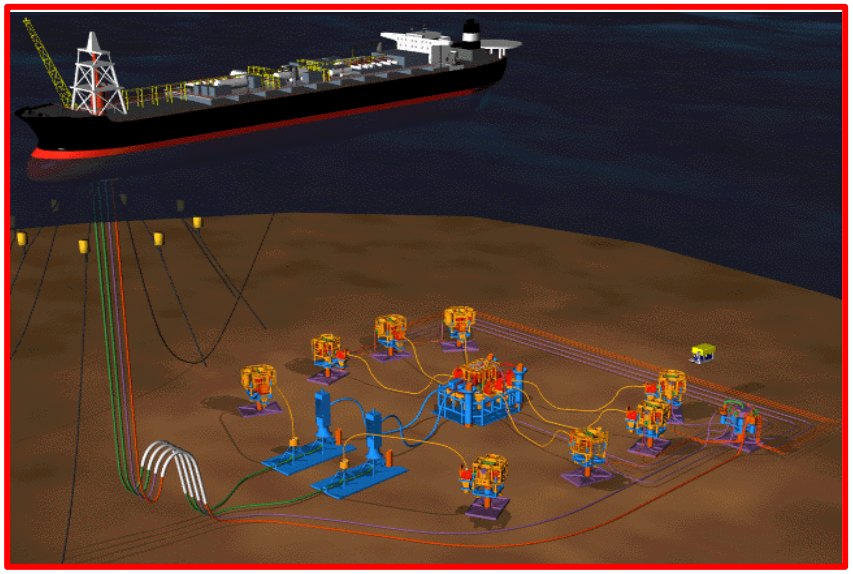
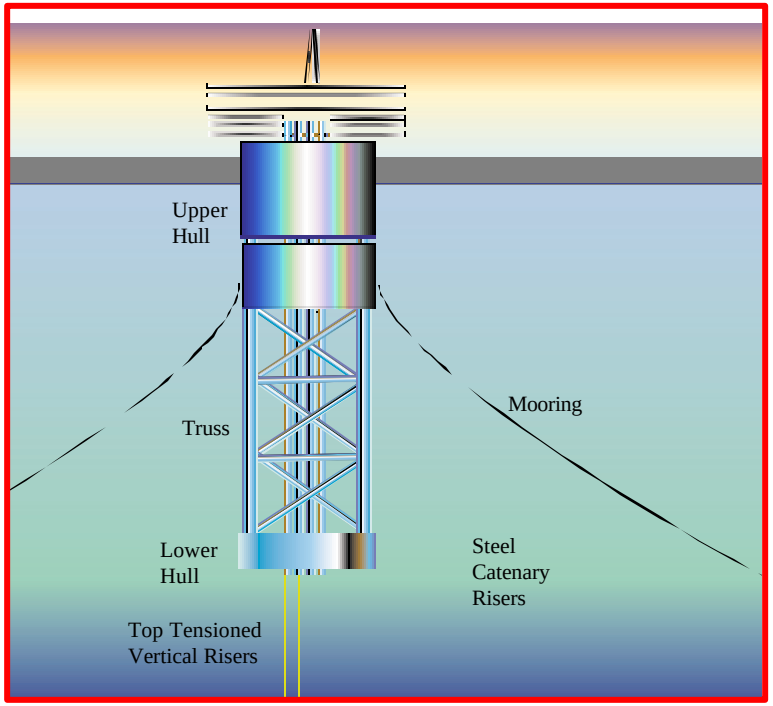
Dynamic Risers for Deepwater Floating Production Systems

- Typical Floating Production Platforms
  - Spar
  - TLP
  - Semi
  - Tanker



FPSO Tanker
Large Water-Plane Area Hull



Hub Class Spar (courtesy Shell DDSI)
Small Water-Plane Area Hull

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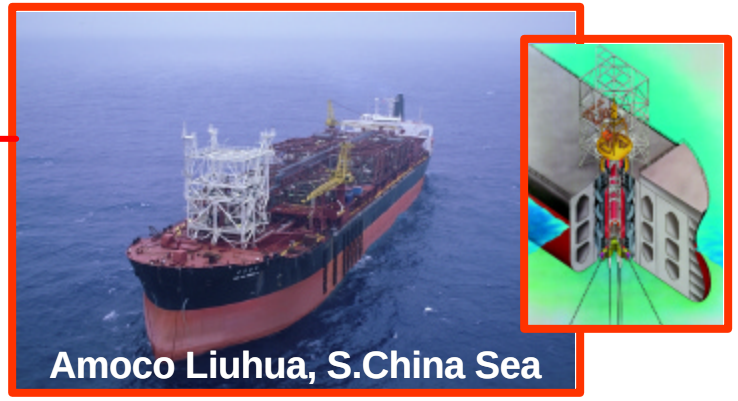
Dynamic Risers for Deepwater Floating Production Systems

- FPSO Turret Systems: Elegant Solution, Highly Functional

External Turret

Internal Turret



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Dynamic Risers for Deepwater Floating Production Systems

- FPSO 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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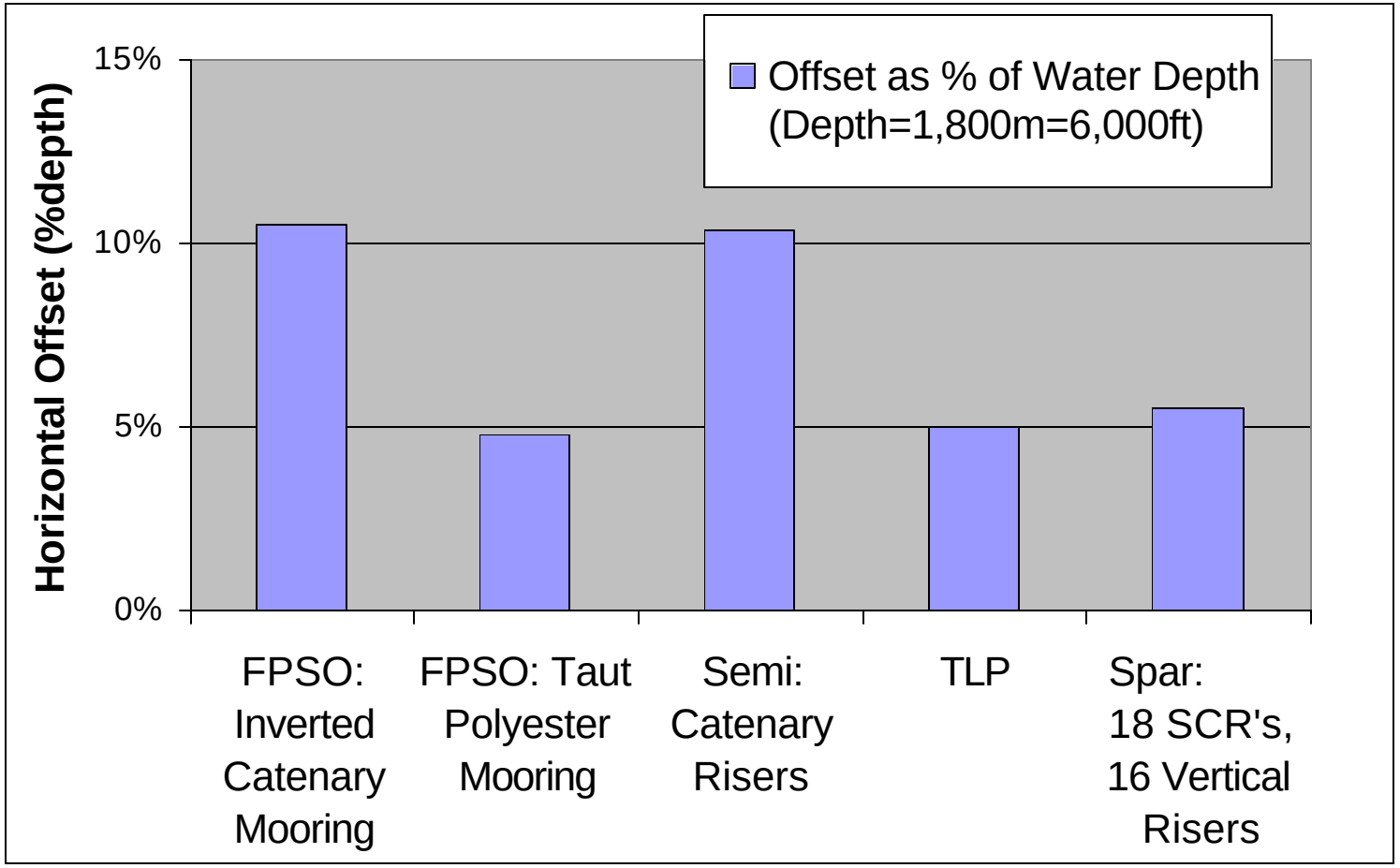
Comparison of Floating Production Platform Motions

- Comparison of Maximum Total Horizontal Offset



Non-FPSO Motions courtesy Shell and Deepstar

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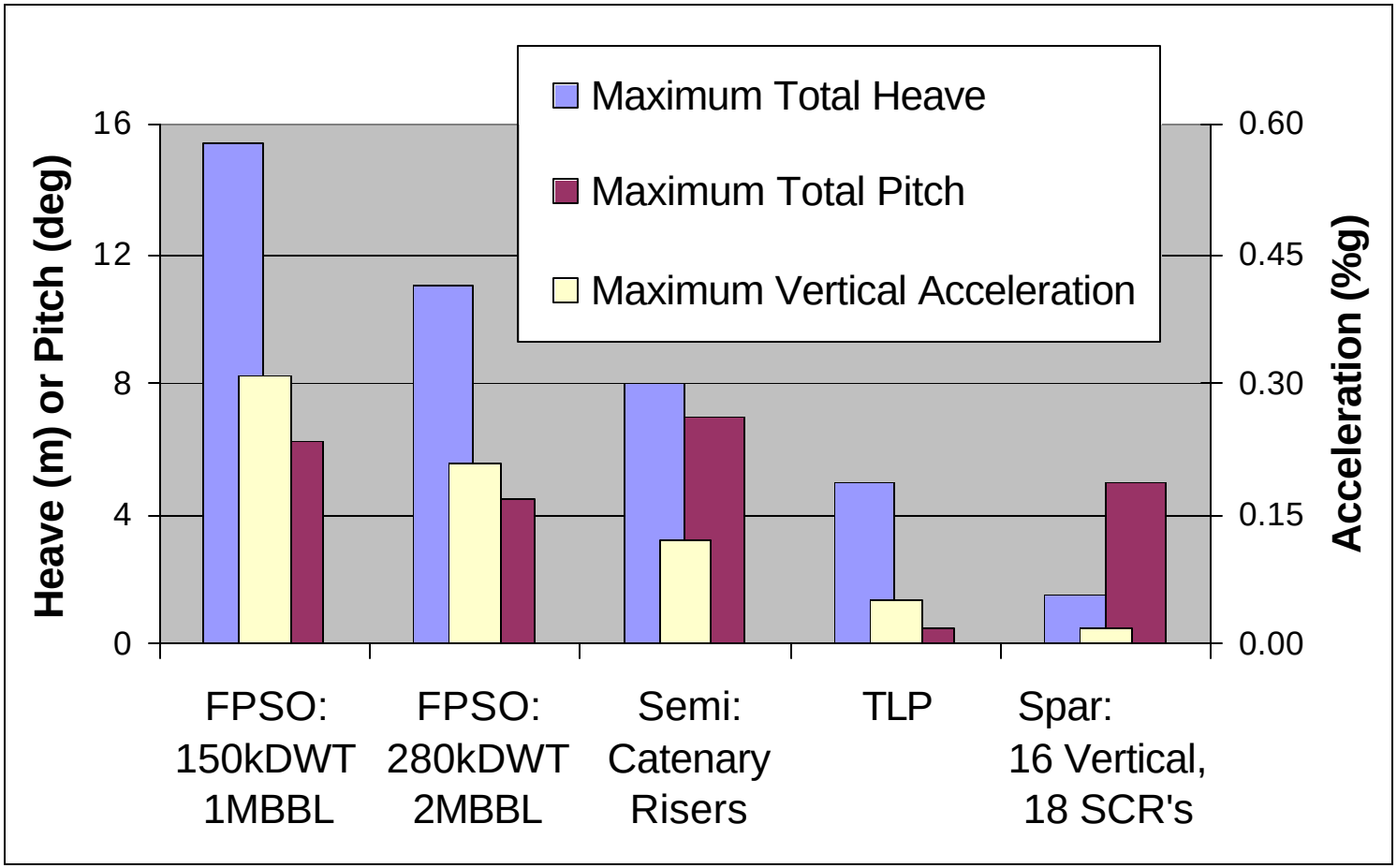
Comparison of Floating Production Platform Motions

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



Non-FPSO Motions courtesy of Shell and Deepstar

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Comparison of Floating Production Platform Motions

- Semi, Spar and TLP motions are “De-Tuned” from Waves (small water-plane area hull forms compared to FPSO)
  - Wave Periods: 4 to 20 seconds (95% energy)
  - Semi Natural Periods: 20 to 50 seconds (heave & pitch)
  - Spar 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
- Tanker-Based FPSO will require a more “compliant” or “de-coupled” riser configuration compared to simple catenary or top tensioned vertical risers

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Comparison of Floating Production Platform Motions

- 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,
    (may require manned platform for Hurricane) ⇒ turret closer to midships reduces wave motions
  - 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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Dynamic Risers for Deepwater Floating Production Systems

- 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 and simultaneous optimization of mooring & risers is critical for deepwater*

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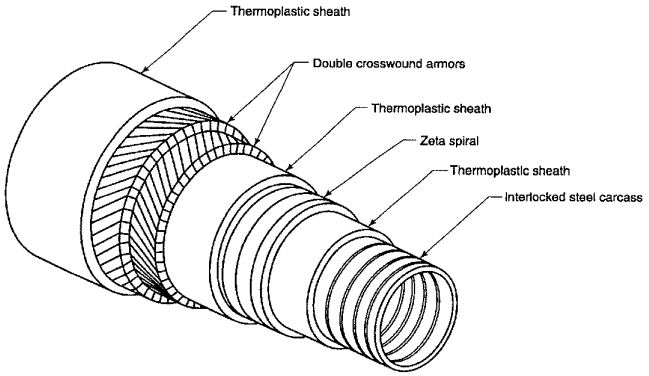
Deepwater Riser Systems
Flexible vs. Steel Pipe

- General Comparison of Flexible and Steel Pipe:

FLEXIBLE PIPE (non-bonded composite)

- Smaller allowable bend radius
- More fatigue resistant
- Simple top connections
- Tolerates larger relative motions
- I.D. limited (practically) to 16 in.

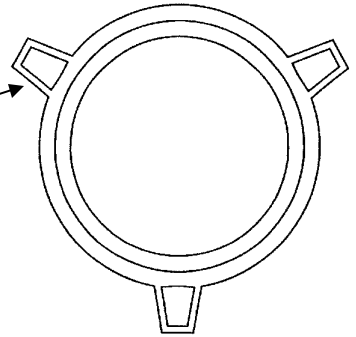


Composite Flexible Pipe Structure

STEEL PIPE

- Approximately half the cost of flexible pipe
- Larger available diameters
- More collapse resistant
- Top connection less tolerant of large motions: use flex-joint or short section of flexible riser
- Lower wet weight than flexible pipe

Helical Strakes for VIV reduction



Steel Pipe Cross Section

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Deepwater Riser Systems
Design Codes

- Riser Design Codes :
  - API RP 2RD (Steel Risers for FPS and TLPs)
  - API RP 1111 (Steel Pipelines)
  - DNV OS-F201 (Offshore Standard for Metallic Risers)
  - API 17B and API 17J (Flexibles)
- Design Codes Specify :
  - Wall Thickness Criteria
  - Global Dynamic Analysis Requirements
  - Detailed Structural Analysis (Components/Connections)
  - Materials (Welds, Coatings, Corrosion, Wear, Marine growth, etc.)

Deepwater Riser Systems
Design Codes

- Steel Pipe Wall Thickness Design Criteria :
  - Internal Pressure
  - Extreme Axial Loads
  - Collapse Due to External Pressure
  - Buckling Due to Combined Bending and External Pressure
  - Buckle Propagation

Deepwater Riser Systems Design Issues

- Global Analysis :
  - Extreme/Survival Analysis

    Check for Extreme Loads & Stresses, MBR, Compression, Interference,

    Top angle variations
  - Fatigue Analysis

    Wave Induced

    Slow Drift Induced (less important for risers connected to a turret moored FPSO)

    Vortex Induced Vibrations (VIV) Induced

    Transport/Installation induced
  - Installation Analysis

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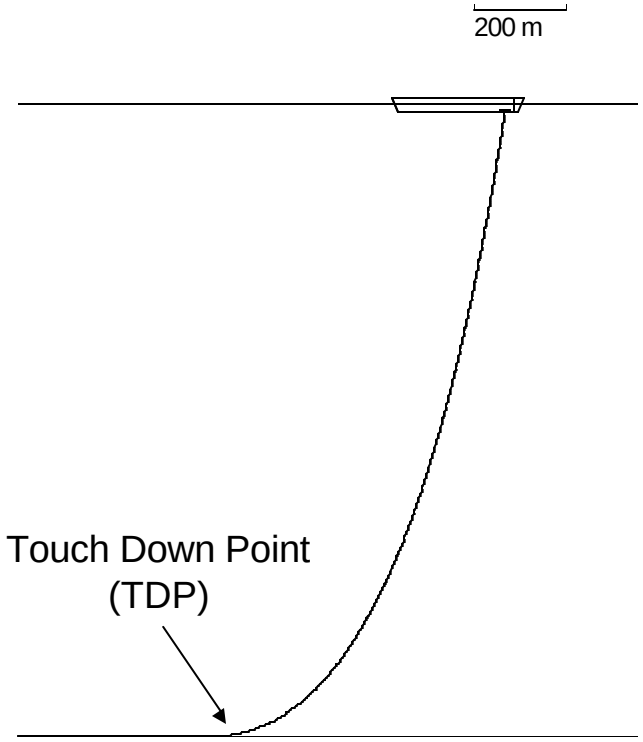
Riser Design Considerations Configuration Vs. Applicability

- Each Geometric Riser Configuration has Unique Performance, Cost and Applicability
- Final configuration depends on :
  - Water Depth & Severity of Environment
  - Vessel Offset
  - Turret Location/Motions
  - Impact on Turret Design (Loading)
  - Number of Risers, Plan Layout
  - Soils and Seabed Topography
  - Flow Assurance Requirements (insulation, pipe-in-pipe, etc.)

Deepwater Riser Systems Configurations

Free Hanging Catenary Riser



Advantages :

- Cost effective solution
- Standard technology/installation

Weaknesses:

- High loads on turret
- Large fatigue at top and TDP
- Not usually feasible on turret except in mild environment

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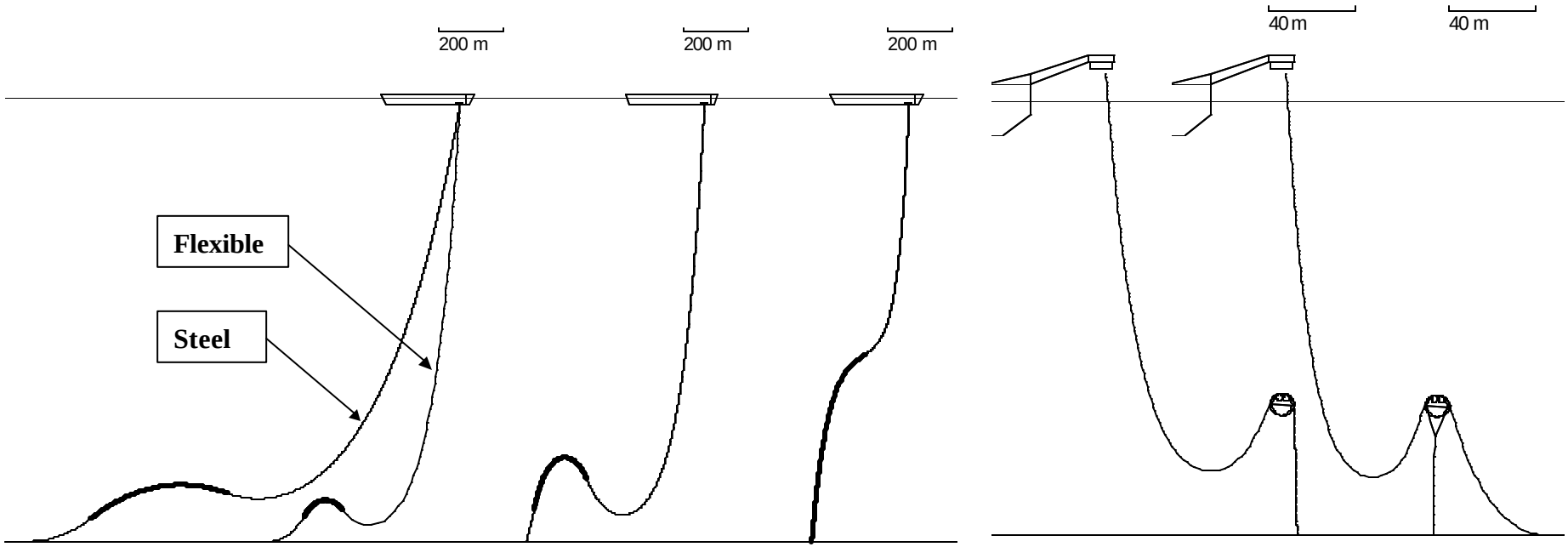
Deepwater Riser Systems
Compliant Systems

Objective: De-couple motion at TDP from the FPSO motions



Lazy Wave Steep Wave CVAR Steep-S Lazy-S

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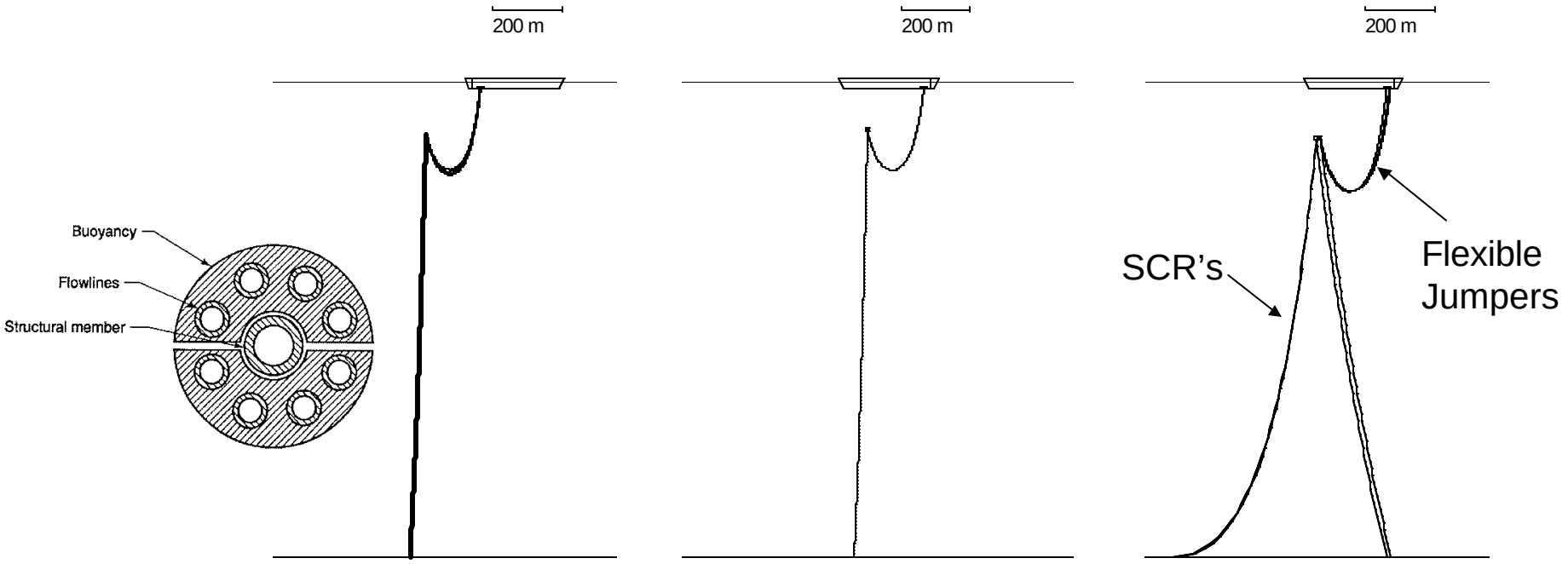
Deepwater Riser Systems
De-Coupled Hybrid Systems

De-couple motions using self-standing hybrid risers or buoy



Multibore Hybrid Tower | Single Leg Hybrid | TLR

Connection to the FPSO via flexibles

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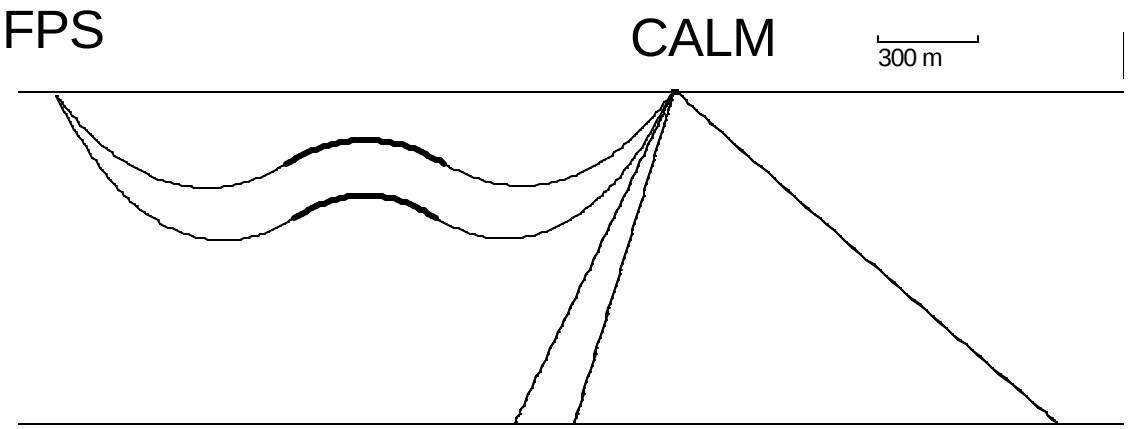
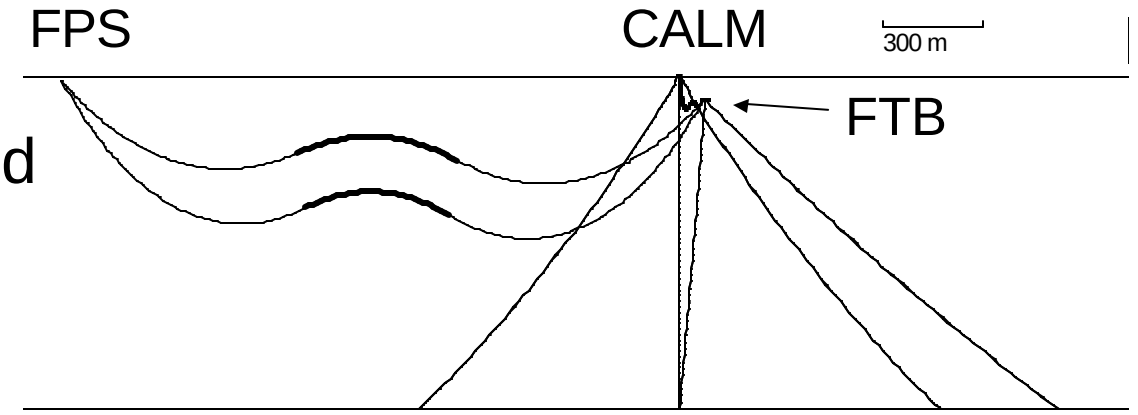
Deepwater Offloading Systems: Steel Suspended-Wave Flowlines

Used to offload an FPS to a CALM or FPSO

Direct Connect



De-coupled Solution



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Riser Design Considerations Configuration Vs. Applicability

- Qualitative Comparison of Deepwater Riser Systems

Category	Configuration Example	Offset Sensitivity	Turret/Buoy Impact	Fatigue Resistance	CAPEX	Installability	Main Design Concerns
Direct Connect	Free Hanging SCR	Medium	High	Low	Low	Easy	Fatigue,Survival,Top Load
Compliant	Lazy Wave	Low	High	Medium	Medium	Moderate	Fatigue,Top Load
Hybrid	Tension Leg Riser	High	Low	High	Variable *	Complex	Installation
Suspended Offloading Flowlines	Surface Buoy	Medium	High	Low	Medium	Moderate	Transport,Installation,Fatigue
	FTB	Low	Low	High	Medium/High	Moderate	Transport,Installation

** Variable cost means lower (higher) cost per riser as number of risers increases (decreases)*

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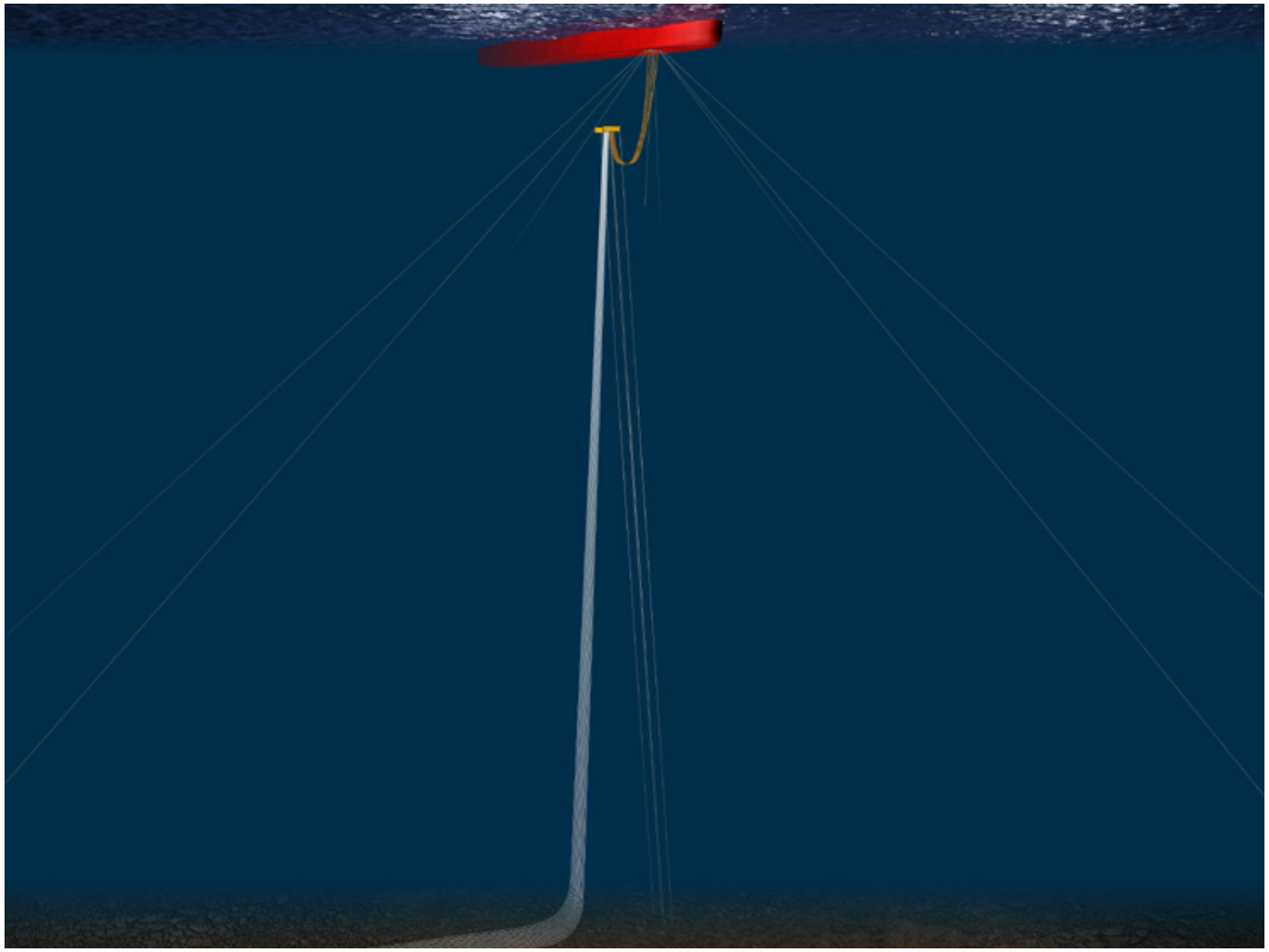
Dynamic Risers for Deepwater Floating Production Systems

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions



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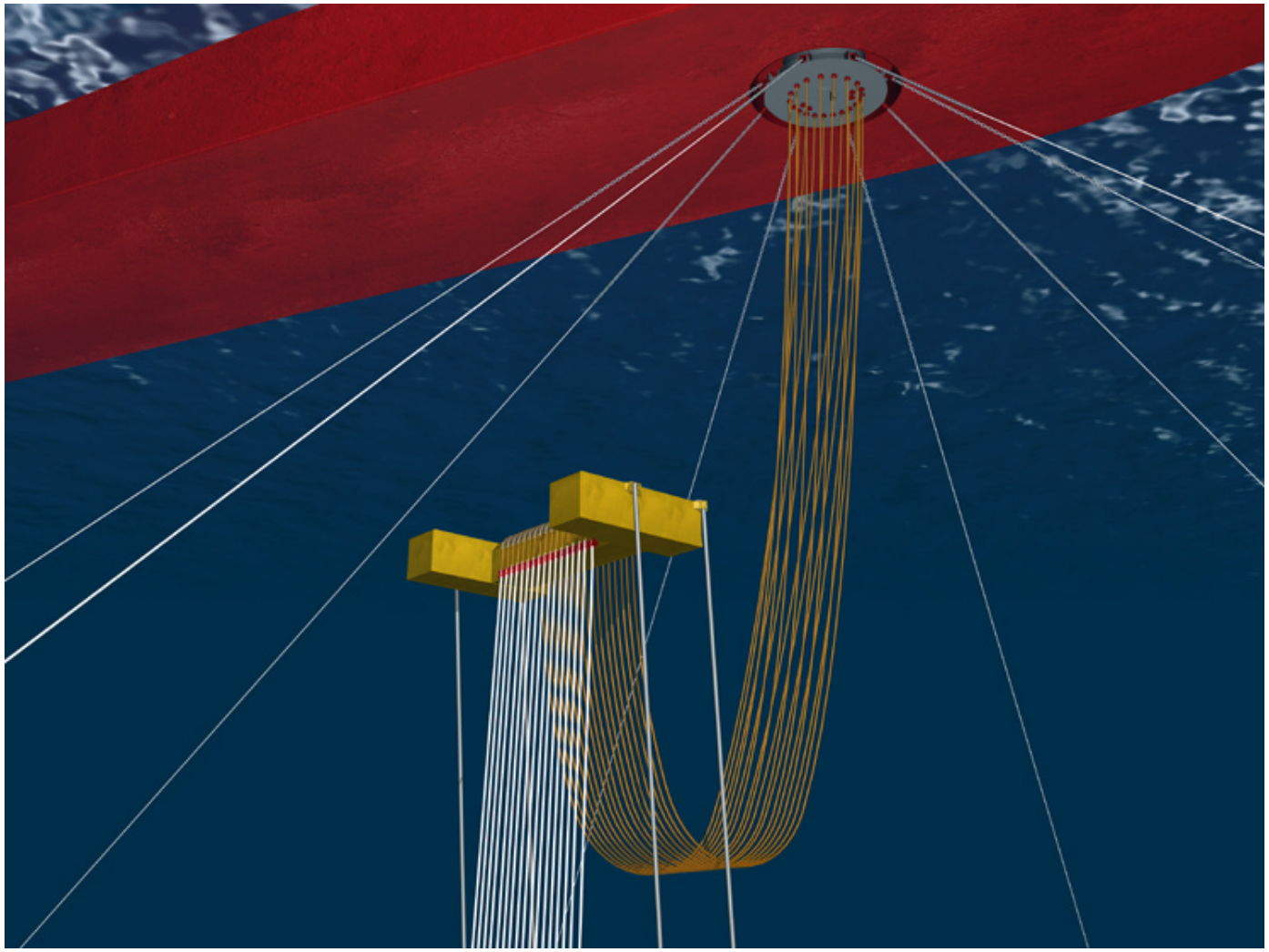
Deepwater Riser Systems
TLR or Hybrid configurations

Steel Lines De-Coupled from FPSO Motions

TDP isolated

Drastically Reduces Turret Loads



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Deepwater Riser Systems
TLR System

- 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%

* TLR cost benefits may be reduced for fewer number of risers.

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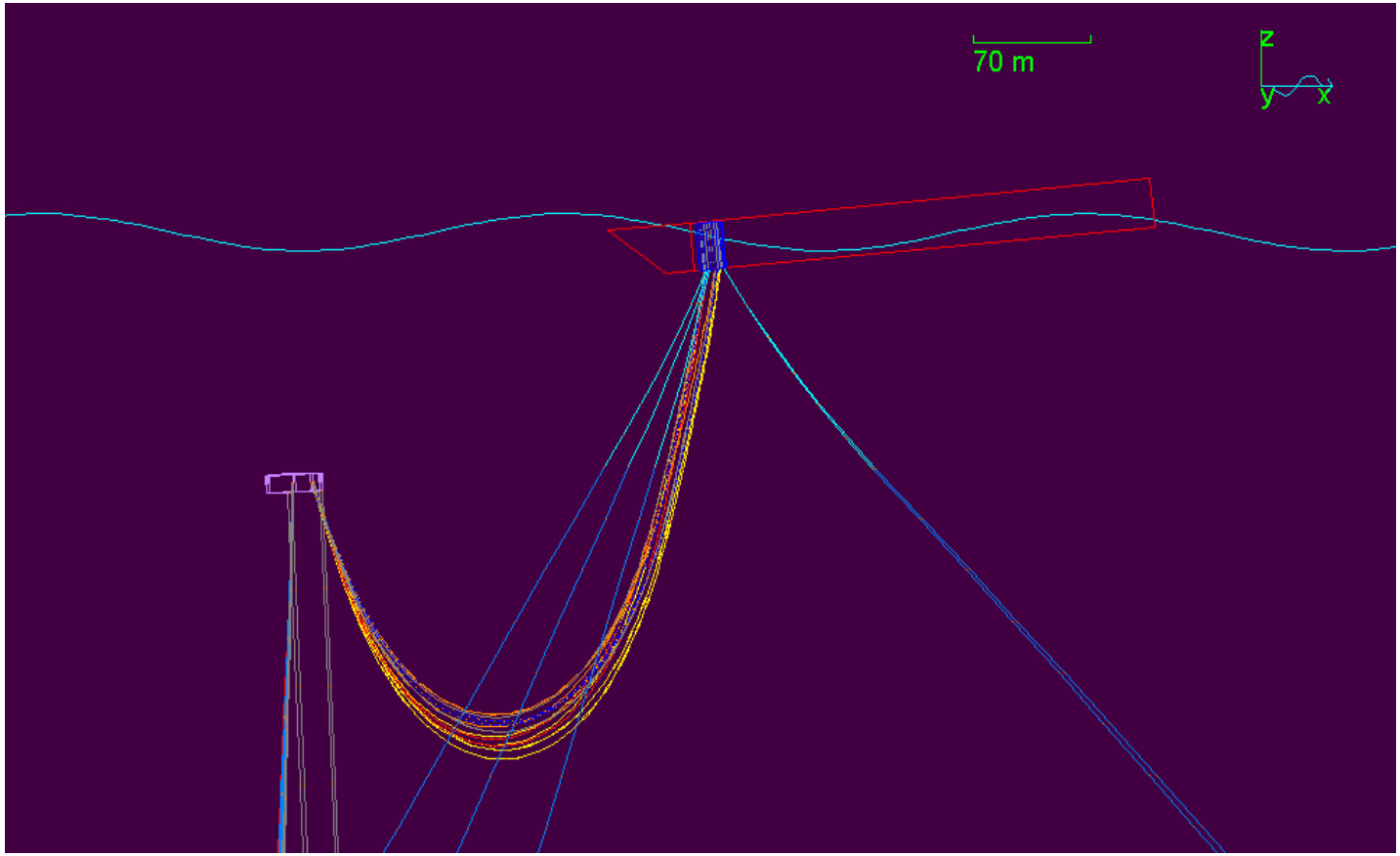
Deepwater Riser Systems
TLR System

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions



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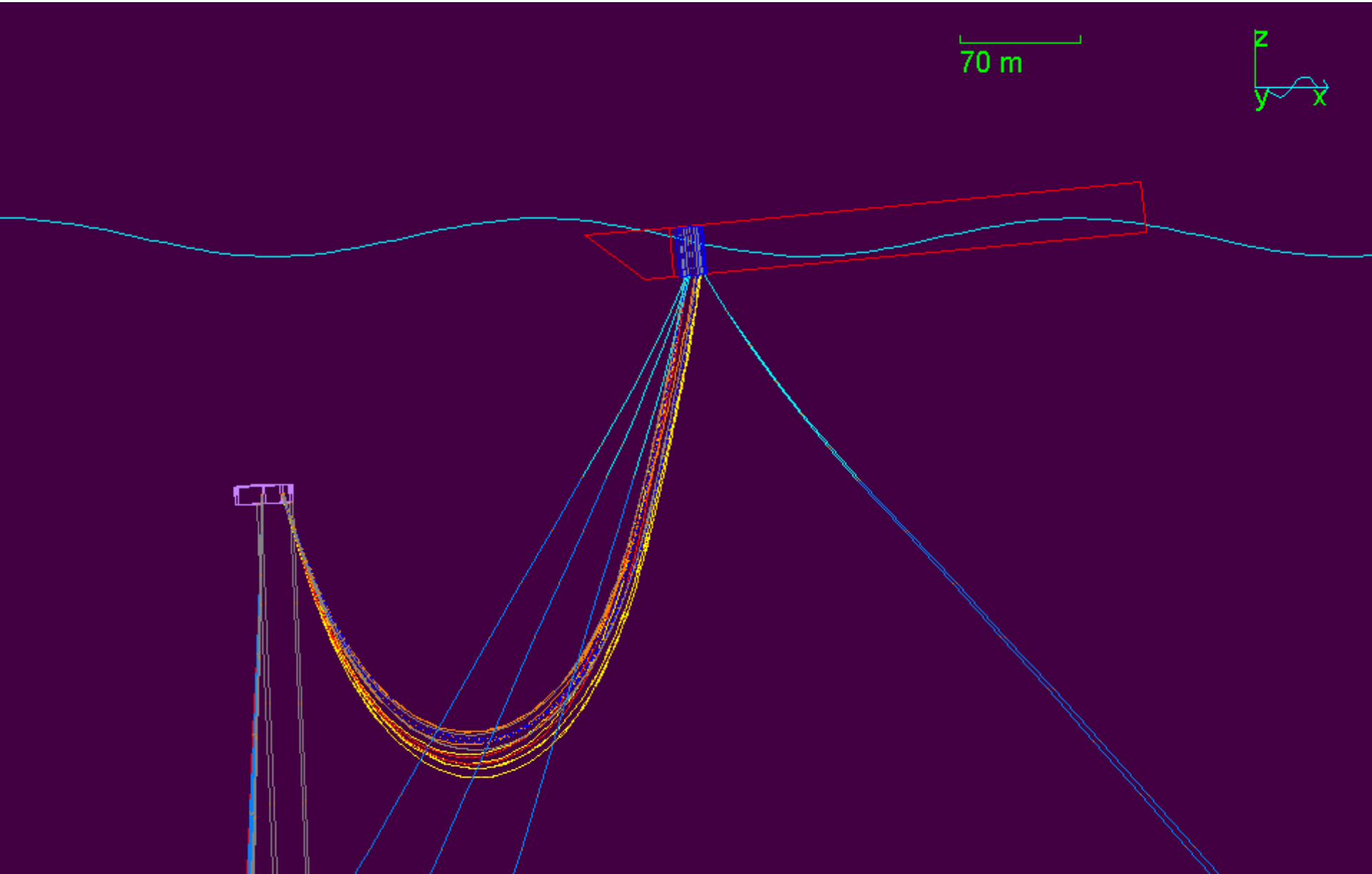
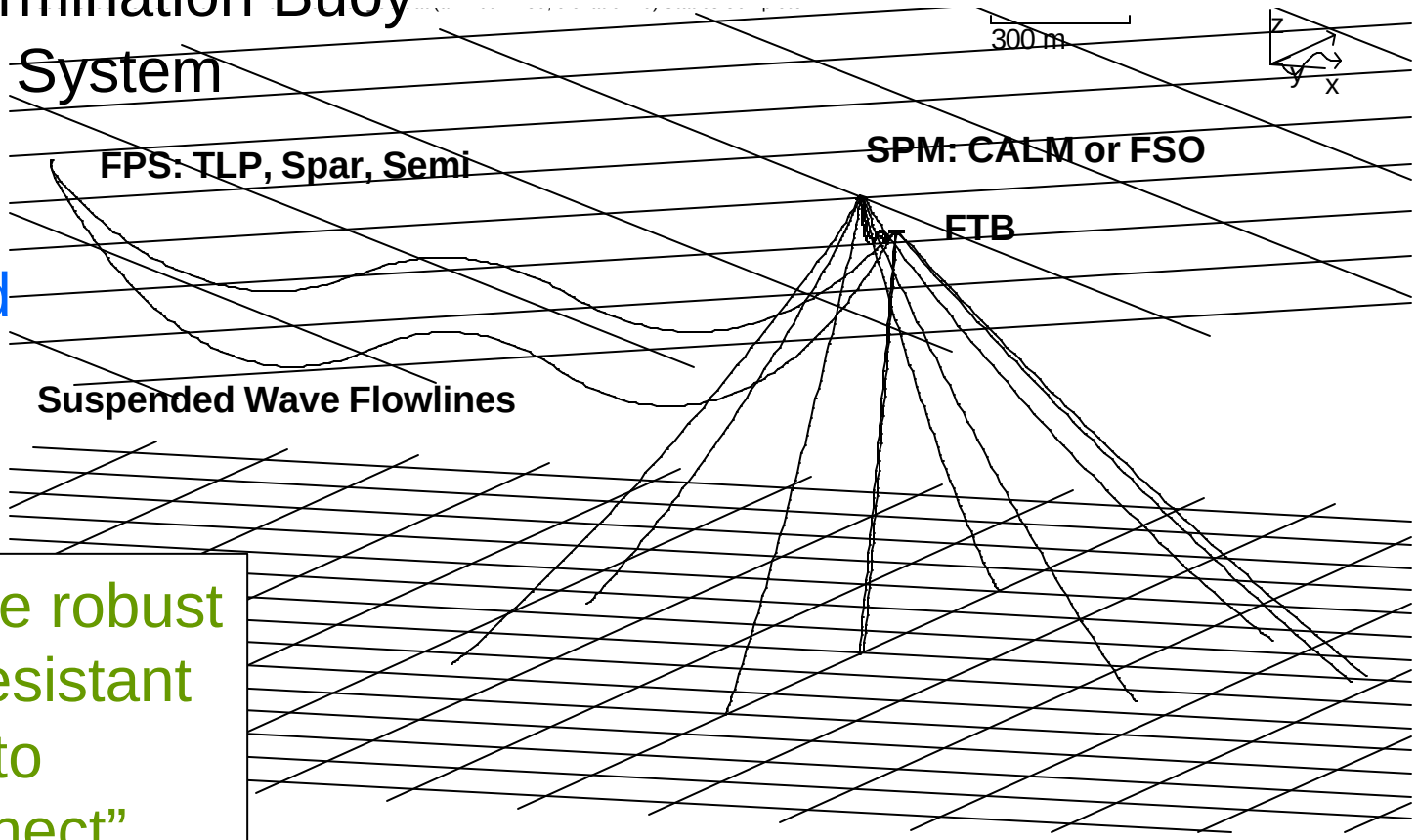
Deepwater Riser Systems
TLR System



Deepwater Riser Systems: Steel Suspended-Wave Flowlines

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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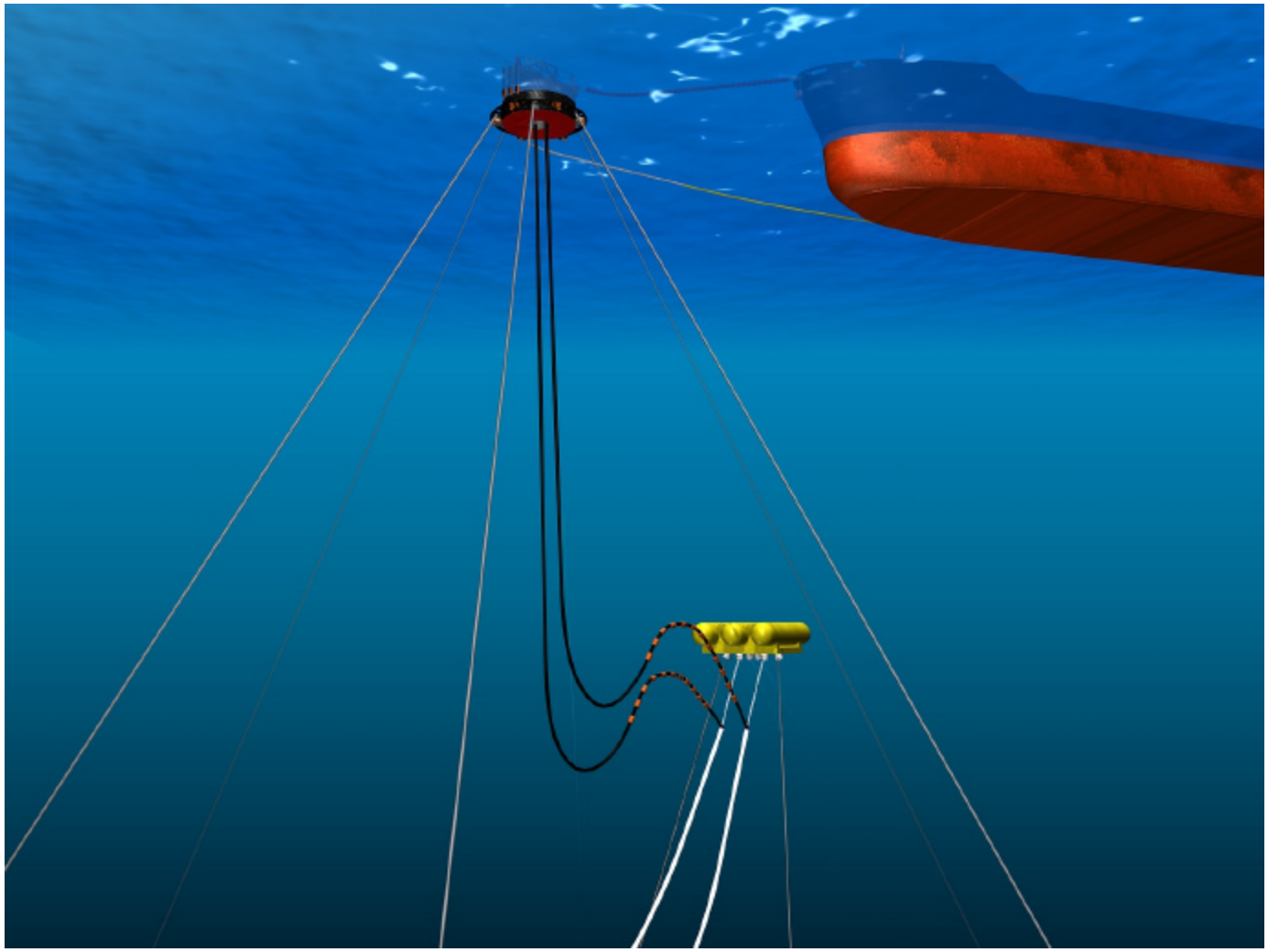
Deepwater Riser Systems: Steel Suspended-Wave Flowlines

SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

SPM can be CALM or FPSO



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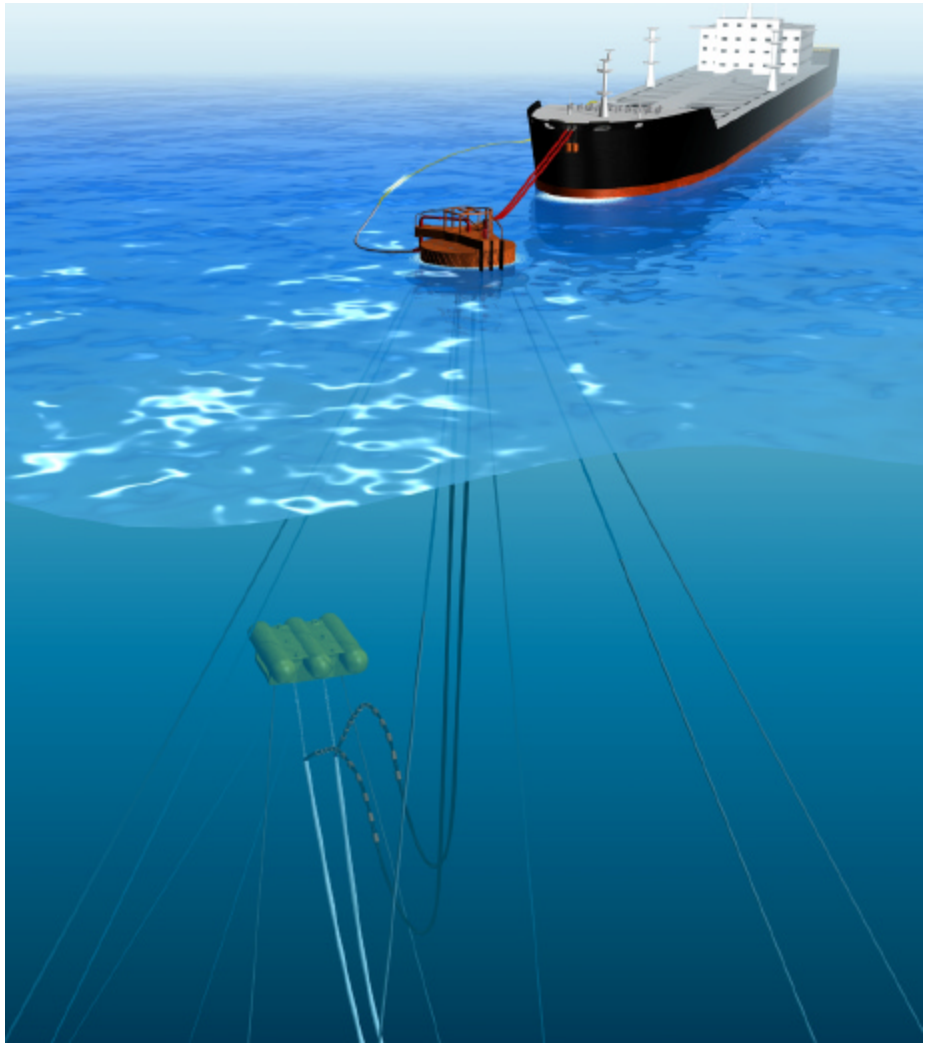
Deepwater Riser Systems: Steel Suspended-Wave Flowlines

SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Fluid Swivels Above Water



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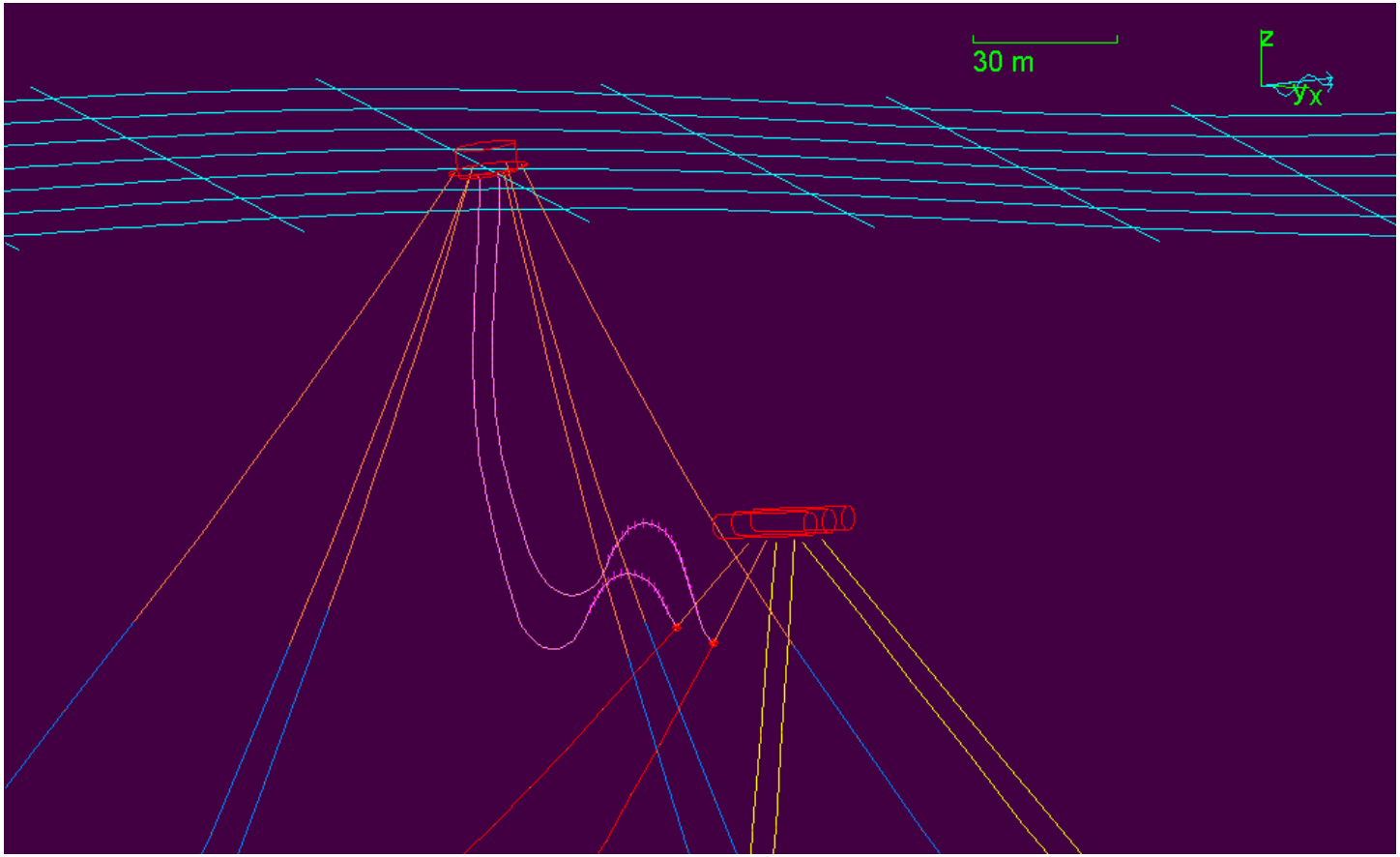
Deepwater Riser Systems: Steel Suspended-Wave Flowlines

SPM to FTB Riser System

Steel Lines De-Coupled from FPSO

Product Swivels Above Water



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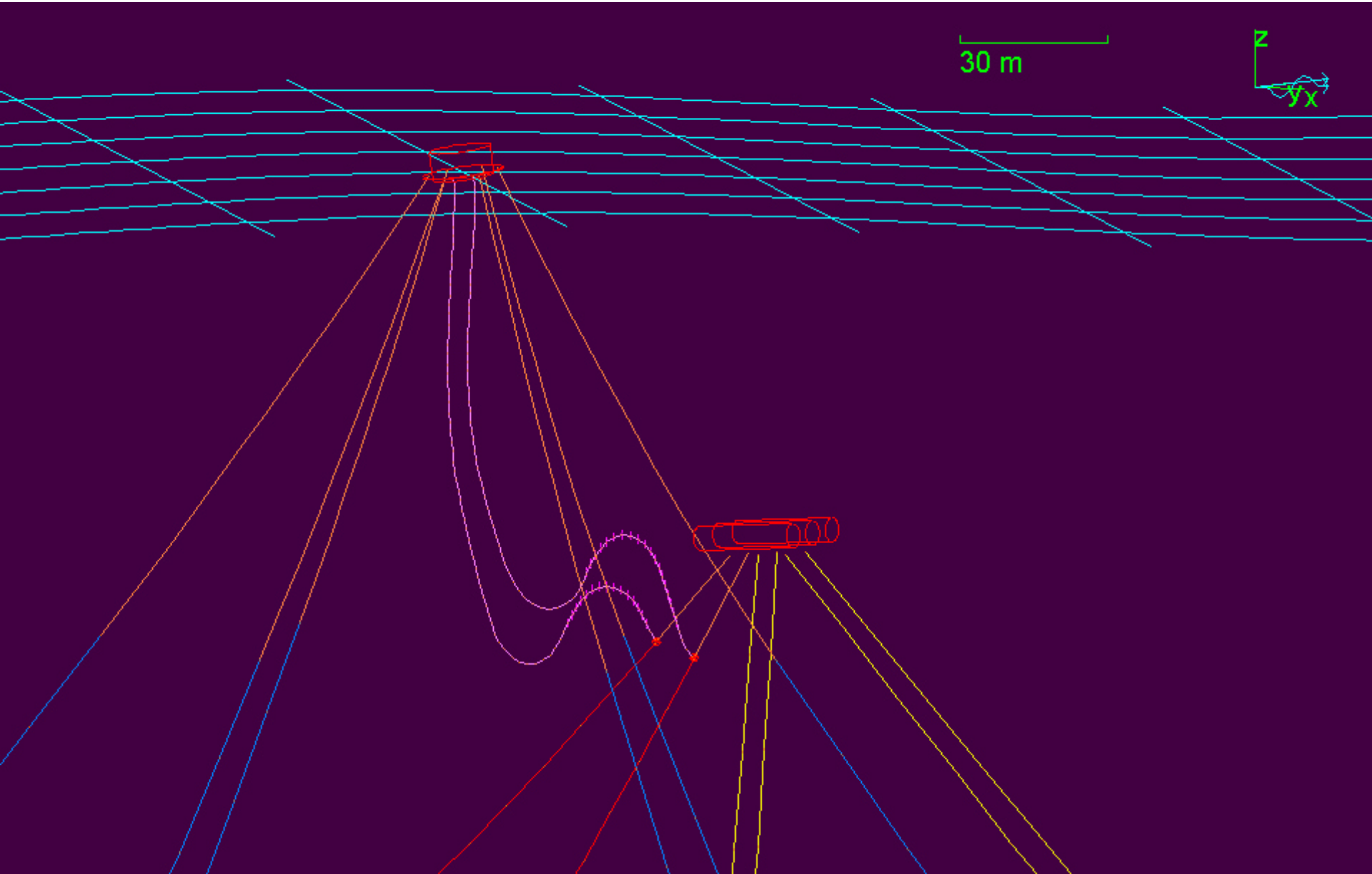
Deepwater Riser Systems: Suspended-Wave Flowlines SPM to FTB



Deepwater Exploration and Production: *Tomorrow's Technology*

- FPDSO → FPSO with Drilling and Workover Capability

  Specialized turret allows simultaneous drilling, production & storage.
  Non-conventional vessel, conventional components.

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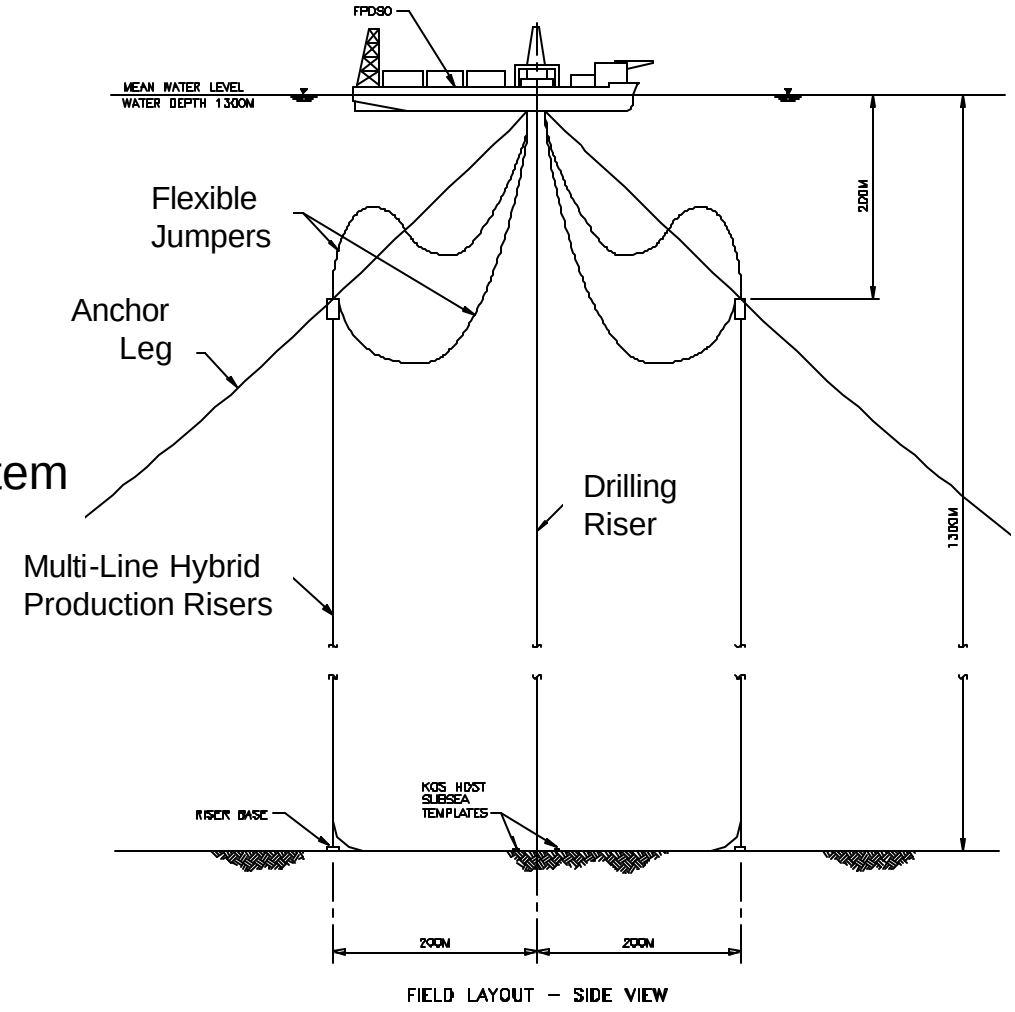
Deepwater Exploration and Production: *Tomorrow's Technology*

- FPDSO

  - Top tensioned drilling risers
  - Tower hybrid production risers
  - Drag Chain product transfer system
  - Turret located near midship
  - Thruster-assist heading control



FIELD LAYOUT – SIDE VIEW

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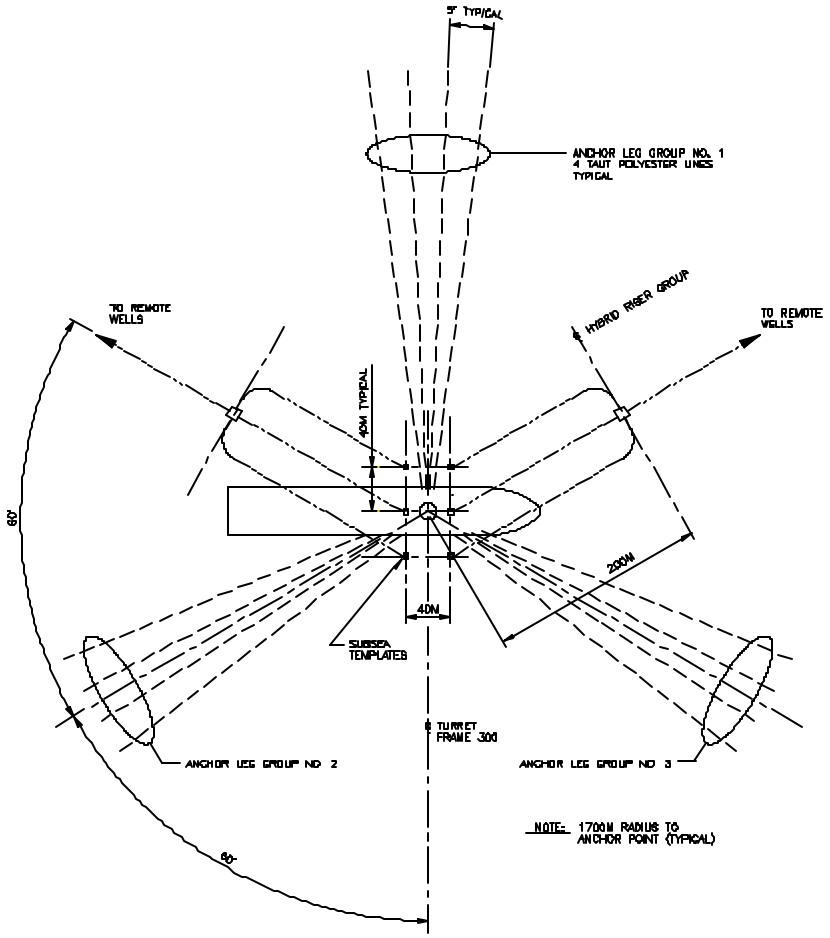
Deepwater Exploration and Production: *Tomorrow's Technology*

- FPDSO

  - Drilling radius = 100 meters
  - Product riser radius = 200 meters
  - Grouped mooring system (3x3)



FIELD LAYOUT – PLAN VIEW

FMC EnergySystems

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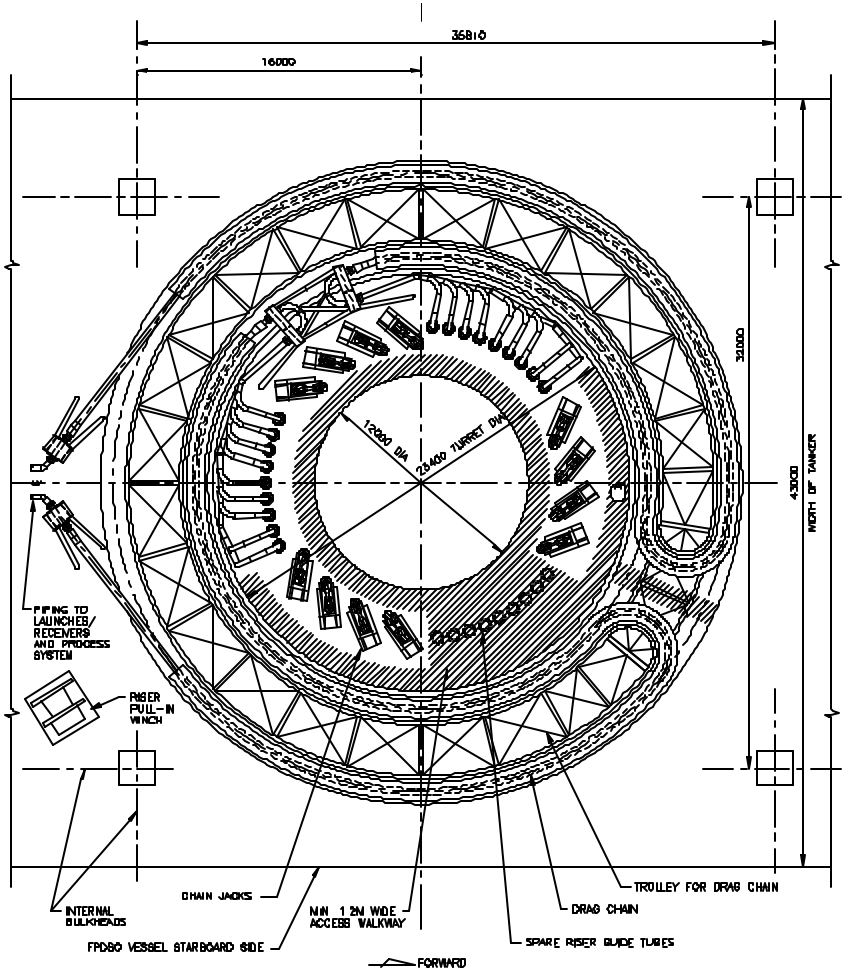
Deepwater Exploration and Production: *Tomorrow's Technology*

- FPDSO

  → Drag Chain product transfer system allows 270 degree vessel rotation (no fluid swivels required)



TURRET AND DRAG CHAIN
PLAN VIEW AT ELEVATION +32250

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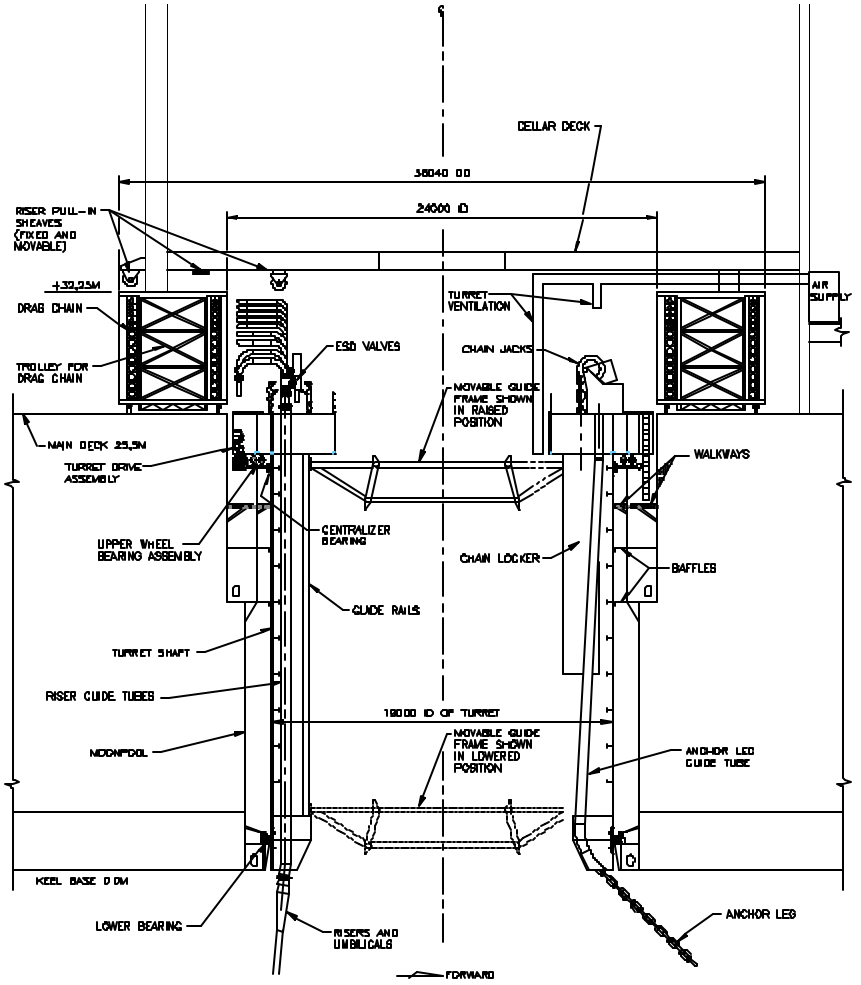
Deepwater Exploration and Production: *Tomorrow's Technology*

- FPDSO

➔ Compact drag chain system allows deployment of BOP stack and subsea templates without disassembly of drag chain system

Net result is balance between production and drilling equipment requirements.



TURRET AND DRAG CHAIN – SIDE VIEW

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