

Emerging FPSO forum

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

Martin J. Krafft, Ph.D.

Lead Research Engineer

R&D / Hydrodynamics Dept.

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

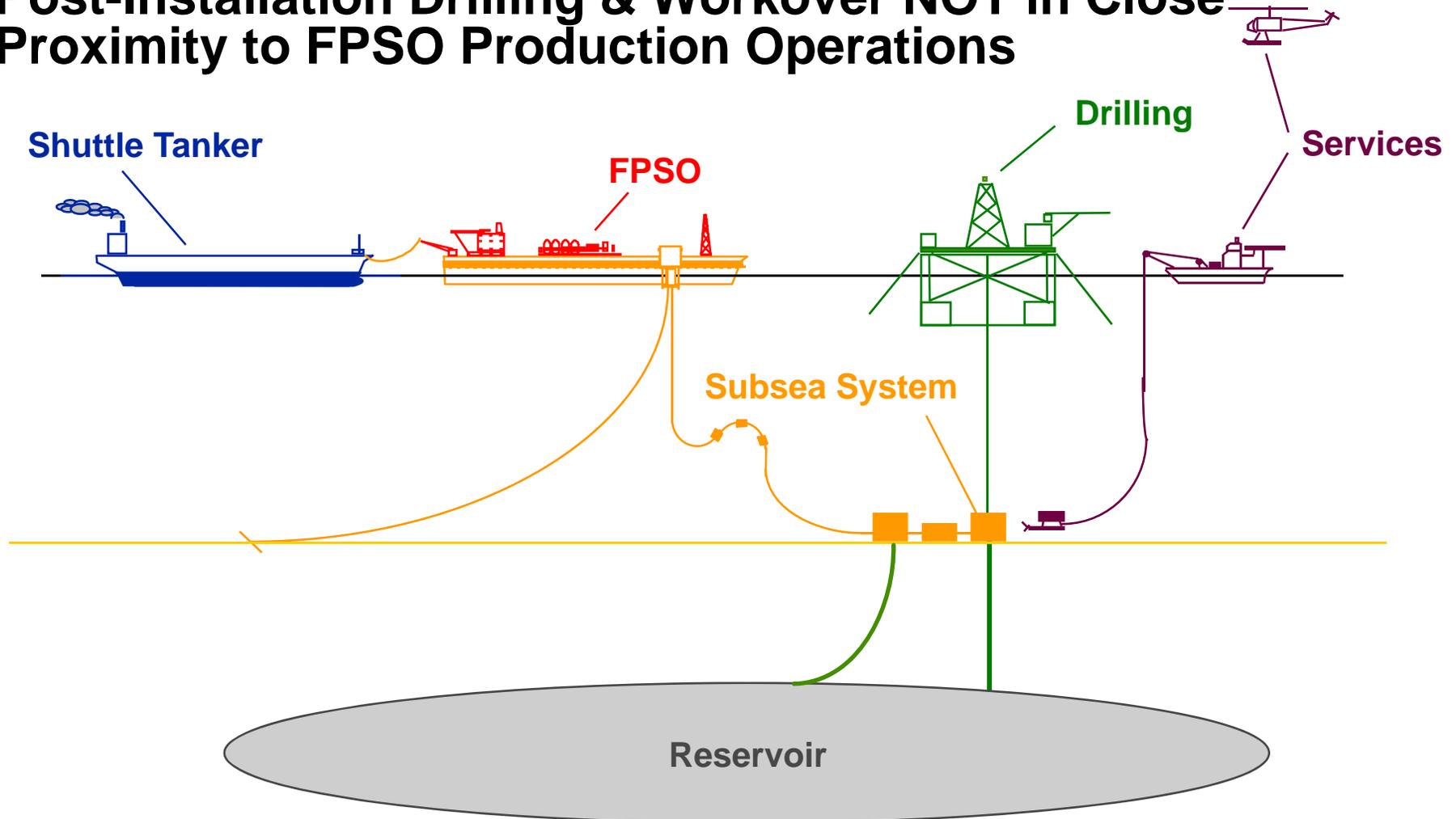
- Accommodates liquid and gas swivels and pig launching/receiving
- Turret manifold system can replace or augment subsea manifolding

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



Vietsovpetro 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



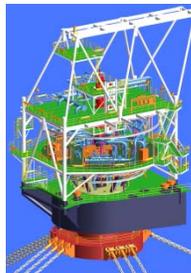
JVPC Rang Dong
Vietnam



BP PSVM
Angola



Tullow Jubilee
Ghana



HLJOC TGT FPSO
Vietnam



Chevron Erawan
Thailand

Existing External Turret Mooring System in Gulf of Mexico



softec

PEMEX Campeche Bay FSO: 1998, MODEC Intl LLC

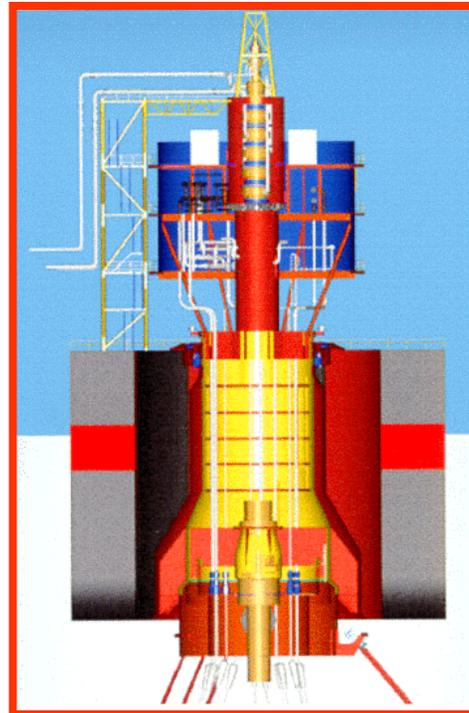
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ 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



PetroCanada - Terra Nova
Newfoundland, Canada



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

sofec

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

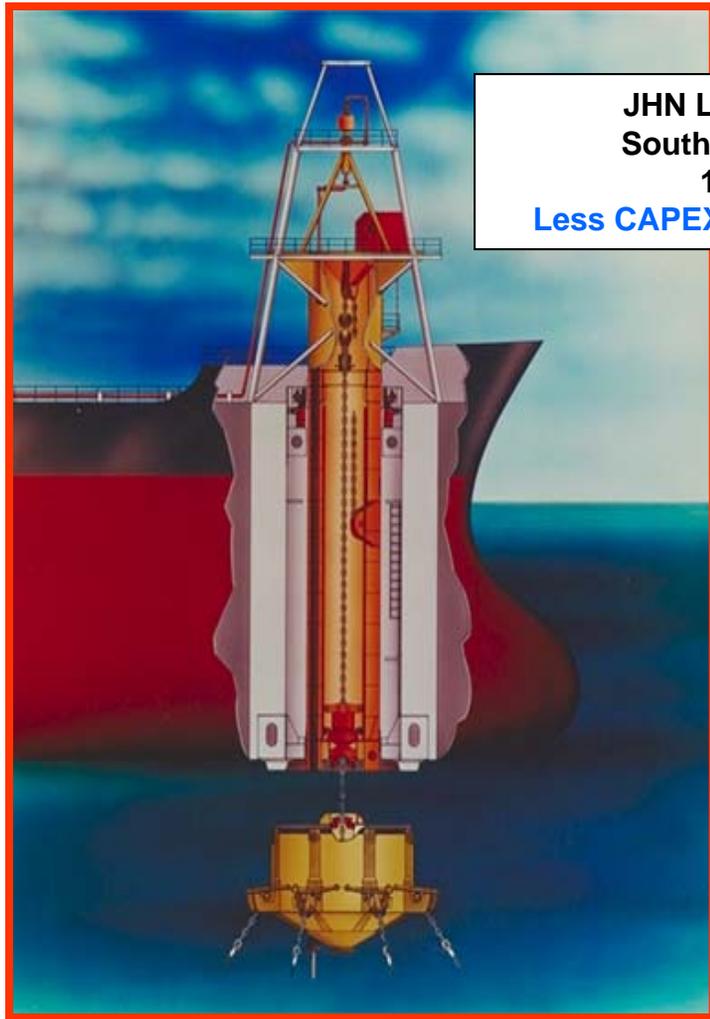
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

■ Permanent Vs. Disconnectable Turret Systems

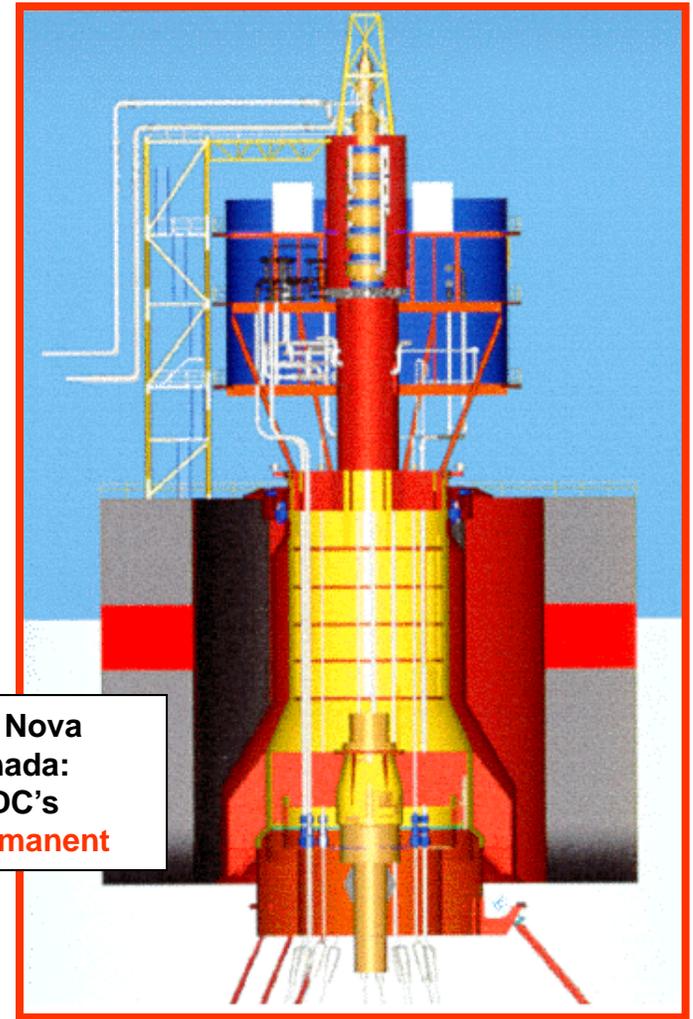
Disconnectable Turret Systems

- ⇒ 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

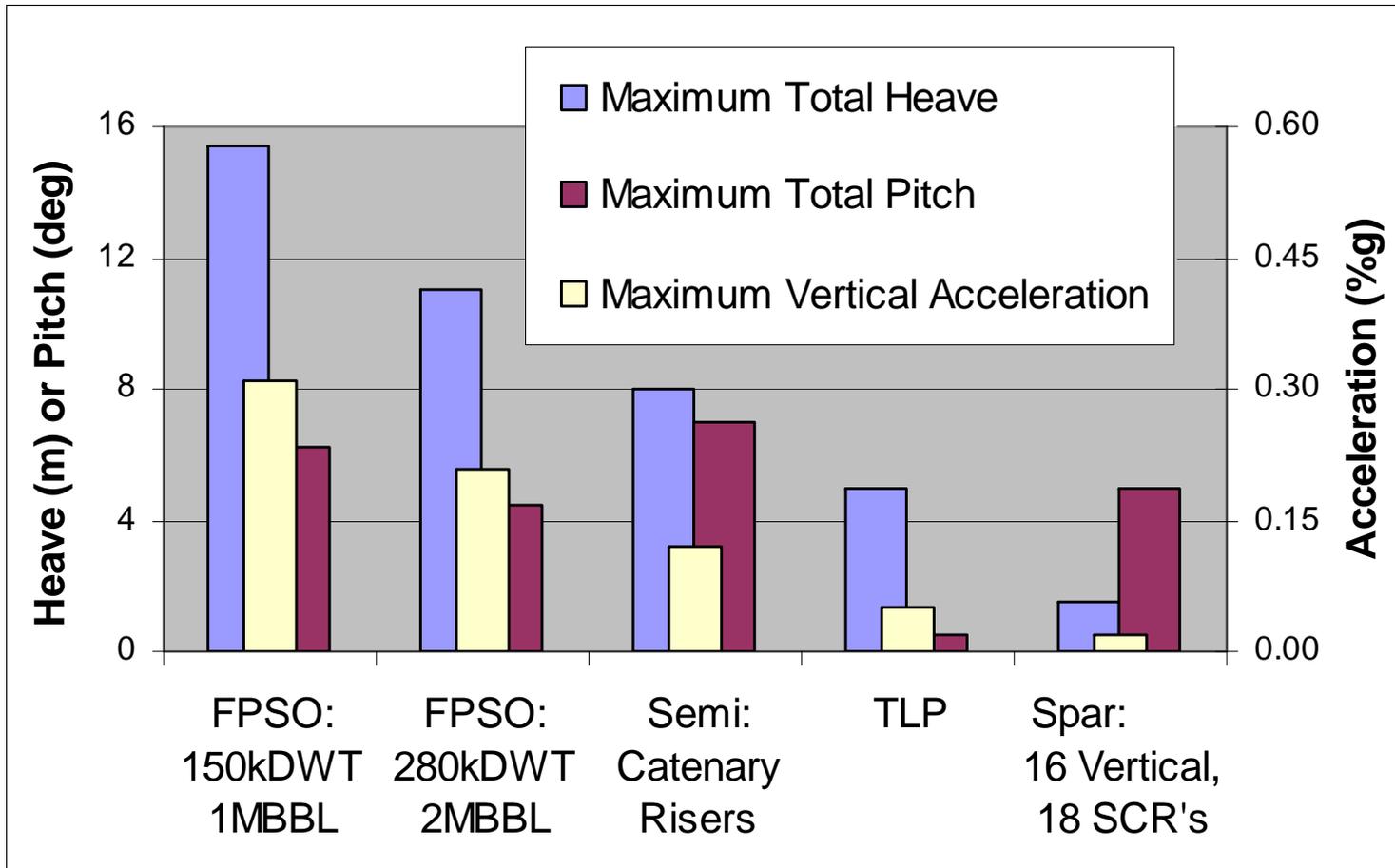
Deep water design

- ⇒ 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

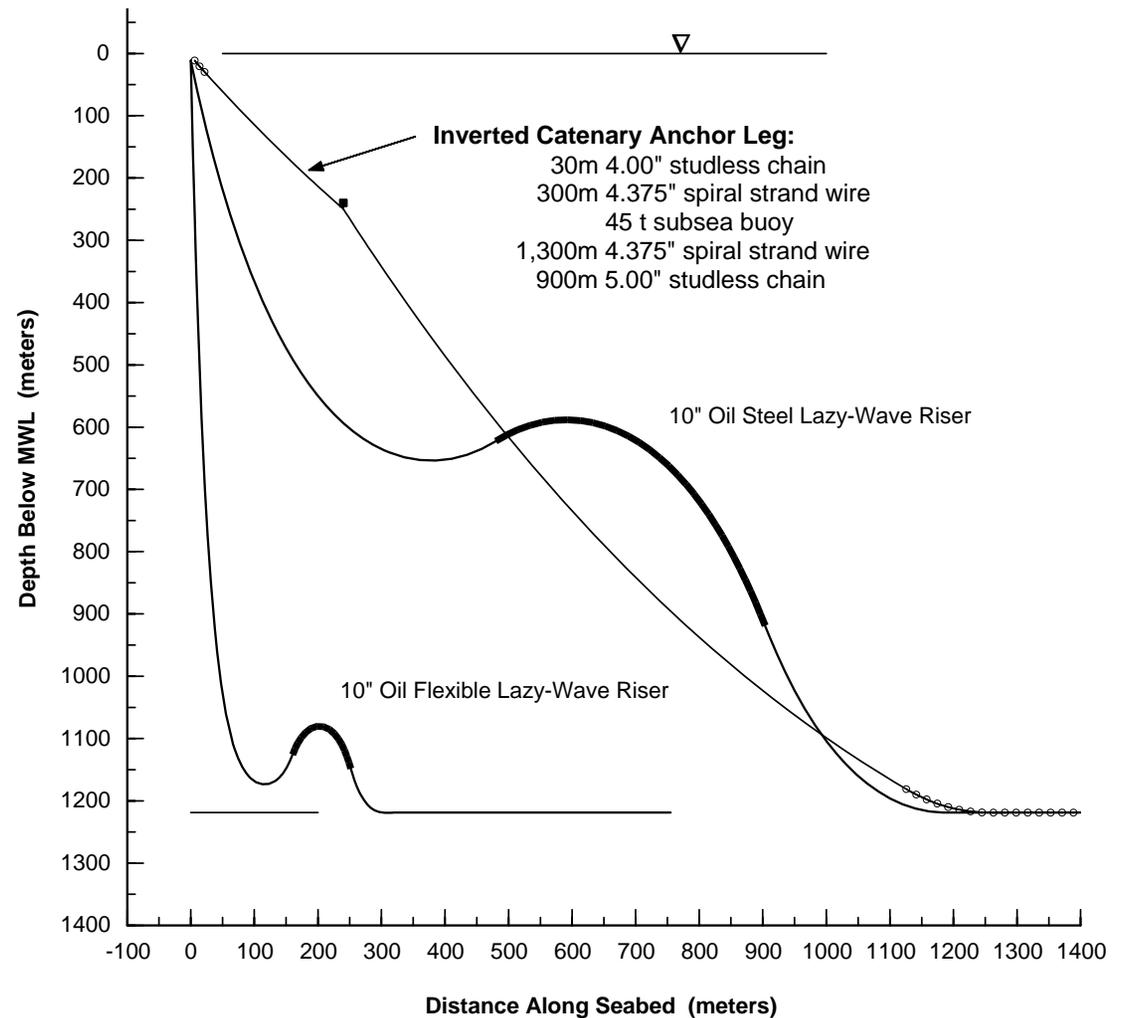


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- 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

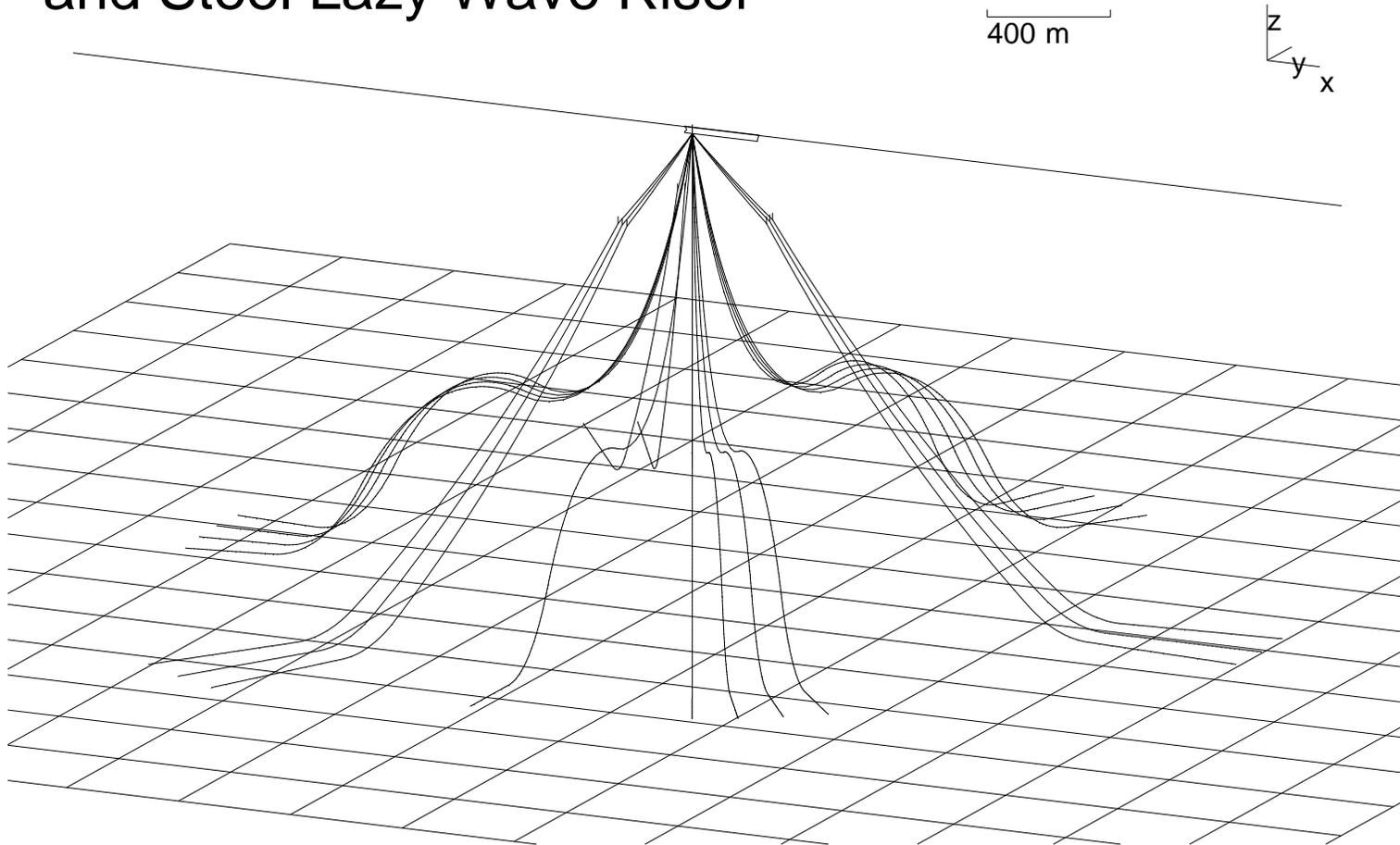
FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

- Steel Lazy Wave Riser (compliant)



Typical Deepwater GoM FPSO Mooring & Riser System

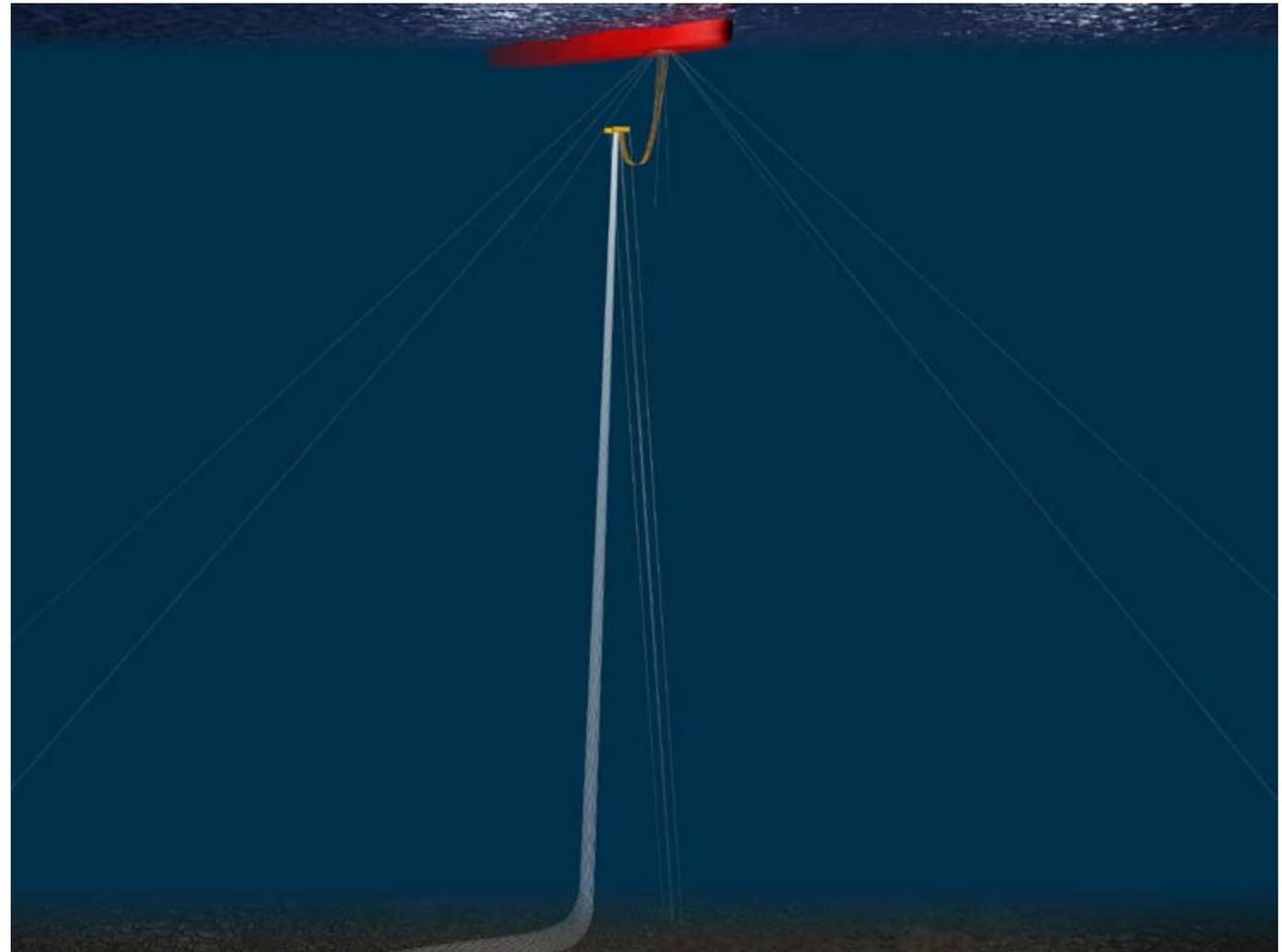
- 3x3 Inverted Catenary Chain & Wire Mooring and Steel Lazy Wave Riser



FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions

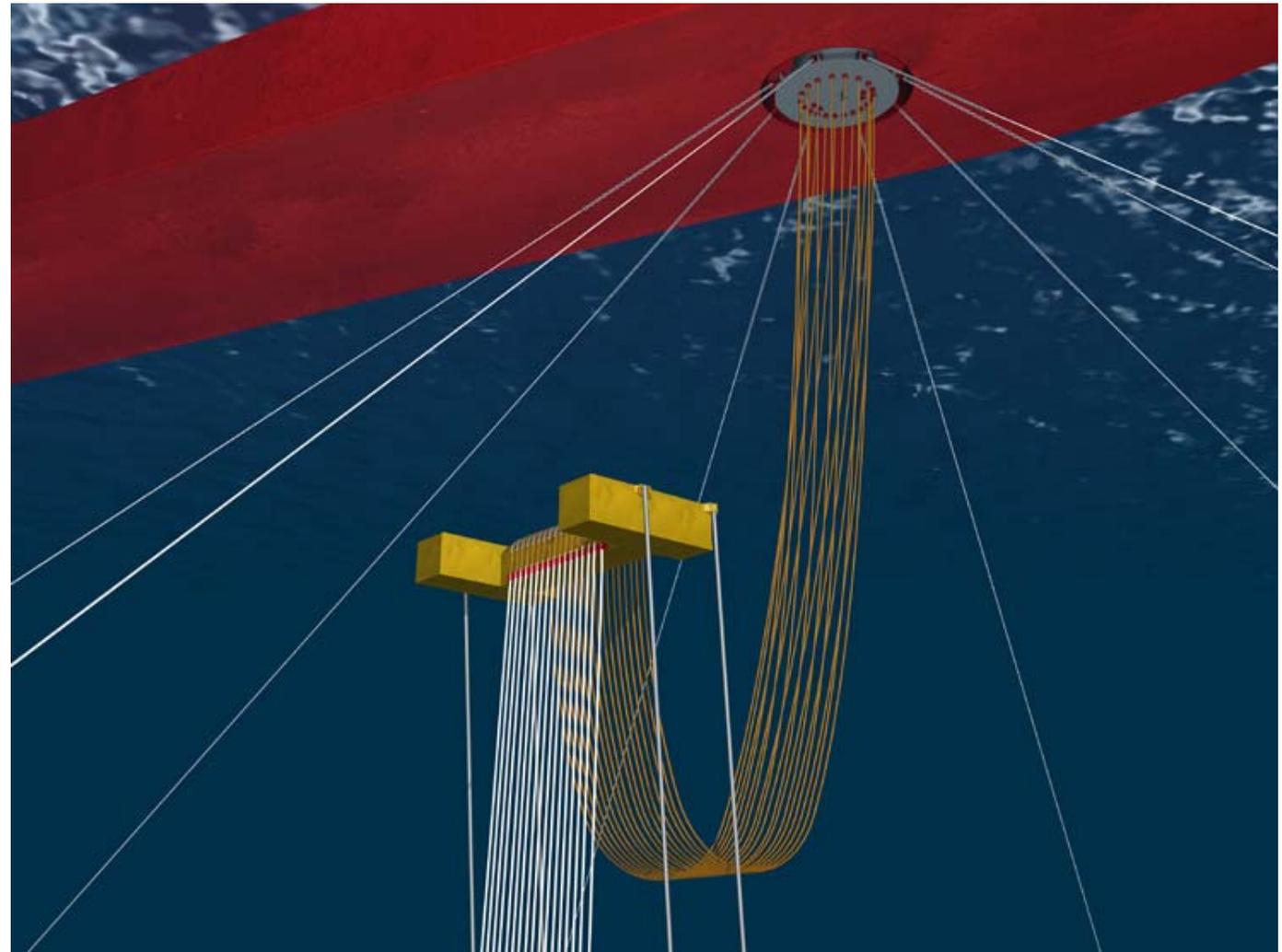


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

Steel Lines
De-Coupled
from
FPSO
Motions

Drastically
Reduces
Turret
Loads



softec

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:

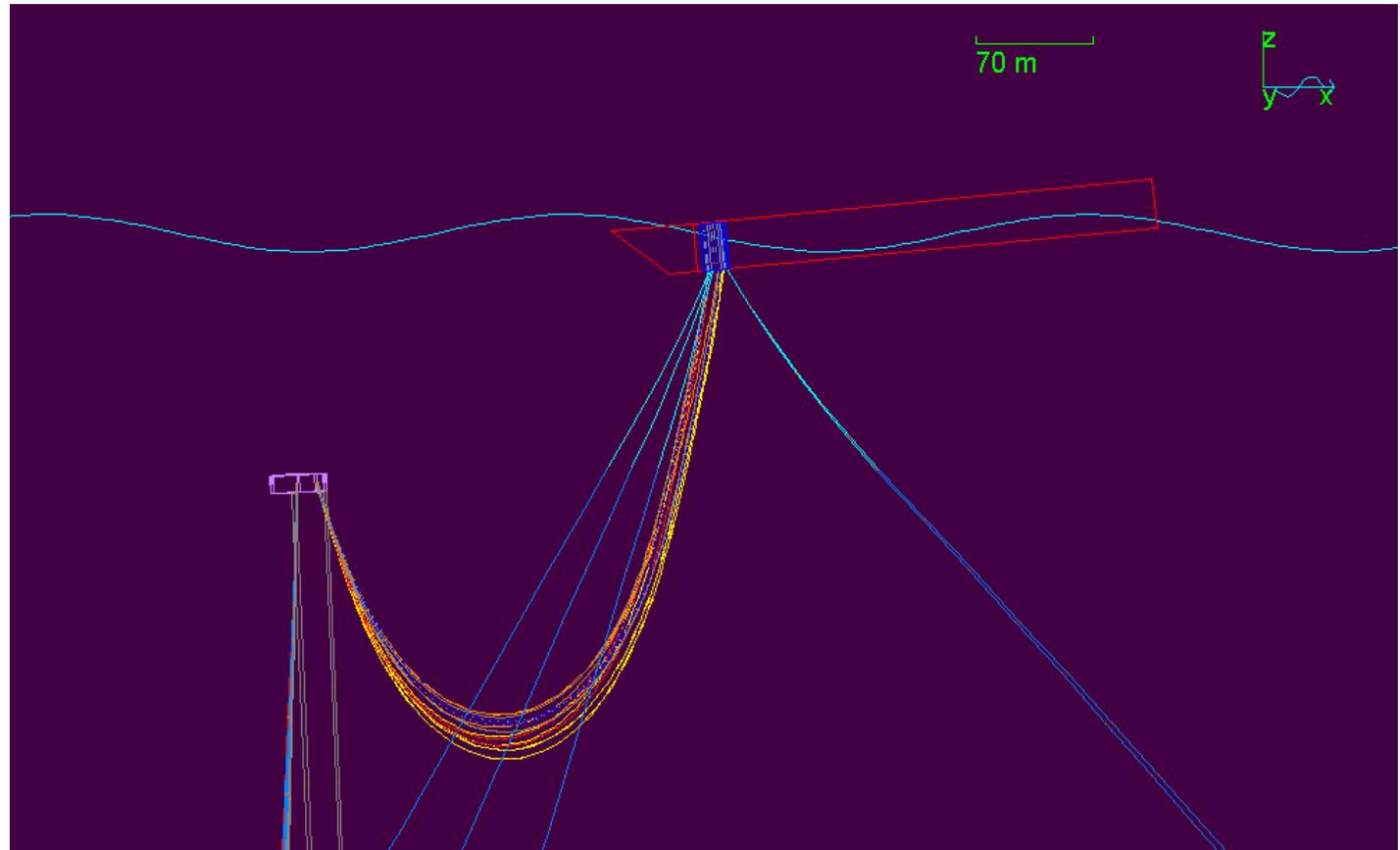
COST COMPARISON:
(based on large, multi-
riser field development)

TLR	100%
Lazy Wave	120%
Hybrid Tower	145%

FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

TLR
Riser
System

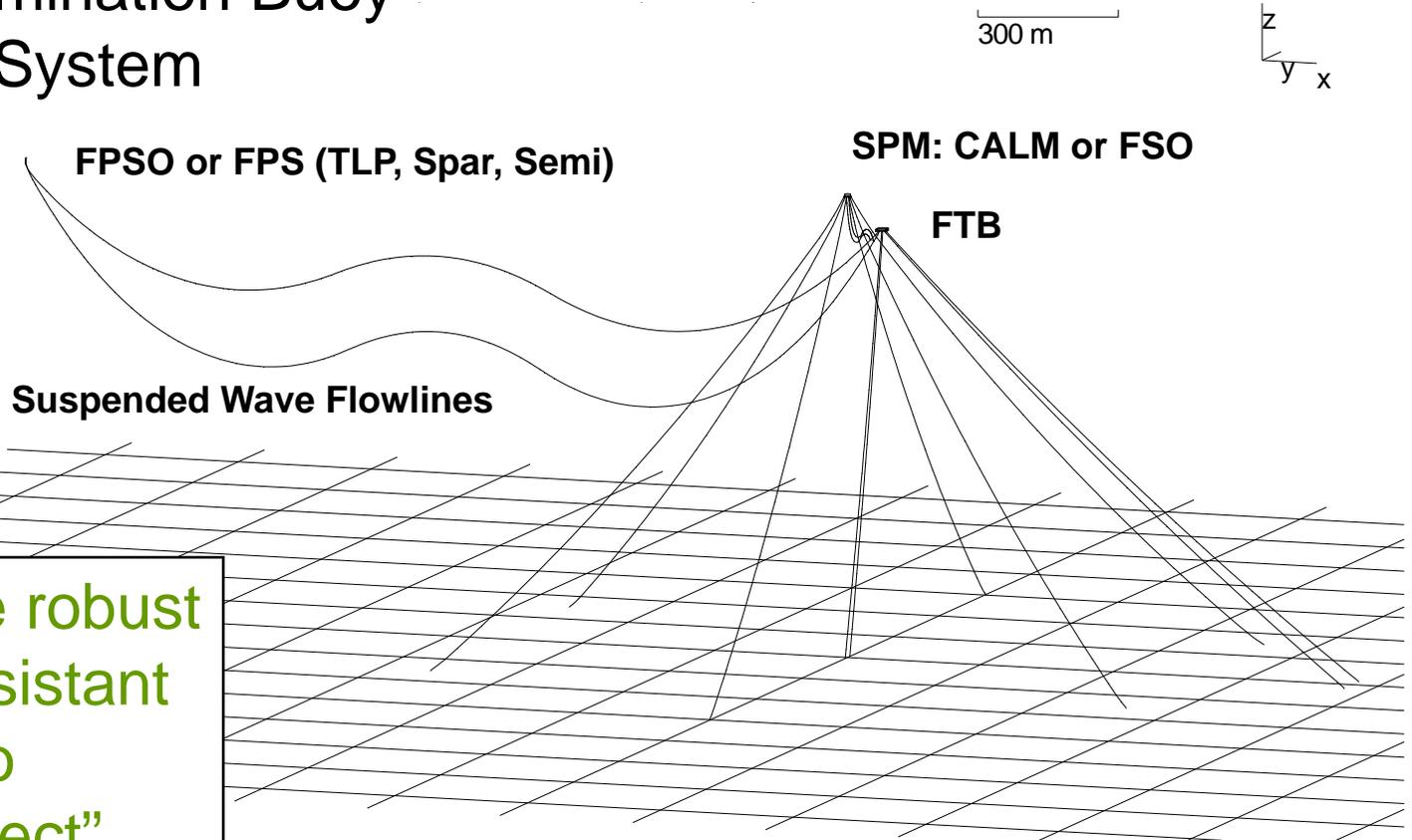
Steel Lines
De-Coupled
from
FPSO
Motions



FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

Flowline Termination Buoy (FTB) Riser System

Steel Lines
De-Coupled
from
FPSO



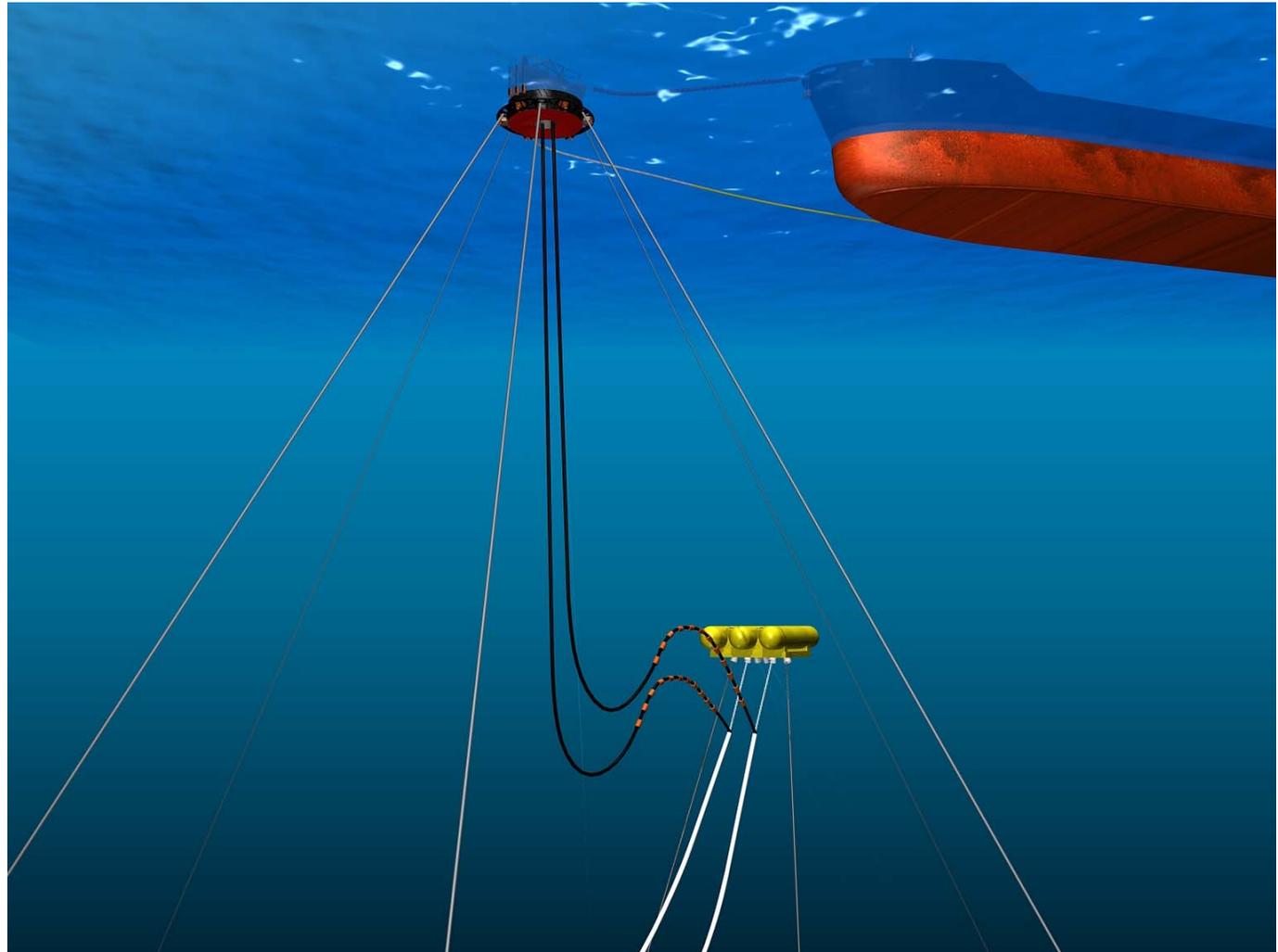
FTB is more robust
& fatigue resistant
compared to
“direct-connect”
riser systems

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

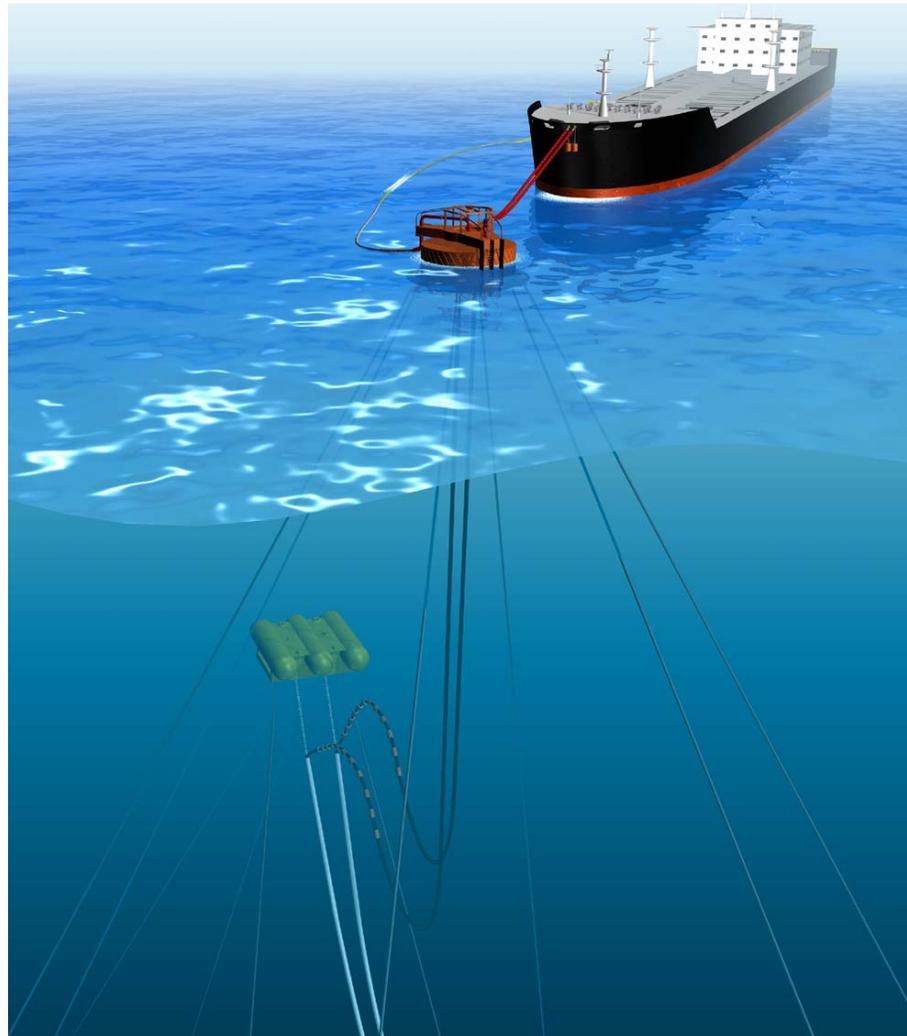


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to
FTB Riser
System

Steel Lines
De-Coupled
from
FPSO

Fluid Swivels
Above Water

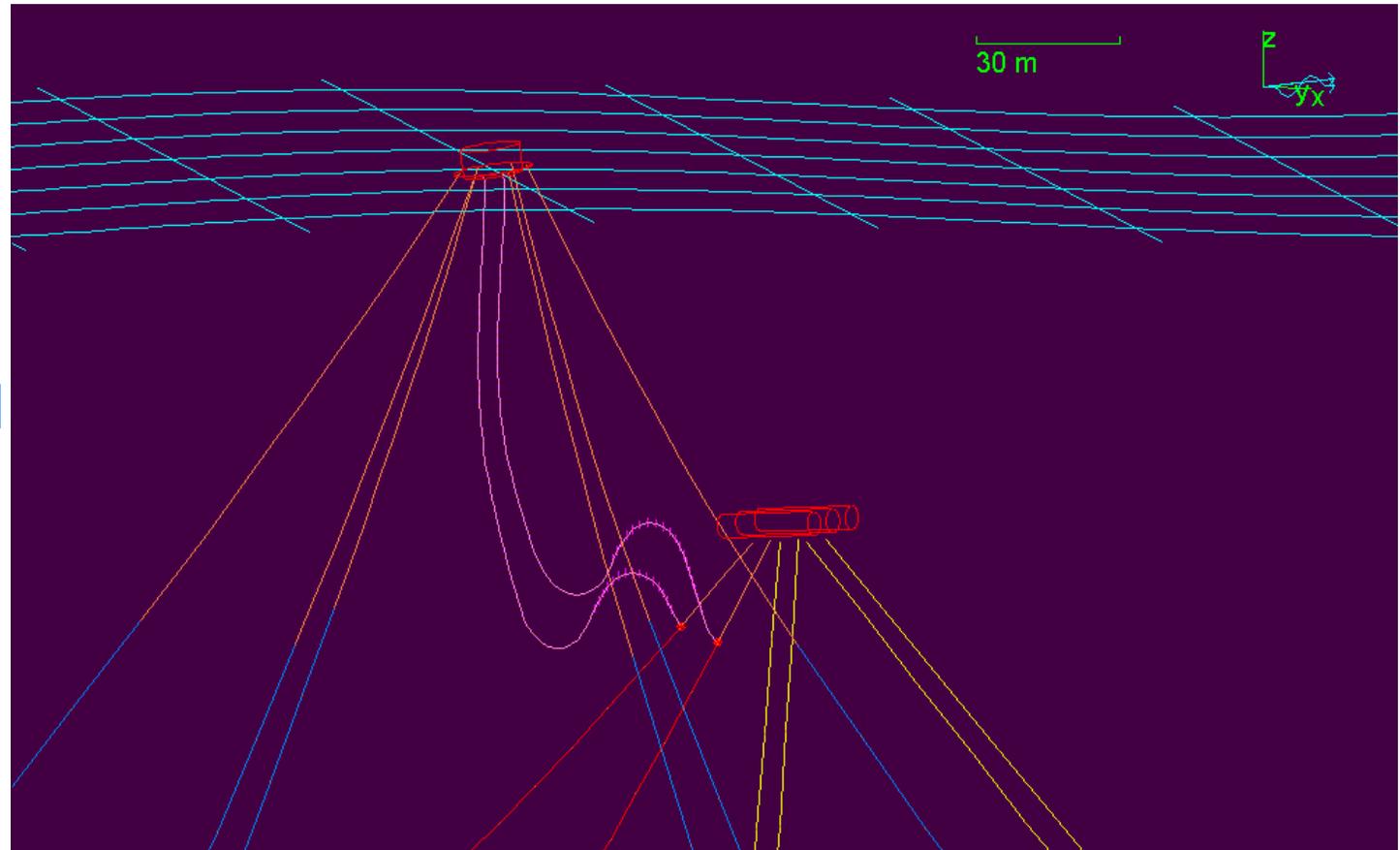


FPSO Turret Mooring and Riser Systems for the Gulf of Mexico

SPM to
FTB Riser
System

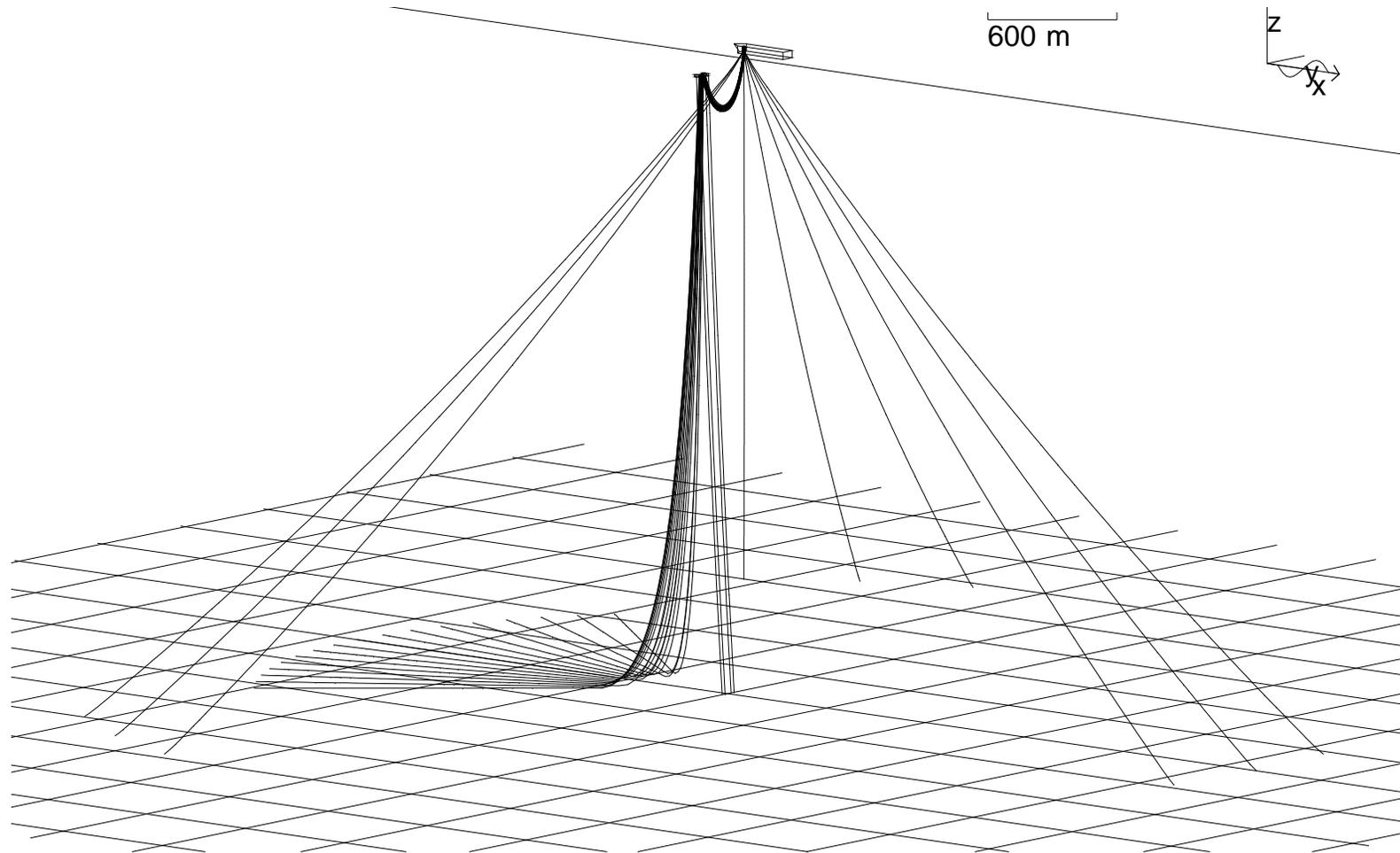
Steel Lines
De-Coupled
from
FPSO

Product
Swivels
Above
Water



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