

Emerging FPSO forum

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

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September 21, 2011



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]*
 - *Risks associated with FPSO systems are no greater than for existing platforms: TLP, Spar, Semi [results of 2001 MMS CRA Study]*
 - *One could argue that FPSO based systems have higher 'availability' than FPS+Pipeline based systems.*
 - *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.*

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

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ Turret Systems: Elegant Solution, Highly Functional

Provides product transfer system

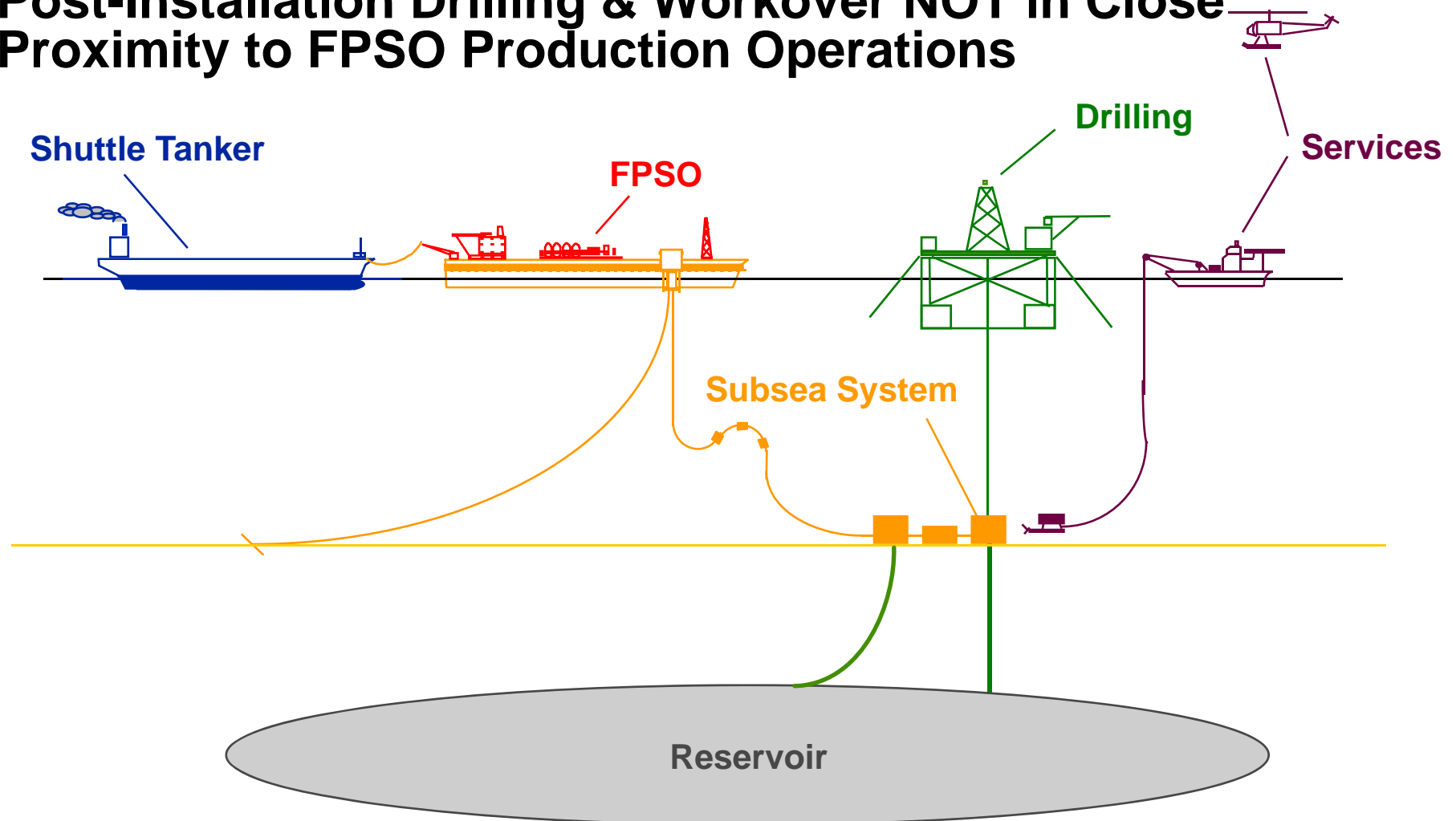
- Accommodates liquid and gas swivels and pig launching/receiving
- Turret manifold system can replace or augment subsea manifolding

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

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

Post-Installation Drilling & Workover NOT in Close Proximity to FPSO Production Operations



FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Turret Systems: Elegant Solution, Highly Functional
Can add drilling and work-over operations
 - Specialized turret design allows simultaneous drilling, production and storage: FPDSO. Non-conventional vessel, conventional components.



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)
- ⇒ Smaller number of risers
- ⇒ Shallow to deep water depth applications

Generally less costly than internal turrets, but not ideal for deep water Gulf of Mexico

External Turret Mooring Systems 17 Installed, 3 under Construction



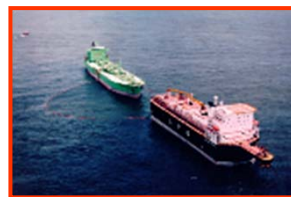
**Yepco Red Sea,
Yemen**



**Amoseas Anoa,
Indonesia**



**Shell Todd Maui
B,
New Zealand**



**Chevron
Escravos, Nigeria**



**PEMEX
Cantarell, Mexico**



**Petronas
(MASA), Malaysia**



**Nexen Buffalo,
Australia**



**Vietsovetro 01,
Vietnam**



**Shell Bijupira-
Salema, Brazil**



**PTTEP Bongkot,
Gulf of Thailand**



**CLJOC Su Tu
Den, Vietnam**



**CNR Baobab
Ivoirien
Côte D'Ivoire,**



**PEARL Jasmine
Thailand**



**KNOC Rong Doi
Vietnam**



**Petrobras PRA-1
Brazil**



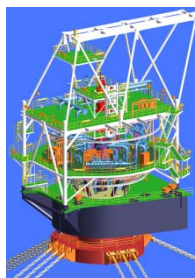
**JVPC Rang Dong
Vietnam**



**BP PSVM
Angola**



**Tullow Jubilee
Ghana**



**HLJOC TGT FPSO
Vietnam**

**Chevron Erawan
Thailand**

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Existing External Turret Mooring System in Gulf of Mexico



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PEMEX Campeche Bay FSO: 1998, MODEC Intl LLC

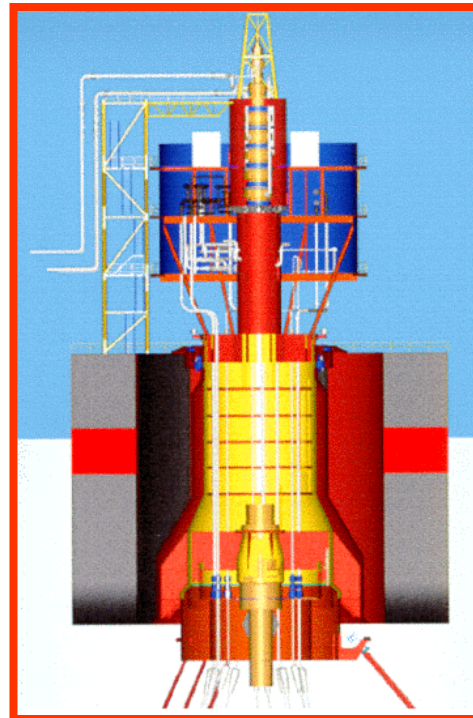
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ 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 Systems: Permanent or Disconnectable

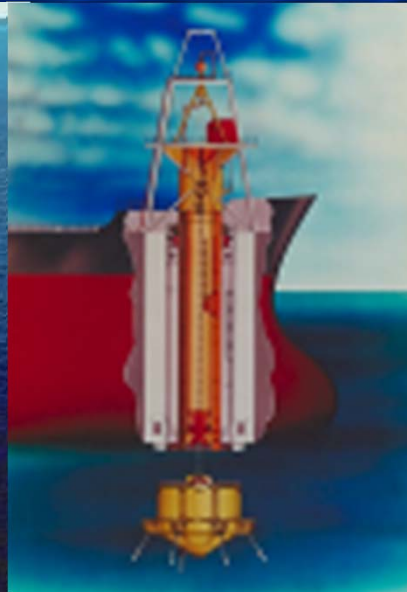


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5 Disconnectable Internal Turret Systems:



JHN Lufeng, South China Sea
30+ disconnects since 1994



Petro-Canada Terra Nova, Eastern Canada
1 disconnect in 2006



BHPB Stybarrow, NW Australia
3 disconnects since 2008



Santos Mutineer-Exeter, NW Australia
11 disconnects since 2006



BHPB Pyrenees, NW Australia
2009

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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ Permanent Vs. Disconnectable Internal 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

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

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

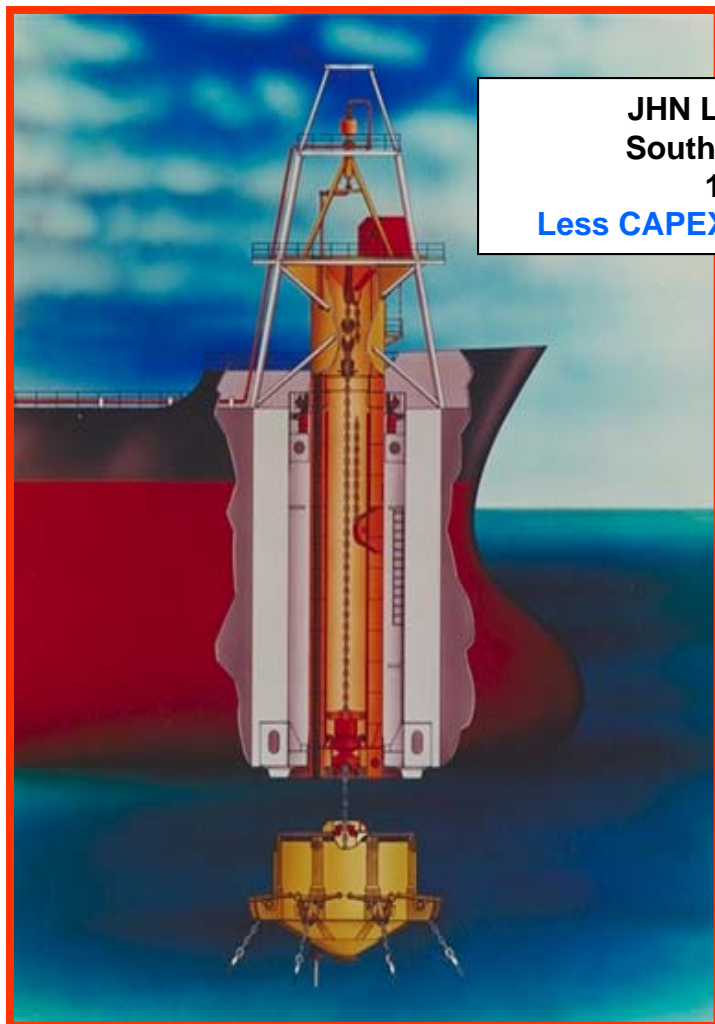
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ Permanent Vs. Disconnectable Turret Systems

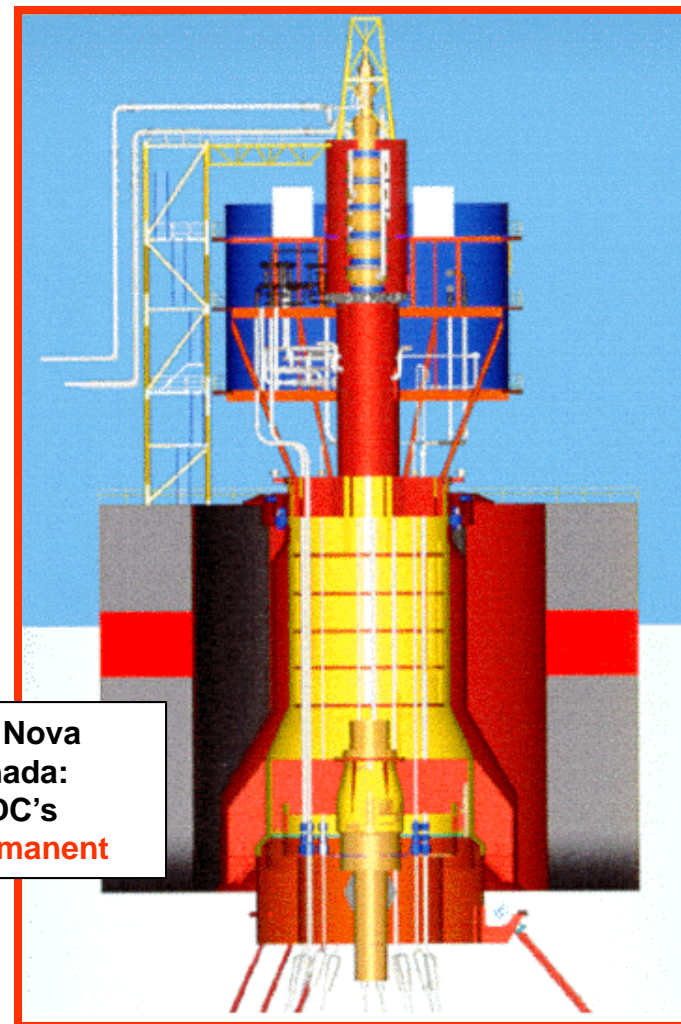
Disconnectable Turret Systems

- ⇒ Potentially lower risk of hurricane damage
- ⇒ Decision to shutdown can be delayed, early return to production
- ⇒ Requires full time marine certified crew and 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.
- ⇒ Number of risers can be a limiting factor compared to permanent turret

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**

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

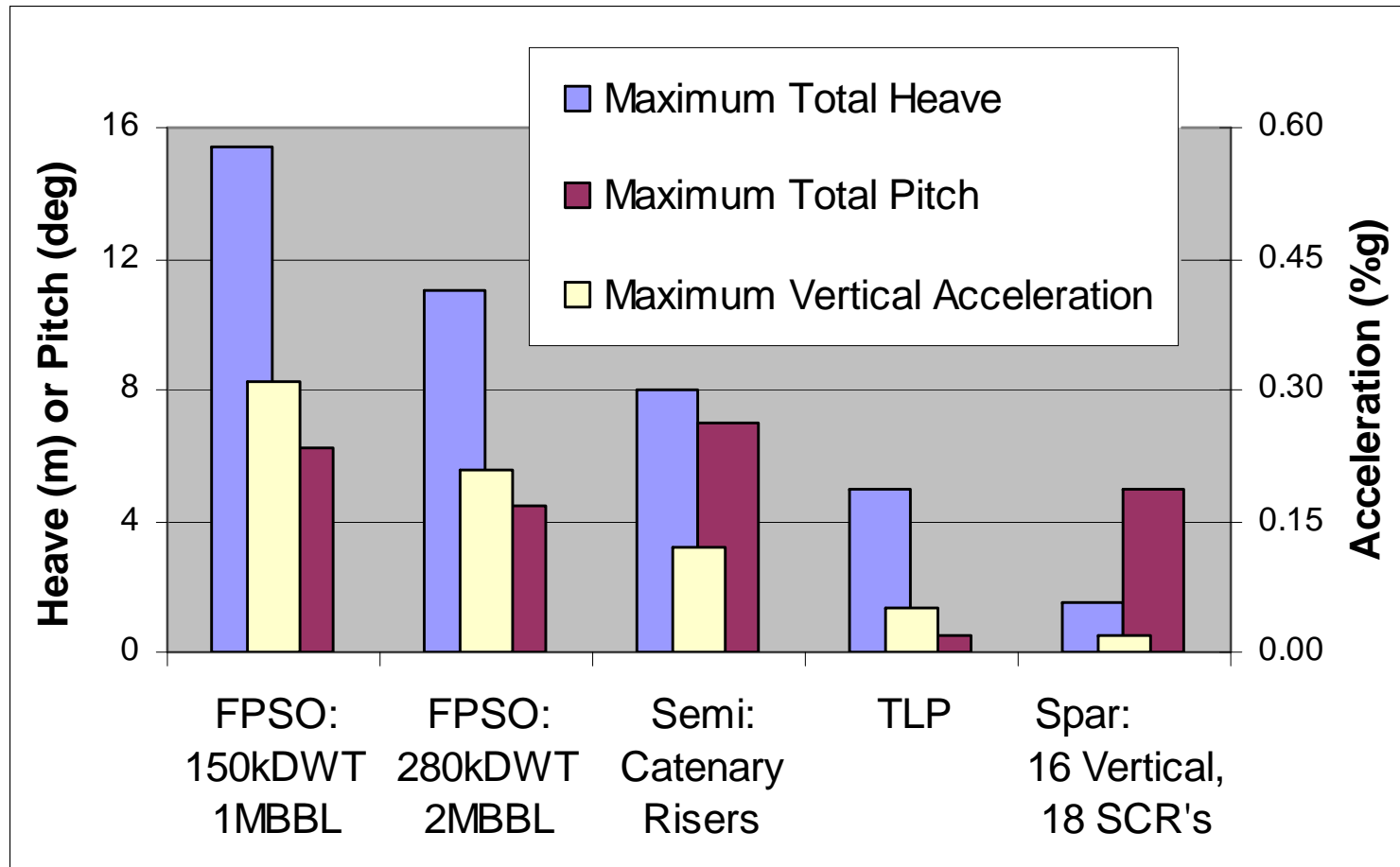
Deep water design

- ⇒ 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

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

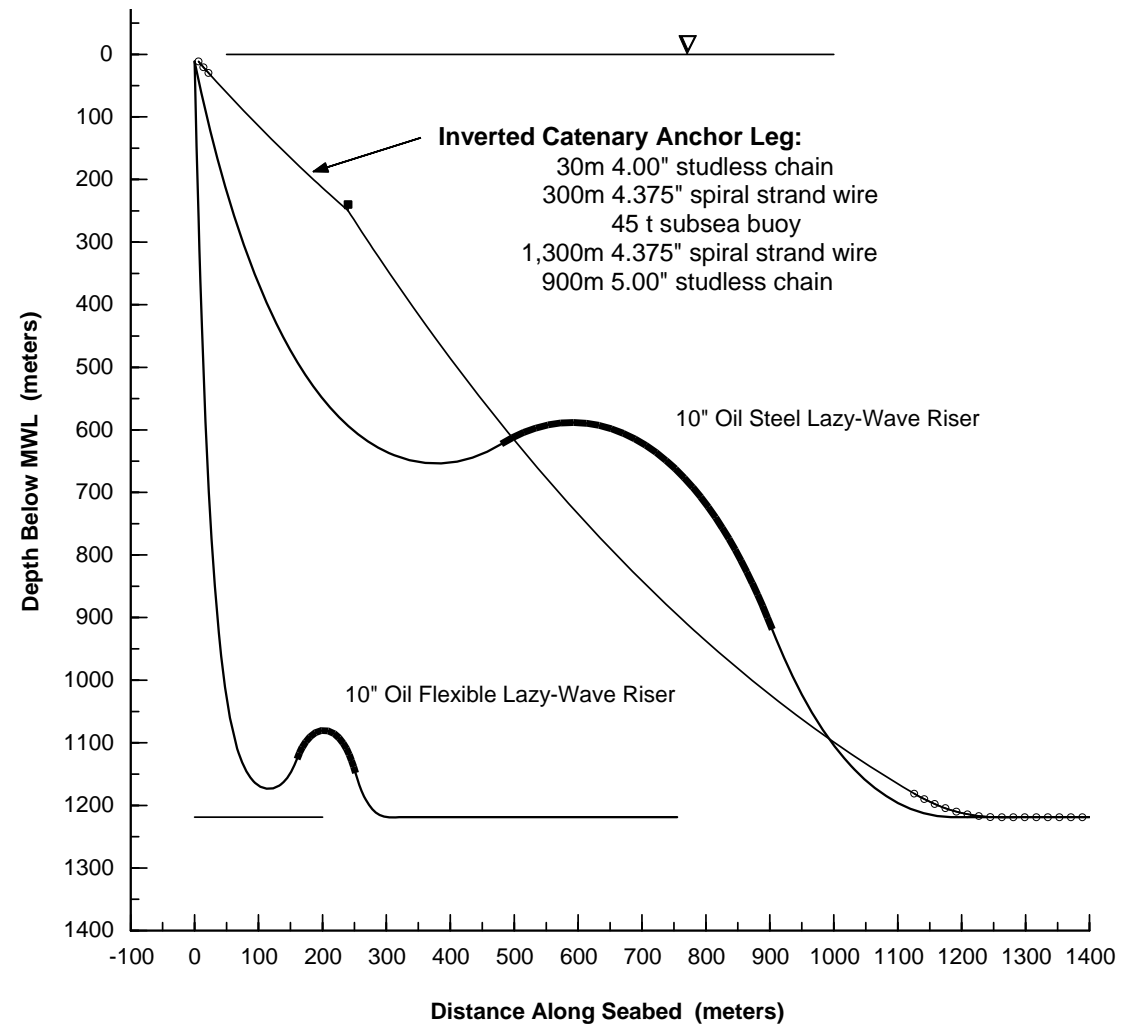


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- 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

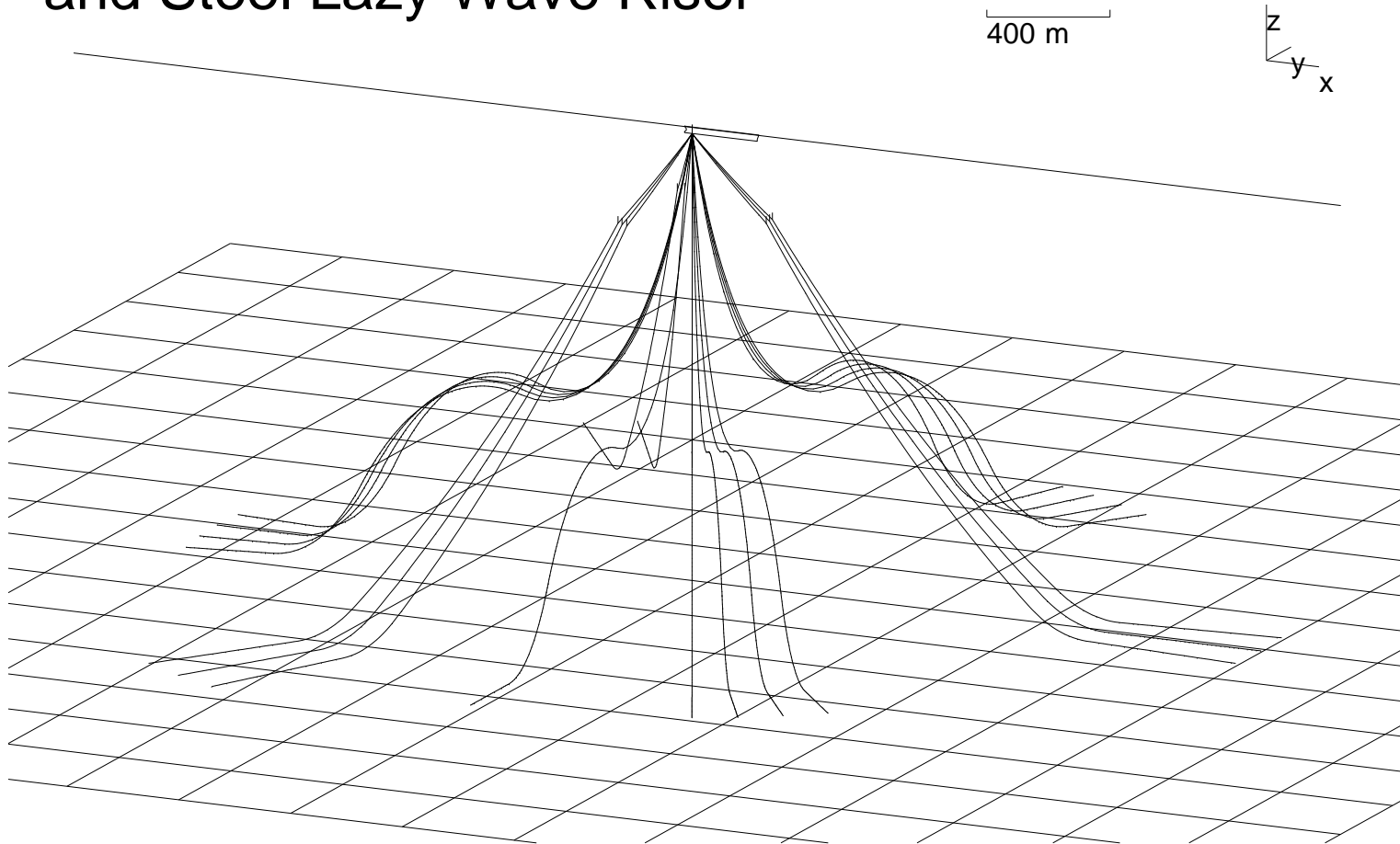
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Steel Lazy Wave Riser (compliant)



Typical Deepwater GoM FPSO Mooring & Riser System

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



FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions



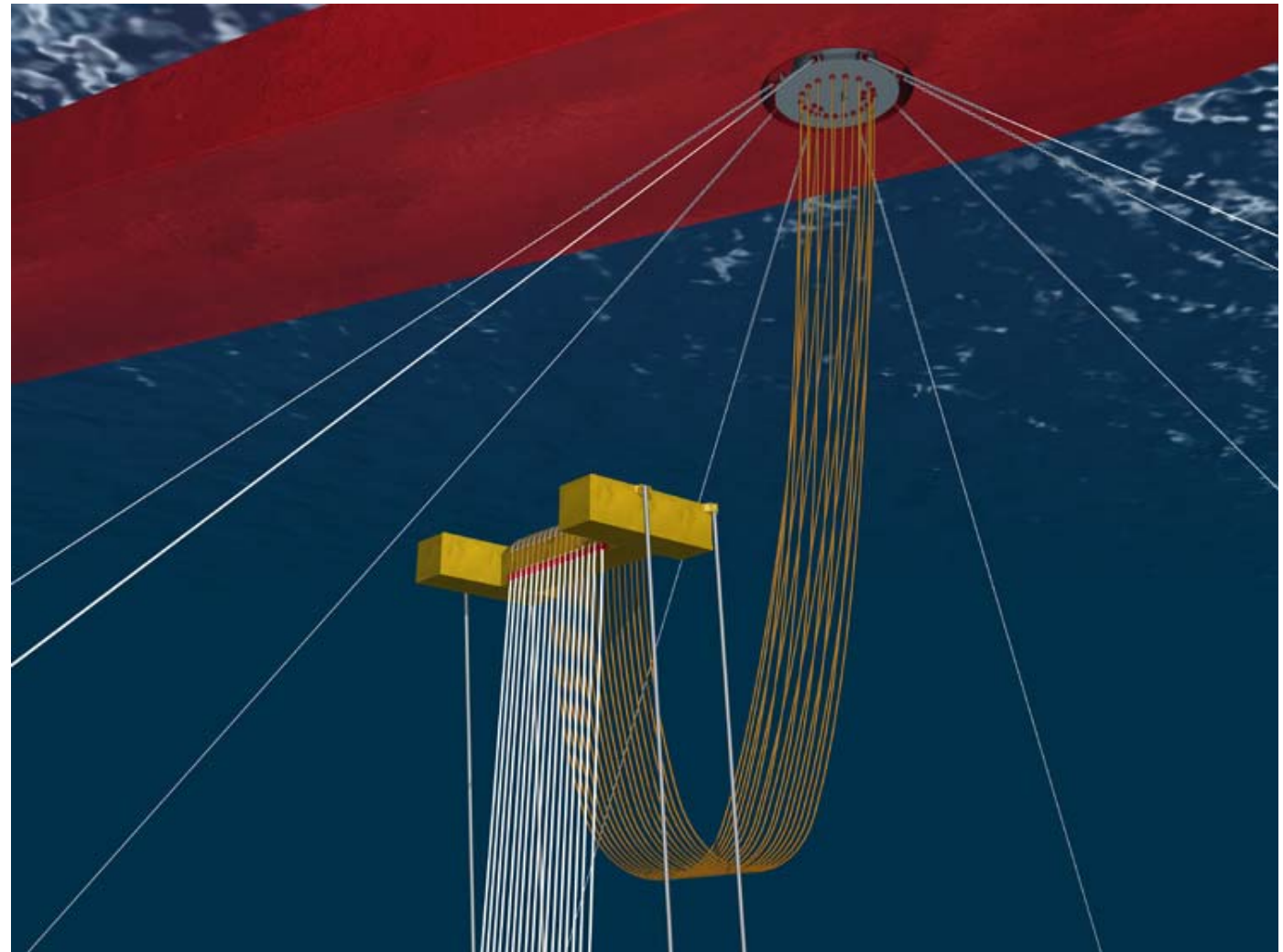
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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

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 \Rightarrow buoy motions are small
- SCR's not affected by the 100-year hurricane or fatigue environments
- Proven technology, with standard fabrication/installation procedures
- DeepStar study concluded that TLR system is feasible in 3,000m depth and less costly than Steel Lazy Wave or Hybrid Riser Towers:

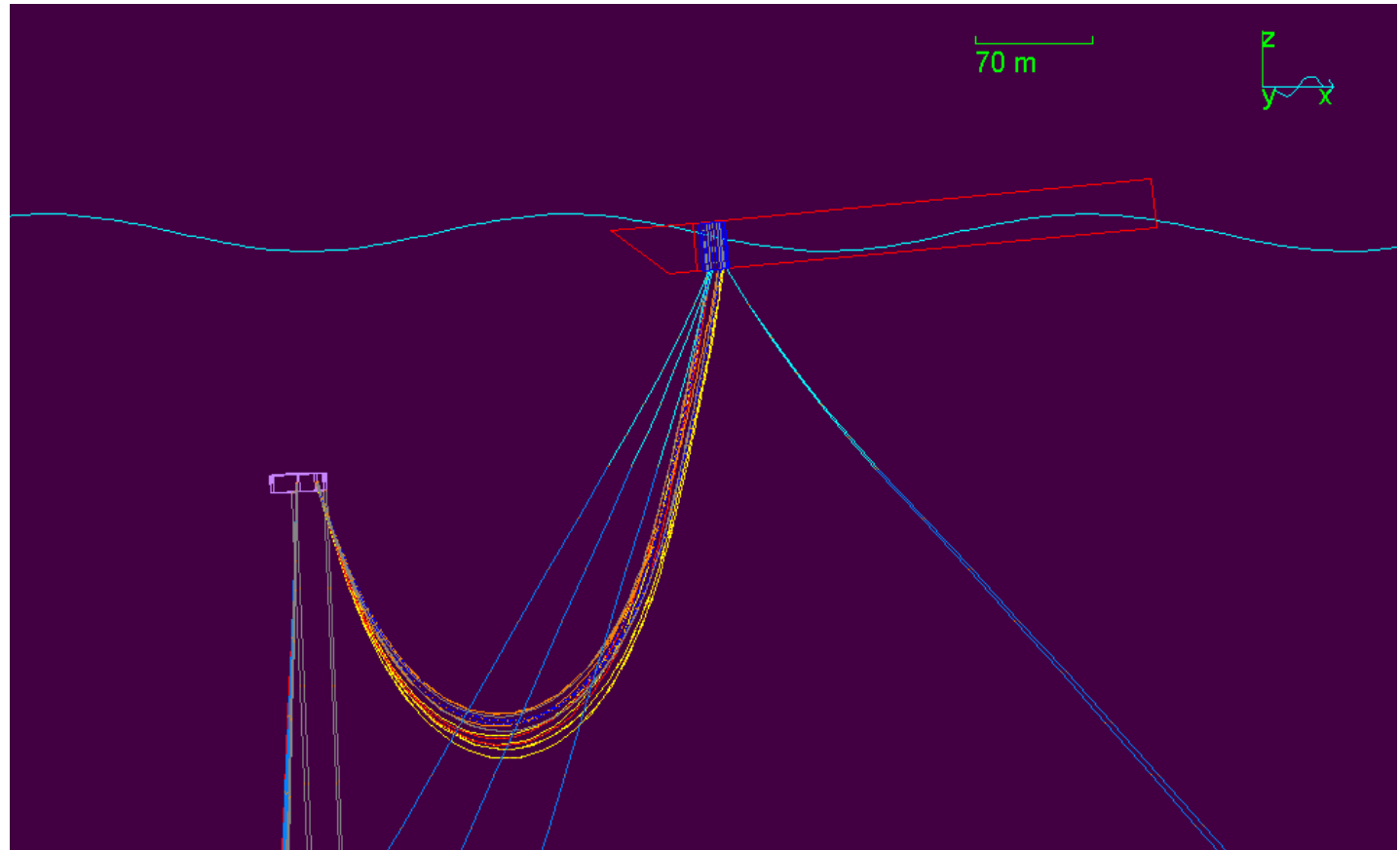
COST COMPARISON:
(based on large, multi-
riser field development)

TLR	100%
Lazy Wave	120%
Hybrid Tower	145%

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions

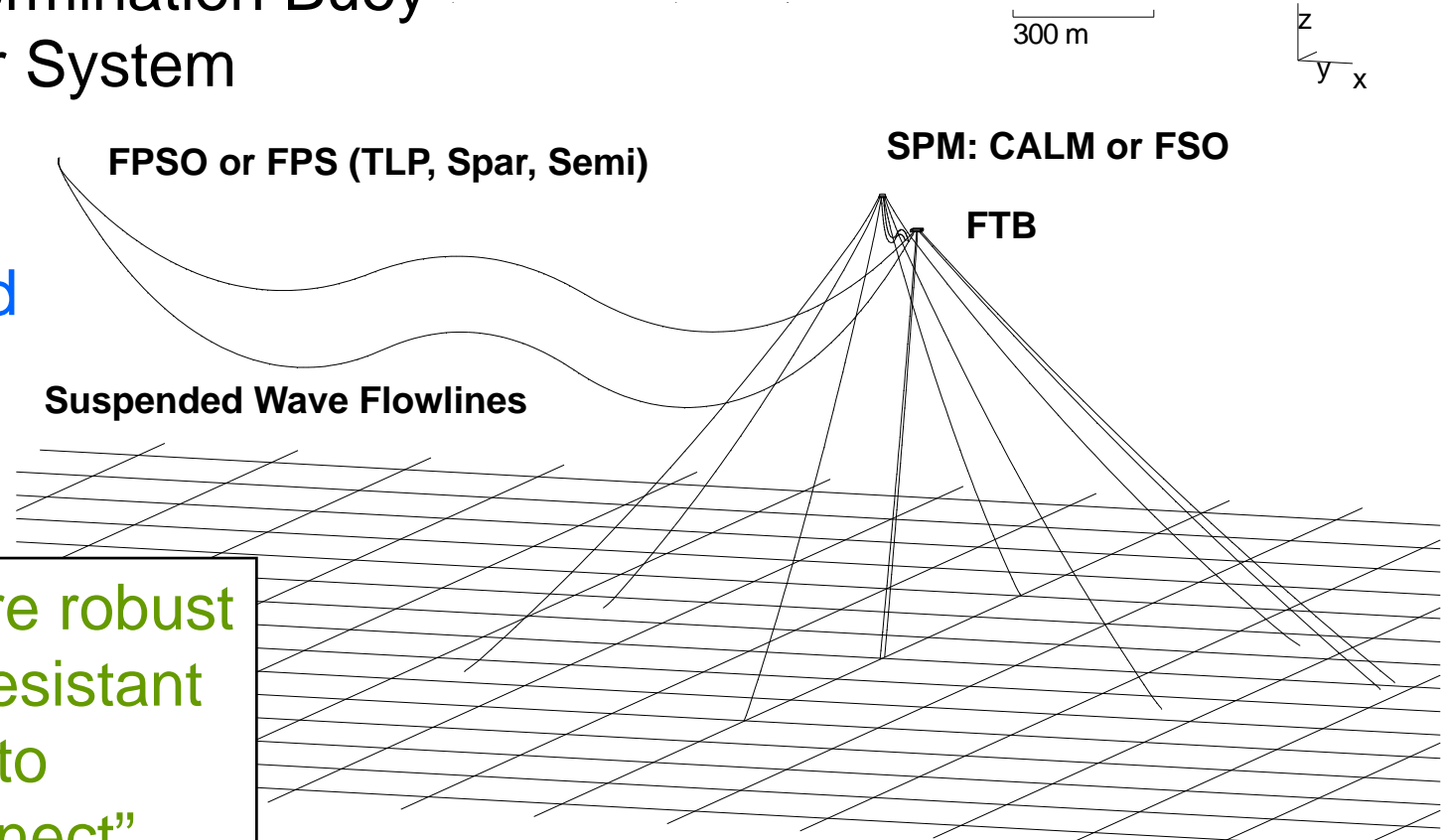


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

Flowline Termination Buoy (FTB) Riser System

Steel Lines
De-Coupled
from
FPSO

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

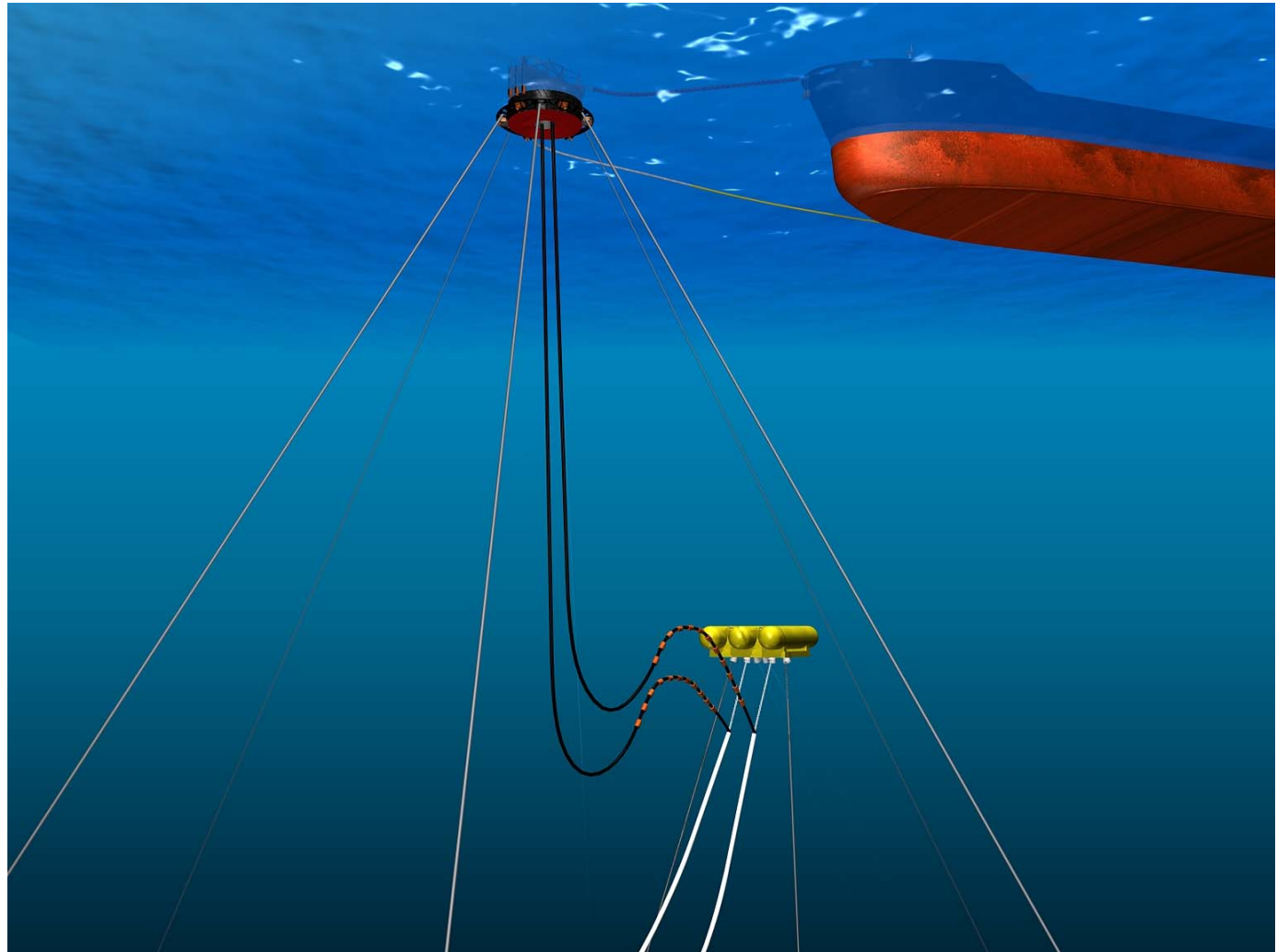


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to
FTB Riser
System

Steel Lines
De-Coupled
from
FPSO

SPM
can be
CALM or
FPSO



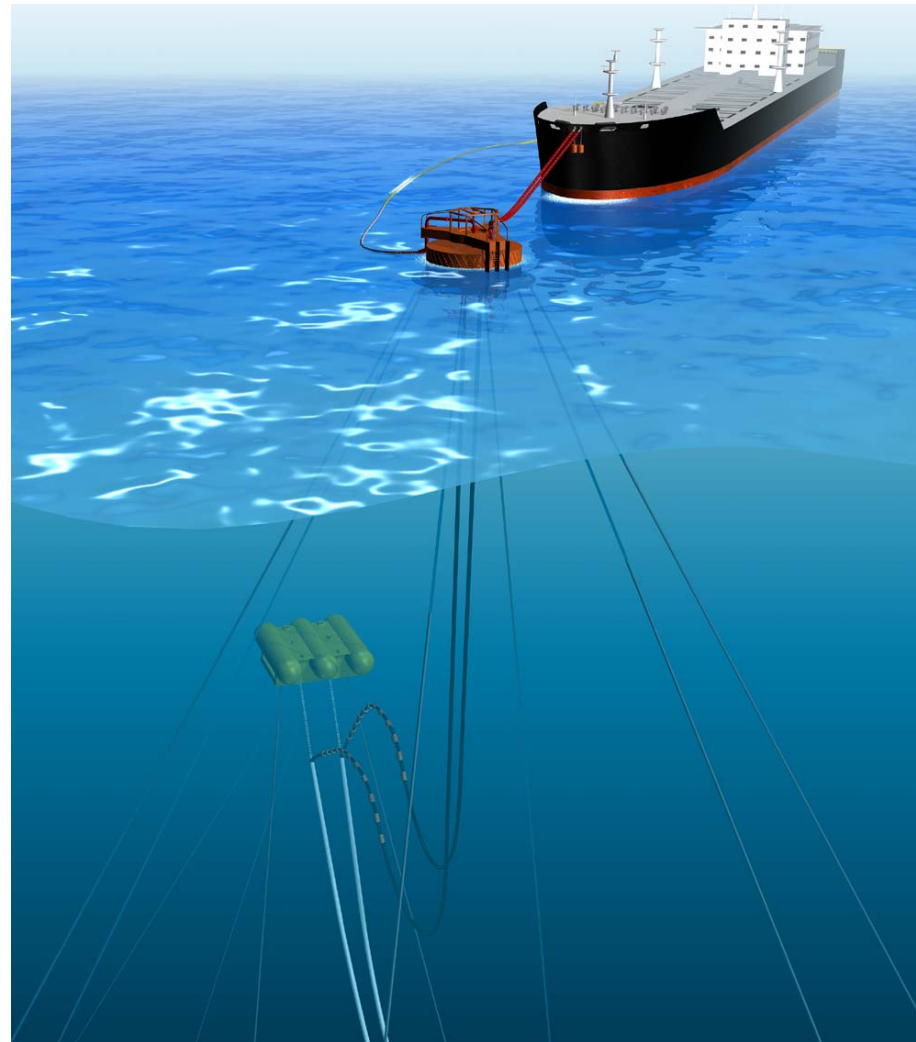
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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to
FTB Riser
System

Steel Lines
De-Coupled
from
FPSO

Fluid Swivels
Above Water



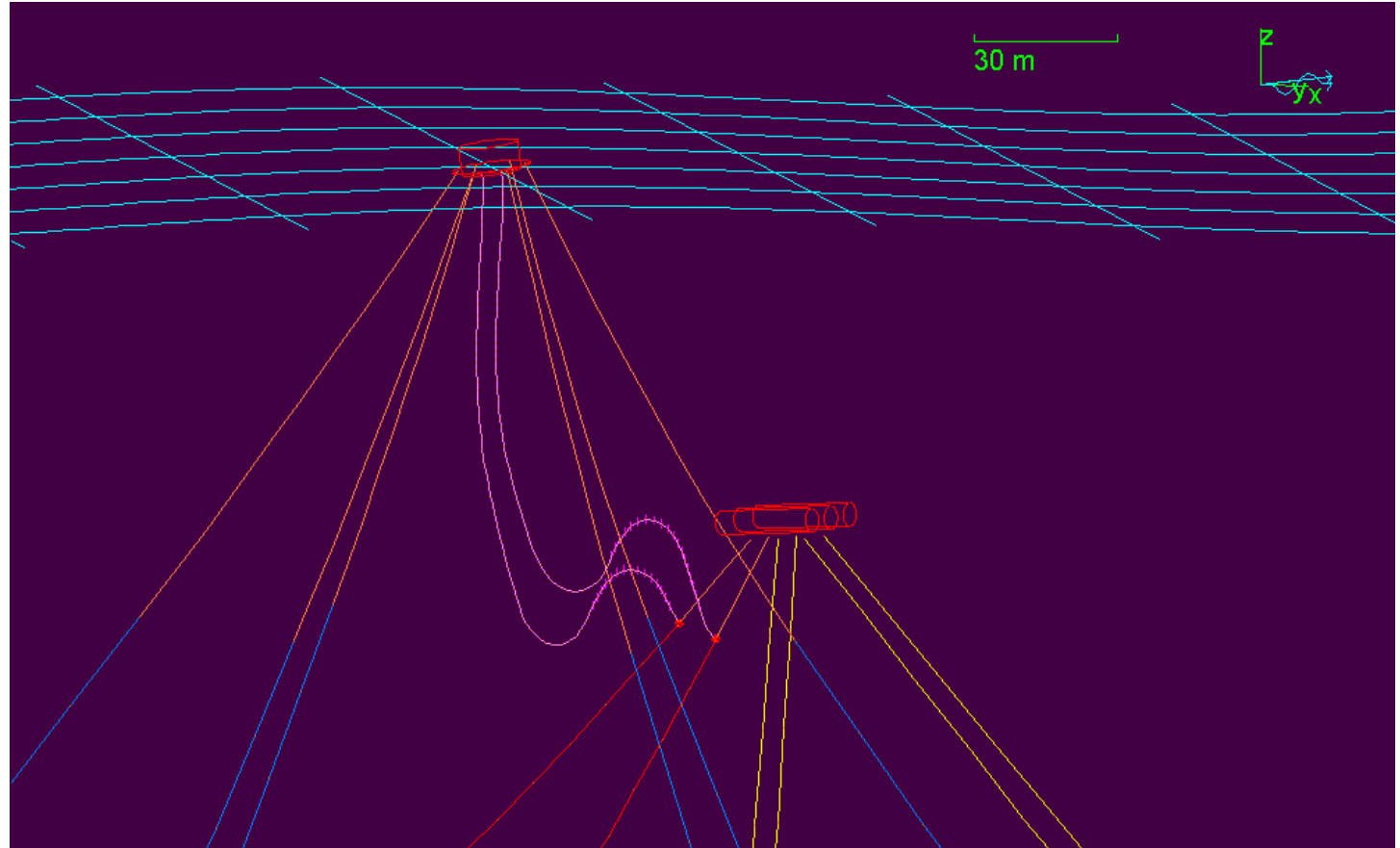
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FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to
FTB Riser
System

Steel Lines
De-Coupled
from
FPSO

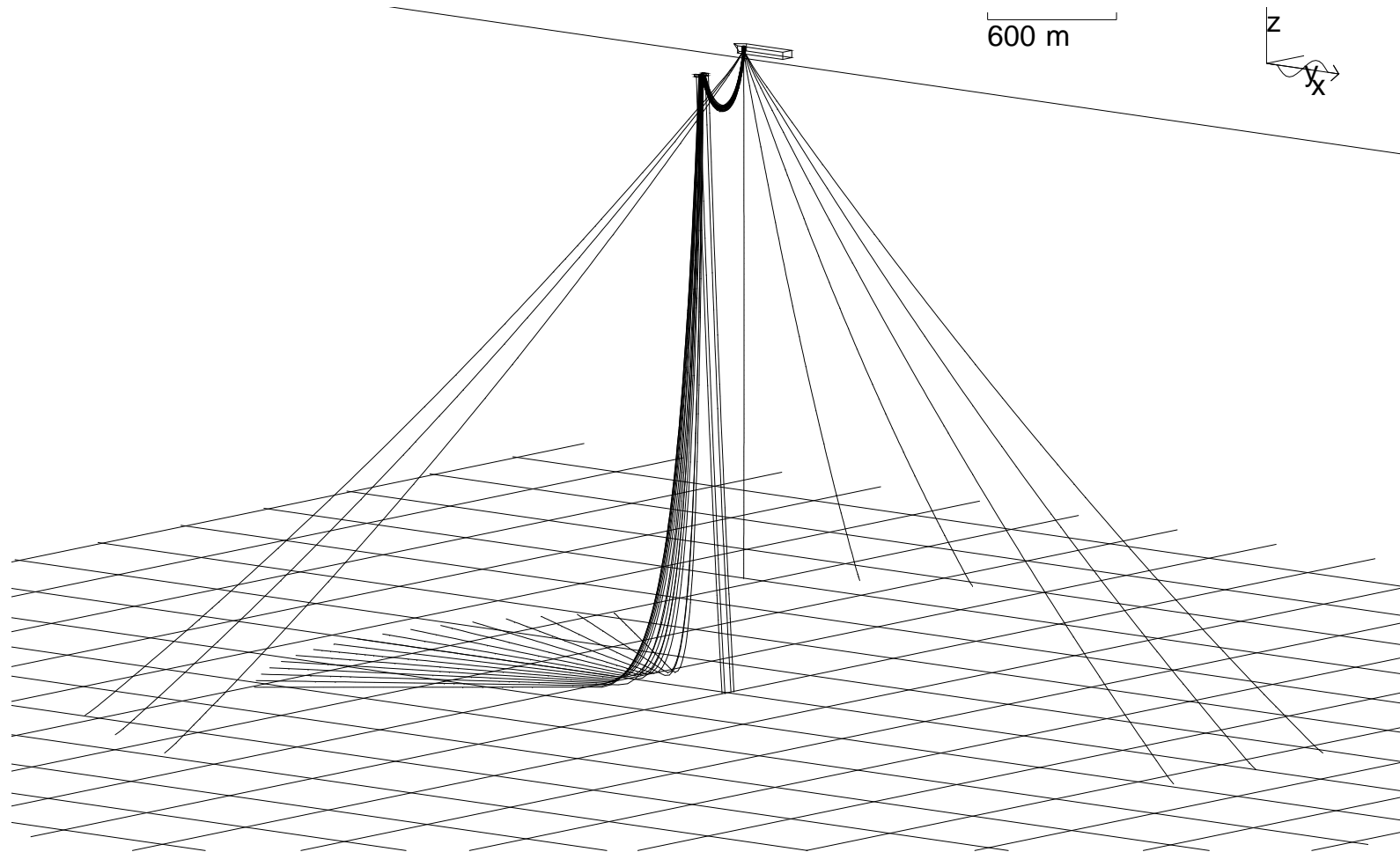
Product
Swivels
Above
Water



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Typical Deepwater GoM FPSO Mooring & Riser System

- 3x3 Taut Polyester Mooring and TLR Riser



FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Likely Characteristics of the “First” FPSO for the US Gulf:
(my predictions from 2000 ABS workshop)
 - Large depth because of vast pipeline infrastructure in shallower water
2011 Petrobras Cascade/Chinook FPSO (field discovered 2002): 2,600 meters
 - > 1,000,000 bbl capacity: large field more economic in deep water
P’Bras Cascade/Chinook FPSO: 600,000bbl (80,000bopd)
 - Internal turret because of large number of risers and extreme harsh environment
P’Bras Cascade/Chinook FPSO: internal turret, 5 riser jumpers + 4 umbilicals
 - Permanent system most economic for many risers / large field
P’Bras Cascade/Chinook FPSO: disconnectable (regulatory/operator preference?)
 - Taut polyester anchor legs: rapidly gaining acceptance (e.g., Brazil)
P’Bras Cascade/Chinook FPSO: polyester moorings
 - Extensive use of steel pipe-in-pipe in riser system: presently the norm in GoM
P’Bras Cascade/Chinook FPSO: FSHR (P-I-P) + flexible jumpers
 - Riser configuration that de-couples steel pipe from vessel wave-freq motions
P’Bras Cascade/Chinook FPSO: FSHR + flexible jumpers