

FPSOs in the Gulf of Mexico

International Mooring Seminar 2003

Arun Duggal

FMC SOFEC Floating Systems

18 February 2003

Outline of Presentation

- **Introduction**
- **Specific requirements for the Gulf of Mexico**
- **FPSO hull**
- **Turret-Mooring System**
- **Riser system**
- **Offloading**
- **Installation**
- **New initiatives**

FPSOs Worldwide

- **Mature FPS: Over 100 units in operation worldwide**
- **FPSO total greater than all other FPS combined**
- **Water depth range from 20 m to > 1,800 meters**
- **1 to 100+ risers**
- **10,000 bbl – 200,000 bbls/day**
- **Up to 2,000,000+ bbls storage**
- **Benign (West Africa) to extreme environments (North Atlantic)**
- **Various configurations:**
 - **Turret-moored**
 - **Spread-moored**
 - **Hard/Soft Yoke-moored**
 - **Hawser-moored**

Specific Requirements for the GoM

- **Environment**
 - Hurricane environment – similar to S. E. Asia typhoons
 - Water depth – from 1000 m (3000 ft) to 3000+ m (10,000ft)
 - Majority of time fairly benign
- **Regulatory requirements (MMS Approval Received)**
- **Pipeline infrastructure – negates requirement for storage in many cases**
- **Jones Act – impact on shuttle tanker availability and costs**
- **New fields will be developed away from existing infrastructure**

Environment: Current FPSO Installations

- North Atlantic (West of Shetlands) $H_s = 18$ meters
- North-West Atlantic (Eastern Canada) $H_s = 16$ meters
- South China Sea $H_s = 13$ meters
- Central to Northern North Sea $H_s = 12$ to 16 meters
- Southern Ocean (New Zealand) $H_s = 11$ meters
- South Atlantic (Brazil) $H_s = 8$ meters
- Gulf of Mexico (Mexico) $H_s = 9$ meters
- *Gulf of Mexico (Deepwater, USA) $H_s = 13$ meters*

Water depths range from » 50 to 1,400+ meters (4,600 feet)

GOM Hurricane Environment

- **FPSOs have an excellent record in similar environments (typhoons)**
 - South China Sea
 - South East Asia
 - Australia
- **Turret-Moored FPSOs**
 - Permanent mooring systems
 - Disconnectable mooring systems

Permanent - AMOCO Liuhua 11-1

South China Sea (1996)

141,000 DWT FPSO

Water depth 293 m

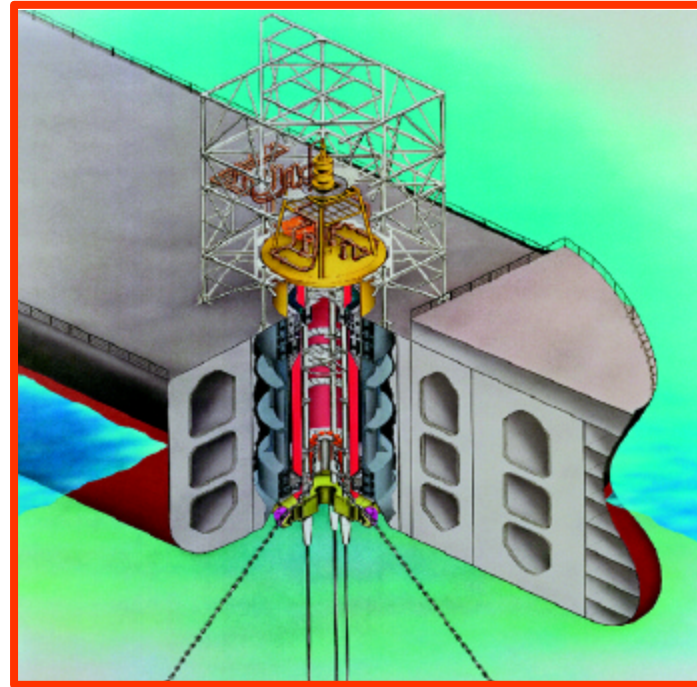
Designed for 100-year typhoon storm environment

- $H_{max} = 23.8 \text{ m}$
- $H_s = 12.8 \text{ m}$
- $V_{wind} = 54.0 \text{ m/s}$

Evacuated before Typhoons like GoM

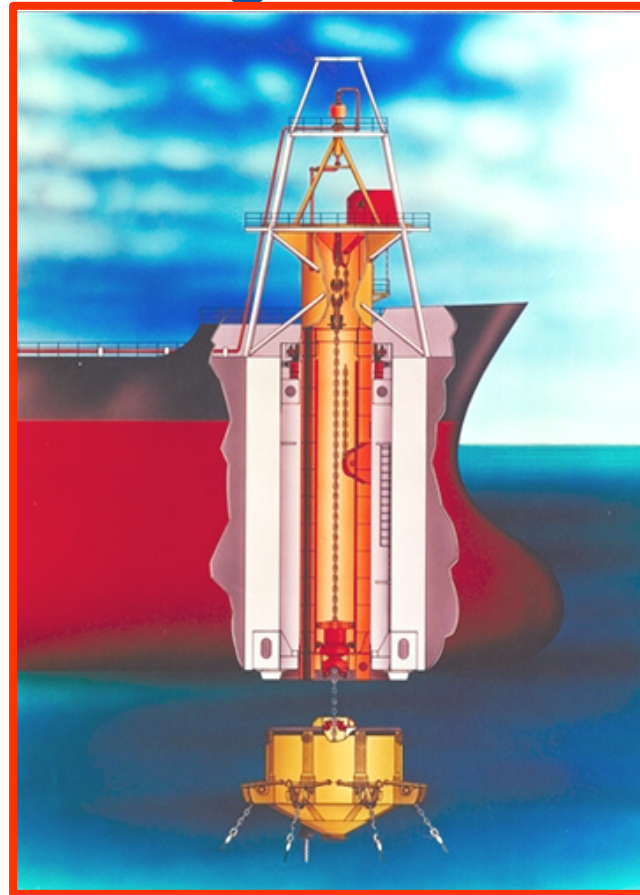
Survived Super-Typhoon Sally (1996),

$H_s = 14.3 \text{ m}$ – no issues



Disconnectable - JHN Lufeng 13-1

- South China Sea (1993)
- 128,000 DWT FSO
- Water depth 142 m
- Features disconnectable Turret
- Disconnect 1 hour, reconnect 3 hours
- Designed to remain on station in the 100-year non-typhoon storm environment
- Designed to disconnect for storm conditions $> H_s=8\text{m}$



PEMEX FSO, GoM

- **Bay of Campeche, water depth = 90 m, Hs = 9 meters**
- **Installed 1998**
- **Conversion 352,000 DWT tanker**
- **External turret mooring system**
- **Storage 2,300,000 bbls**
- **800,000 bbls/day maximum throughput**
- **Designed for both tandem and side-by-side offloading**
- **Since 1999 – total of 514 tanker loadings (285 million barrels)**
 - **2002: 219 tanker loadings (122 million barrels)**
- **100% offloading uptime**

Offloading in the Gulf of Mexico



Likely Characteristics of FPSOs for the GoM

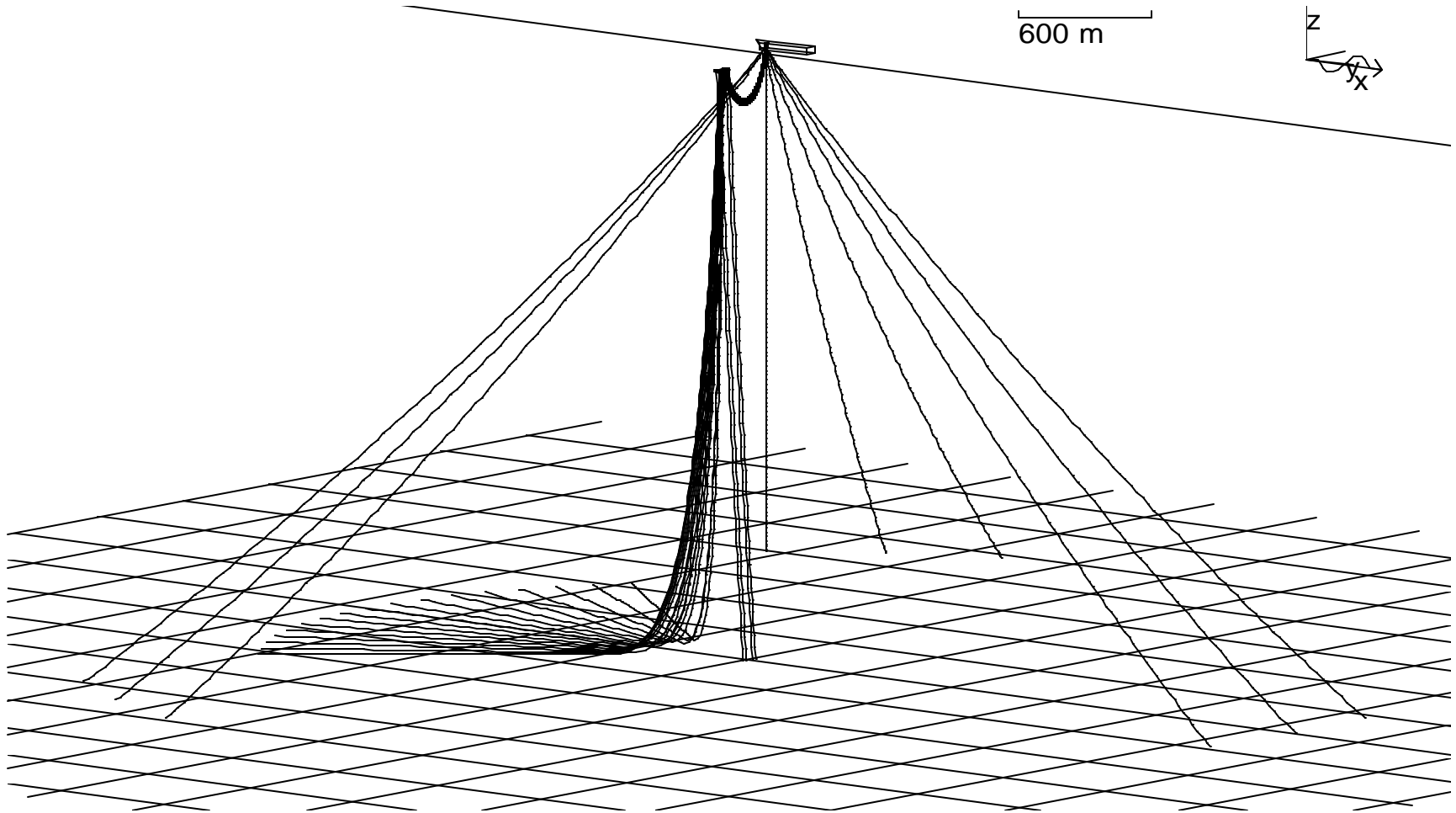
- Large depth / remote location due to vast pipeline infrastructure
- Internal turret due to large number of risers, and harsh environment
- Permanent system most economic for many risers / large field
- Taut polyester anchor legs: rapidly gaining acceptance
- Suction piles or vertically loaded anchors
- Extensive use of steel pipe in riser system: presently the norm
- Riser configuration that de-couples steel pipe from vessel motions
- Tandem offloading with US-built DP shuttle tankers
- Gas export via pipeline
- **Exceptions:**

Floating Production Vessel (no storage)

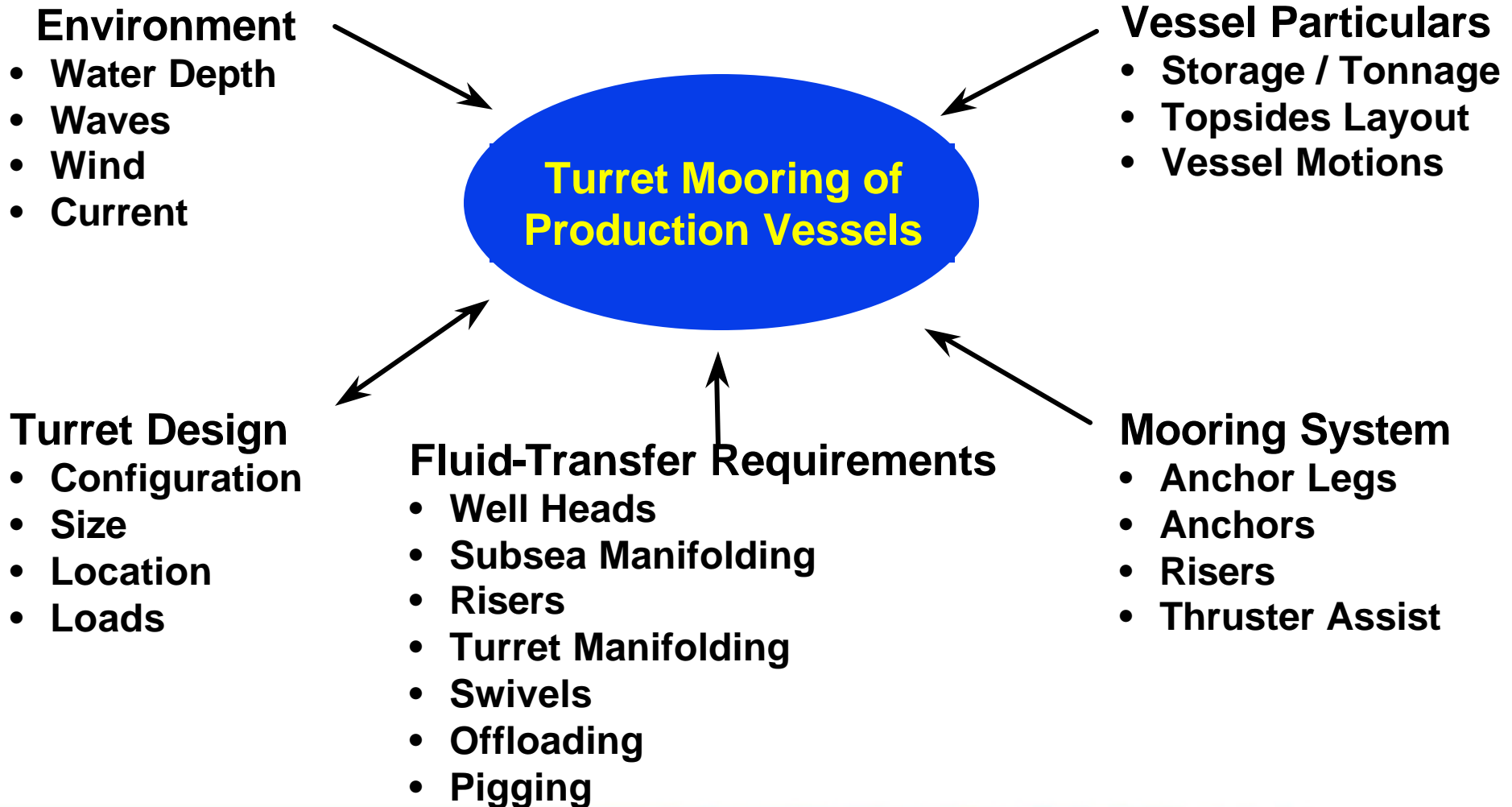
Early Production System waiting on pipeline infrastructure

Generic FPSO, GoM 3,000 meters [10,000 ft]

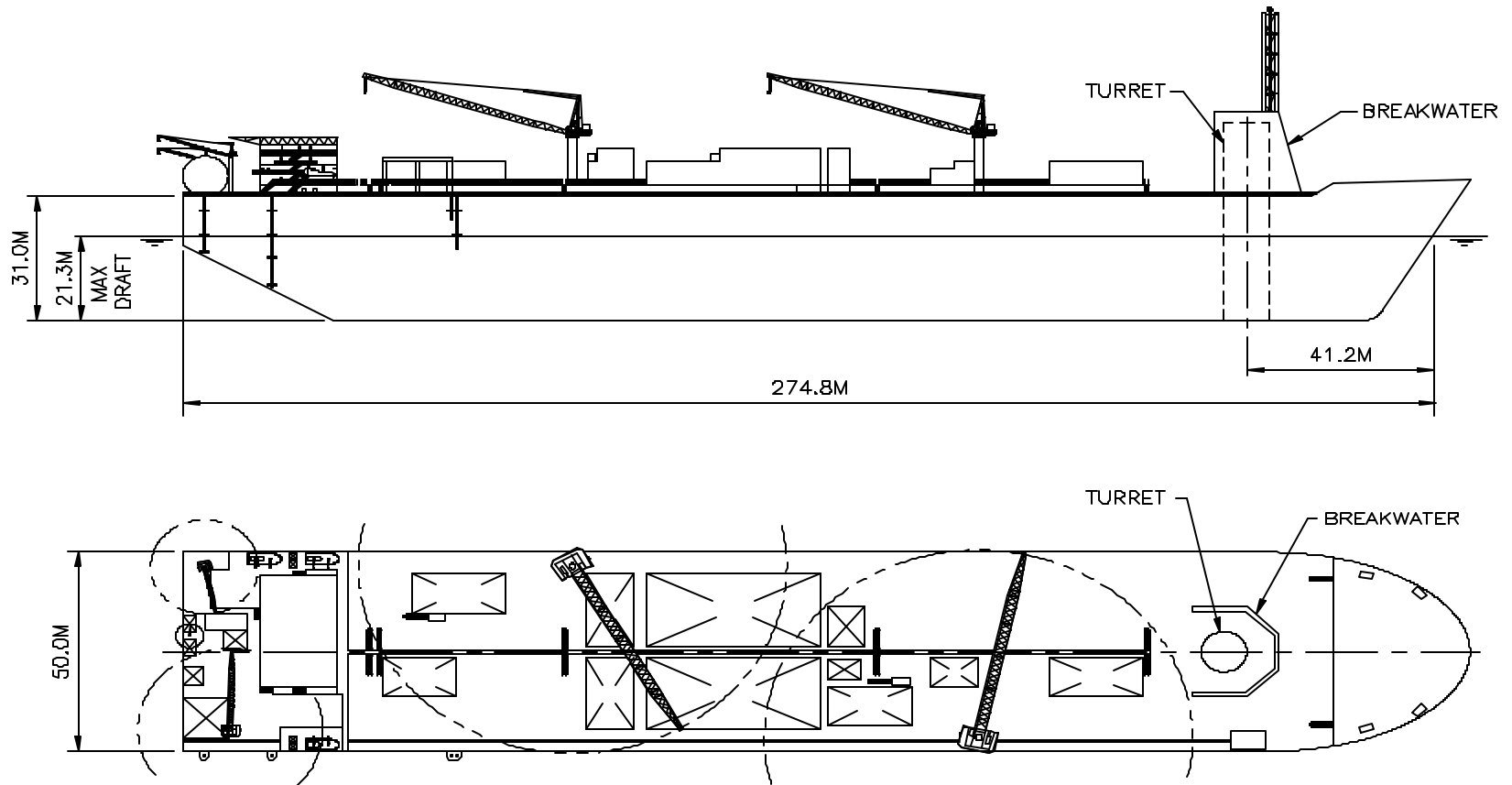
3x3 Taut Polyester Mooring and TLR Riser



Design Considerations



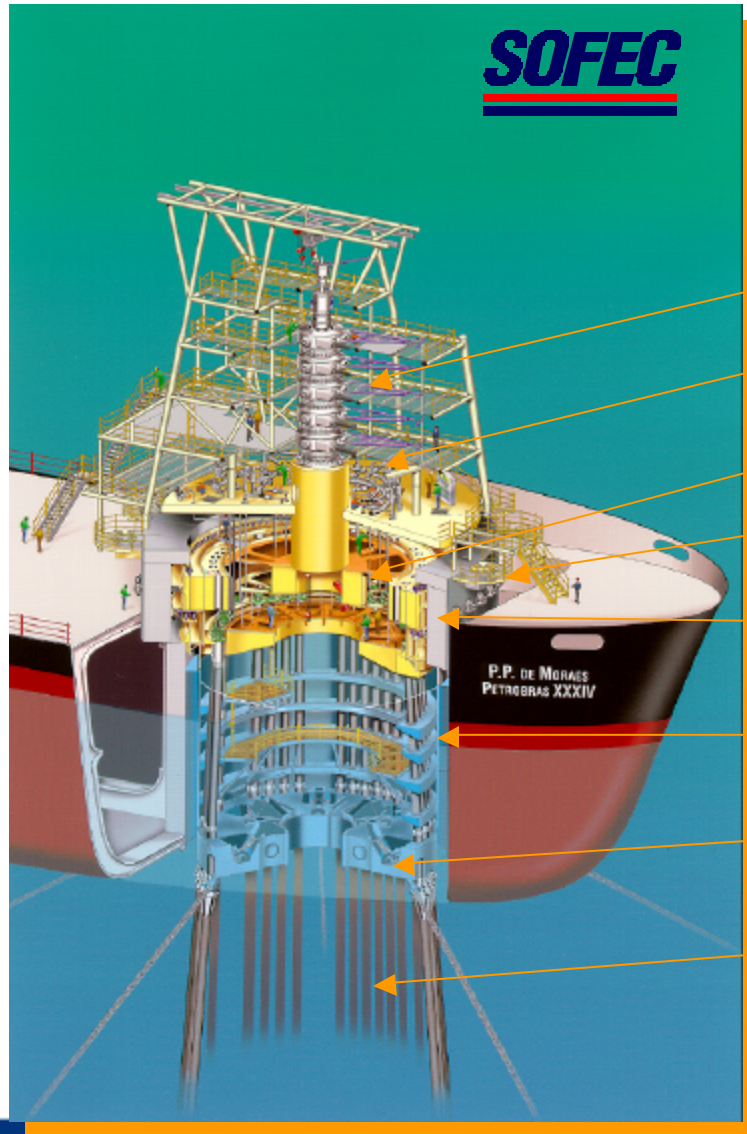
Typical Deepwater GoM FPSO



Turret-Moored FPSO Systems

- **Provides station keeping, load transfer & fluid-transfer functions**
- **Allows 360 degree weathervaning**
 - **Reduces loads on mooring system**
 - **Efficient 3X3 or 3X4 mooring arrangement**
 - **Restricts offsets to maintain riser system integrity**
 - **Reduces motions for riser system and process (roll)**
 - **Passive system can be unmanned during hurricanes**
- **Platform for mooring and riser systems pull-in equipment**
- **Fluid-transfer system**
 - **Fluid & gas swivels, manifolding, pig launching/receiving**
- **Includes well safety, control and maintenance systems**

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

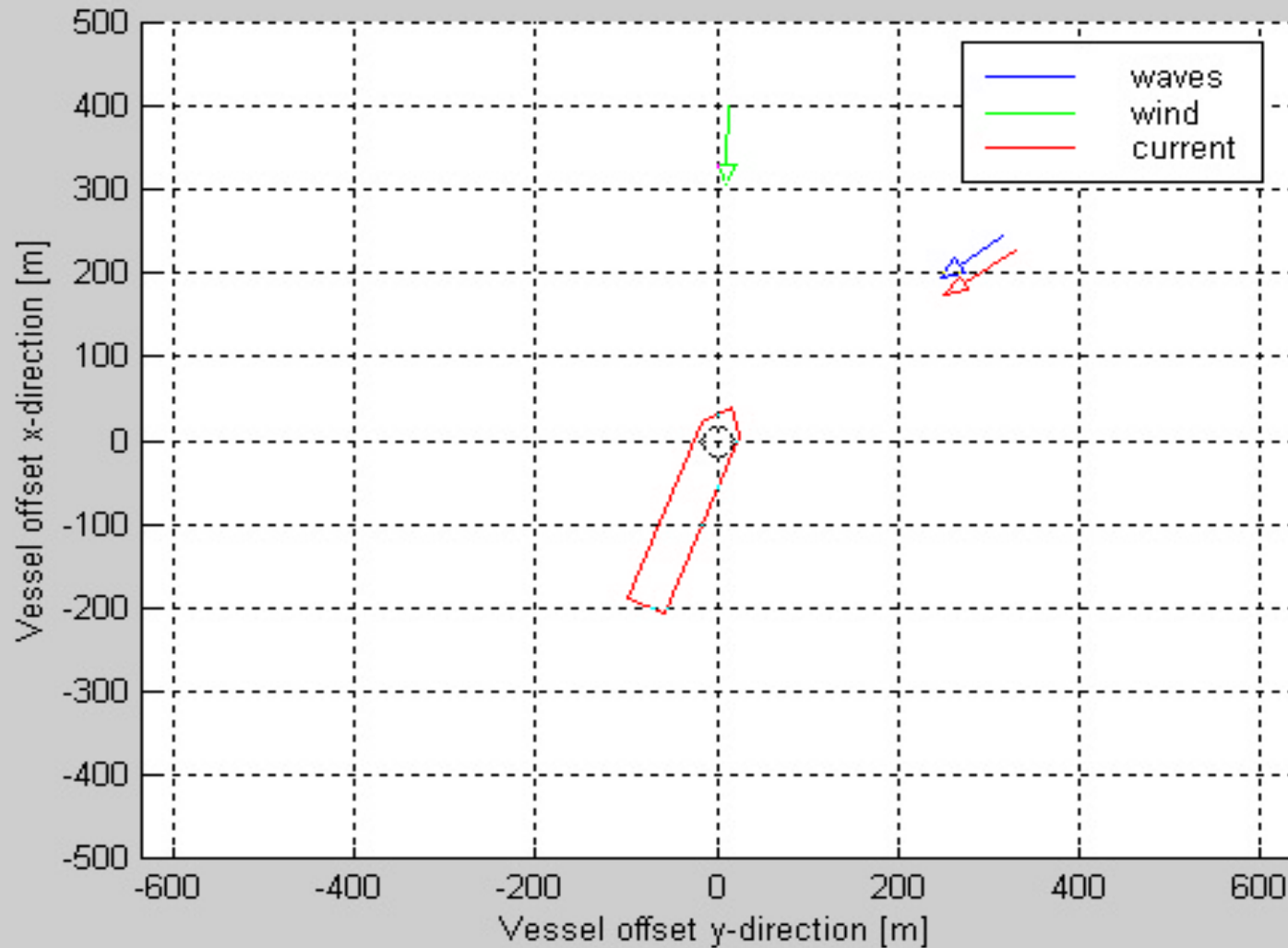
Chain Table (Hawse Pipes/Chain Supports)

6 Anchor Legs + 34 Risers

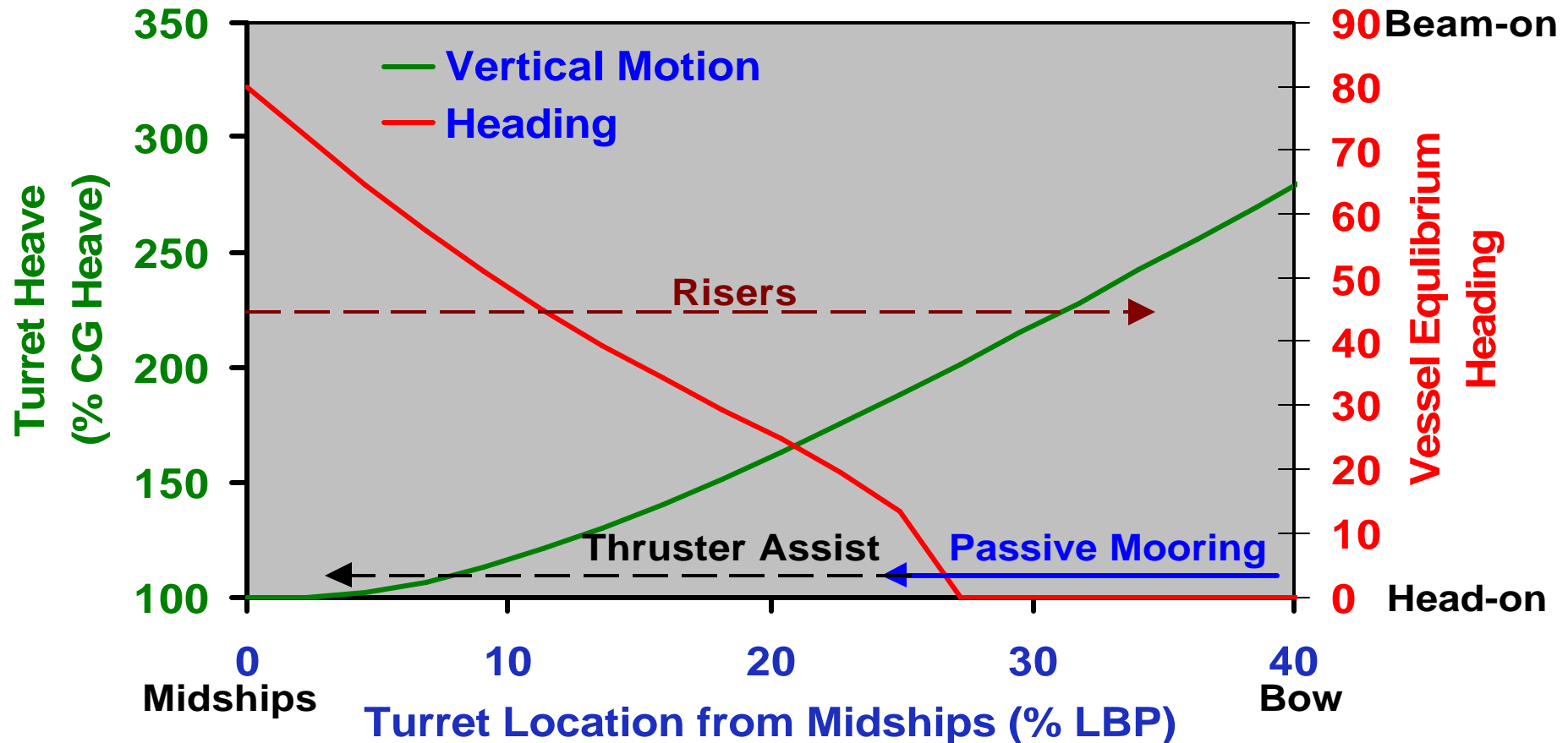
Anchor Leg Systems in Deep Water

- **Catenary mooring system (chain/wire/chain)**
 - Up to 1,500 meters
- **Inverse catenary mooring system (with buoys)**
 - Up to 3,000 meters
- **Taut-leg polyester mooring system**
 - 1,500 + meters
- **Anchors**
 - Driven piles
 - Suction embedded piles
 - Vertically loaded anchors

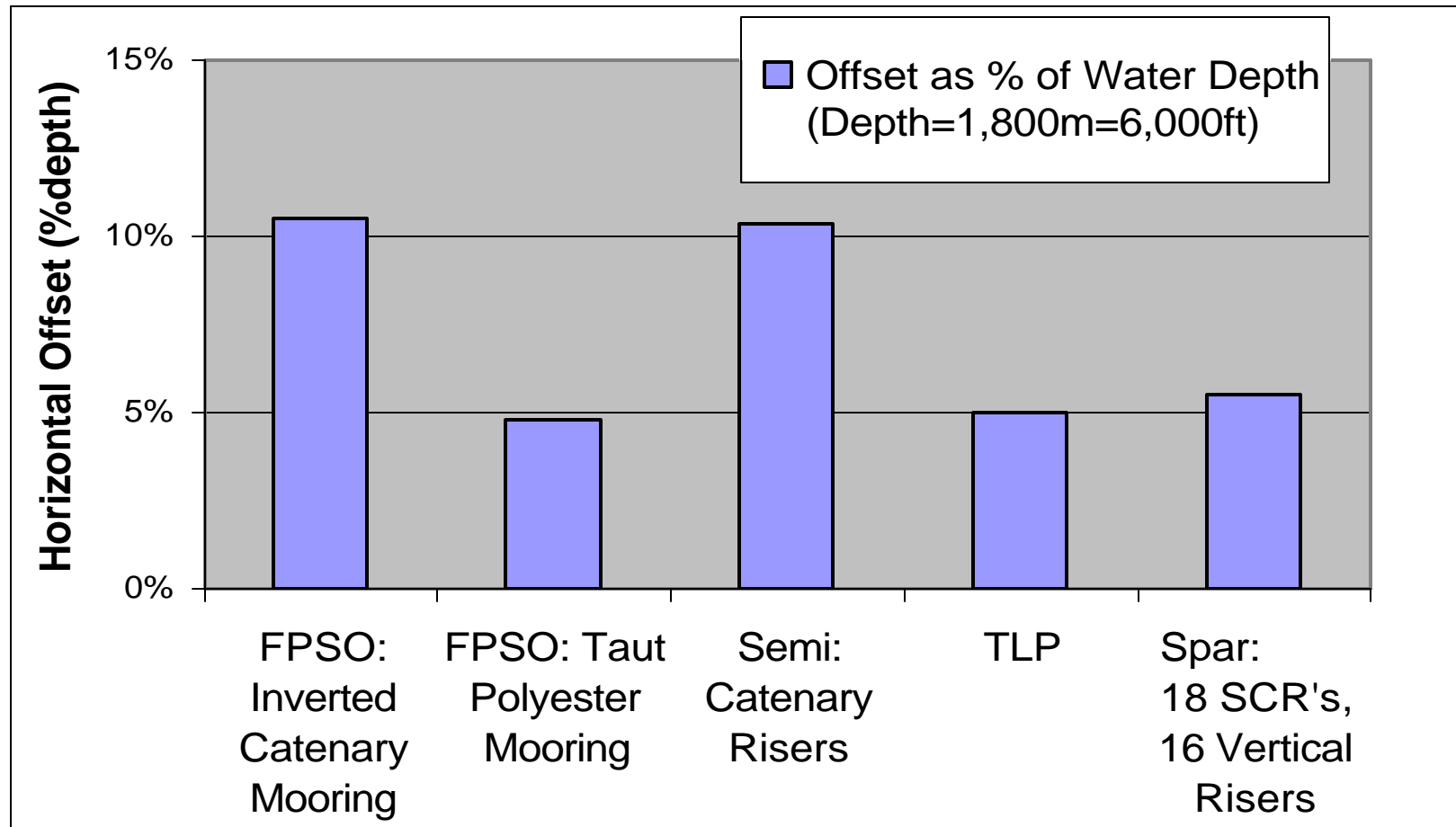
Response of a Turret-Moored FPSO in a Hurricane



Optimizing Turret Location

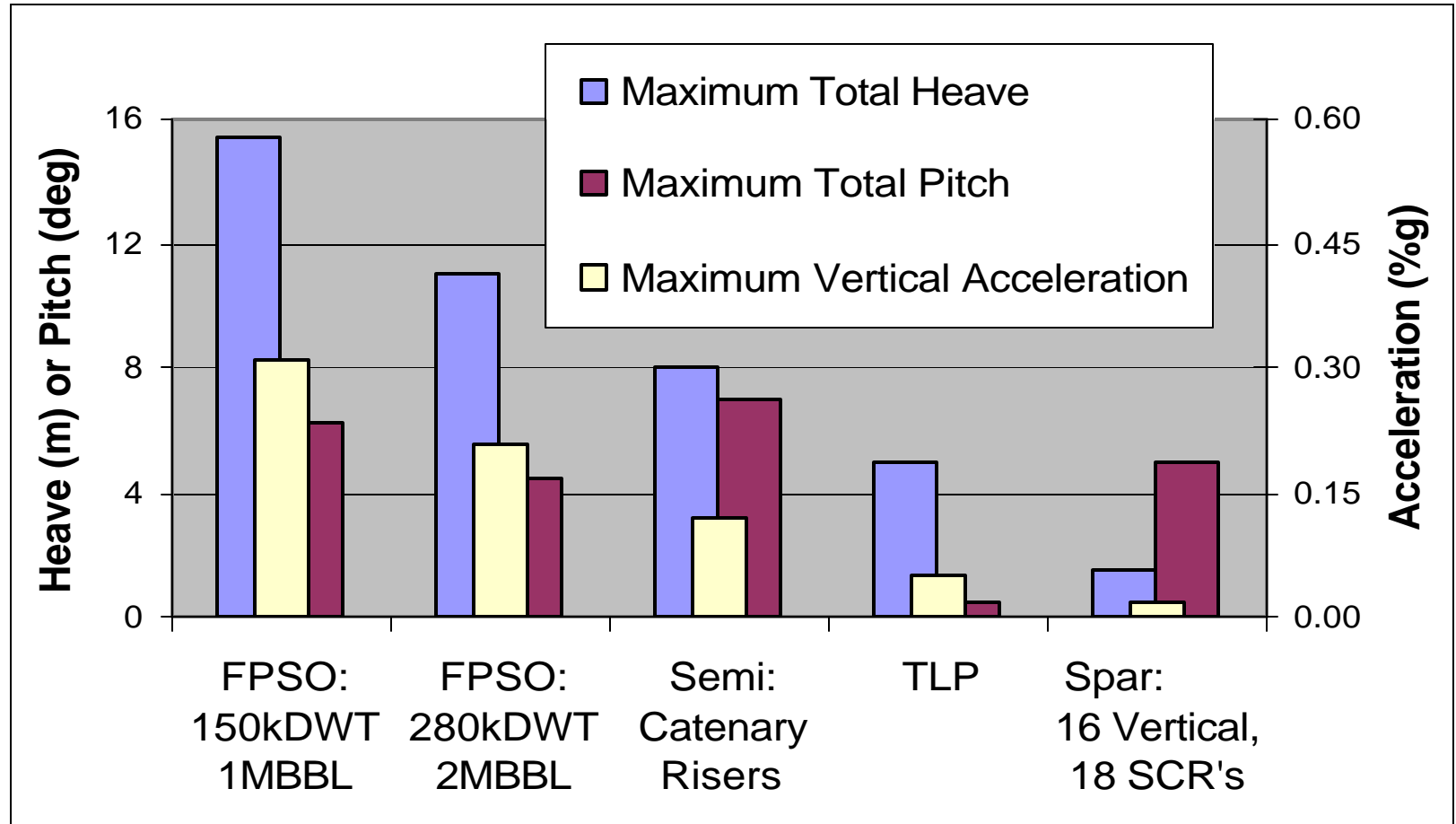


Maximum Total Horizontal Offset compared to other FPS



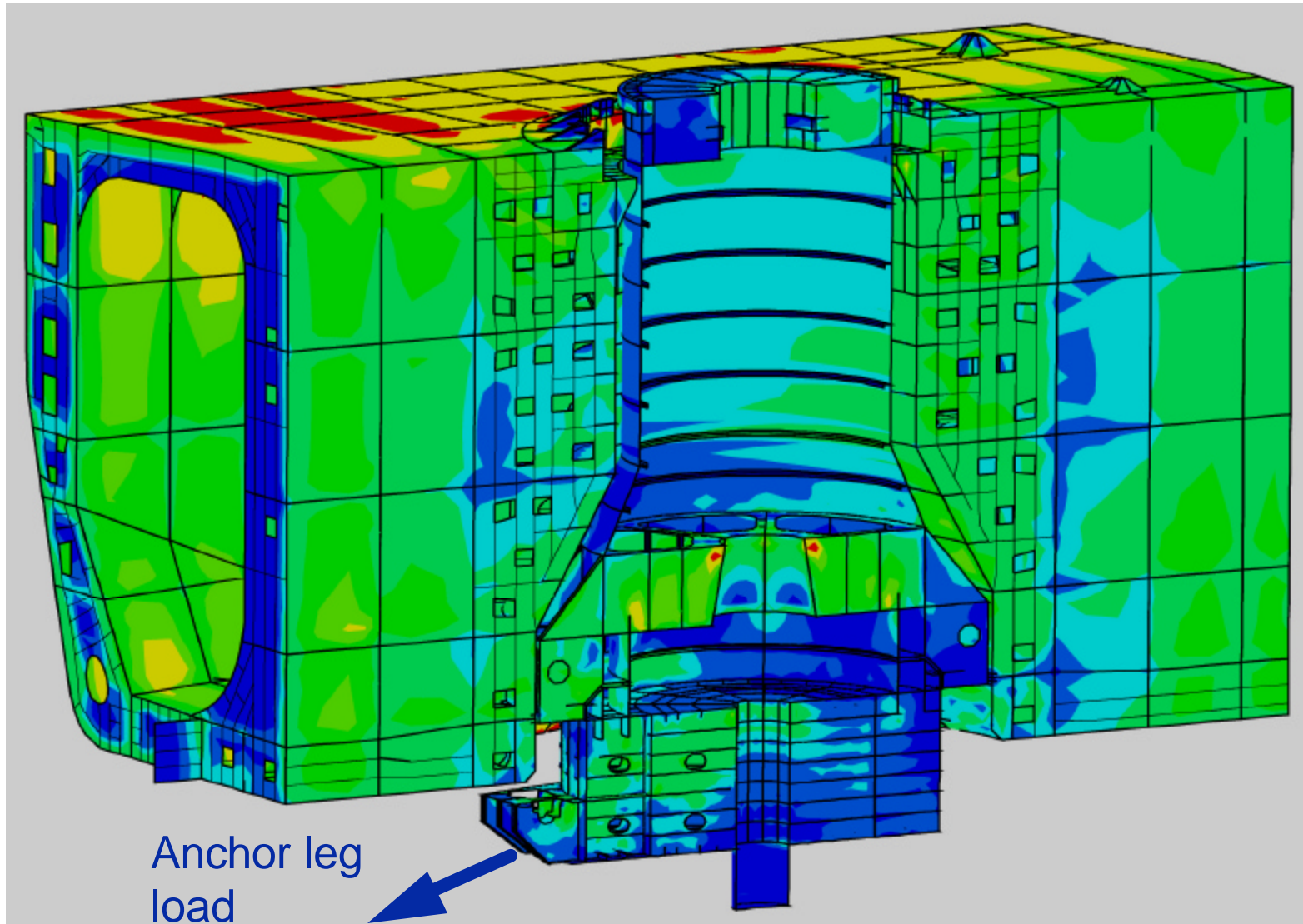
Non-FPSO Motions courtesy Shell and Deepstar

Wave-Frequency Motions compared to other FPS

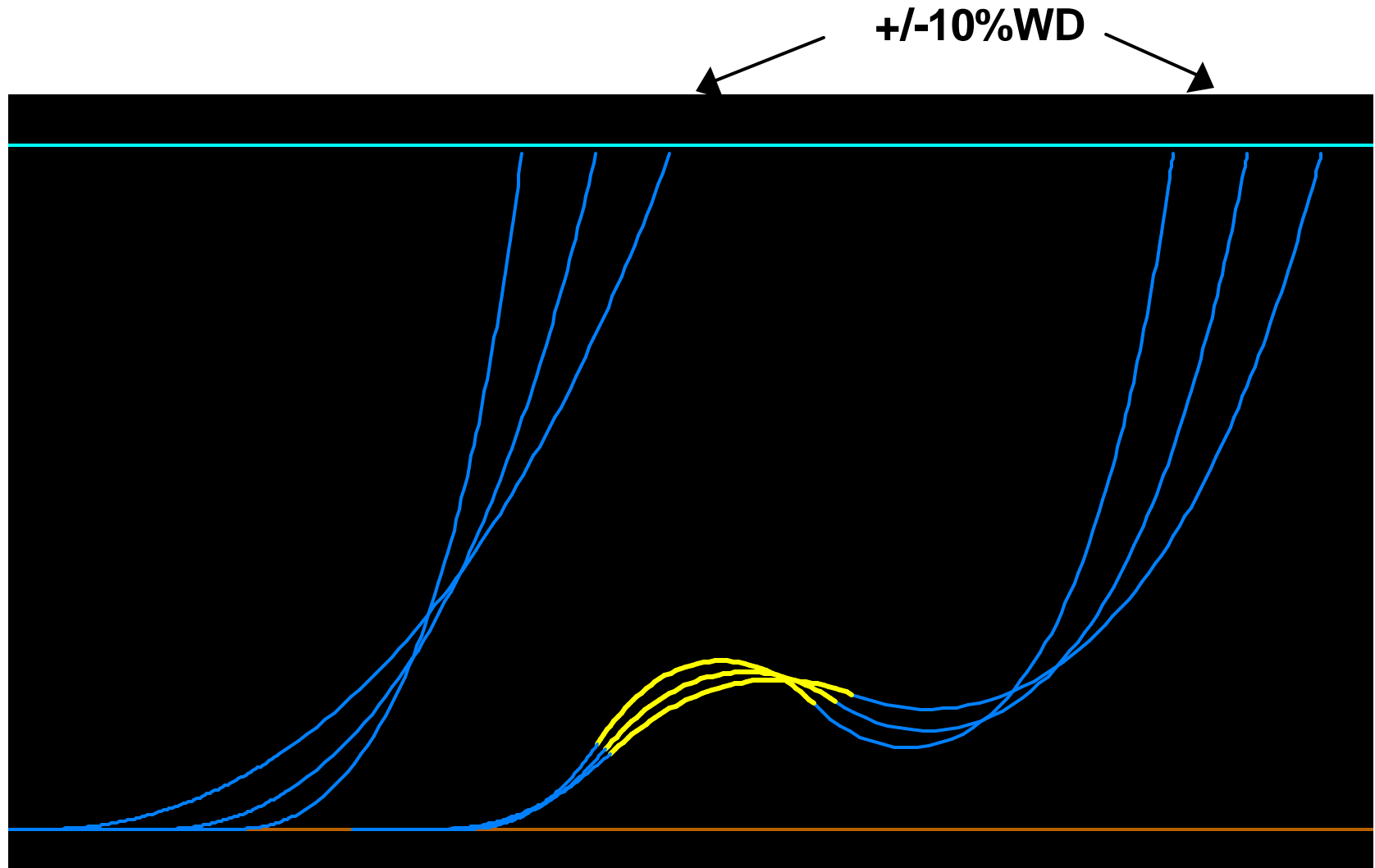


Non-FPSO Motions courtesy Shell and Deepstar

Turret-Vessel Interface Analysis



Steel Catenary Risers

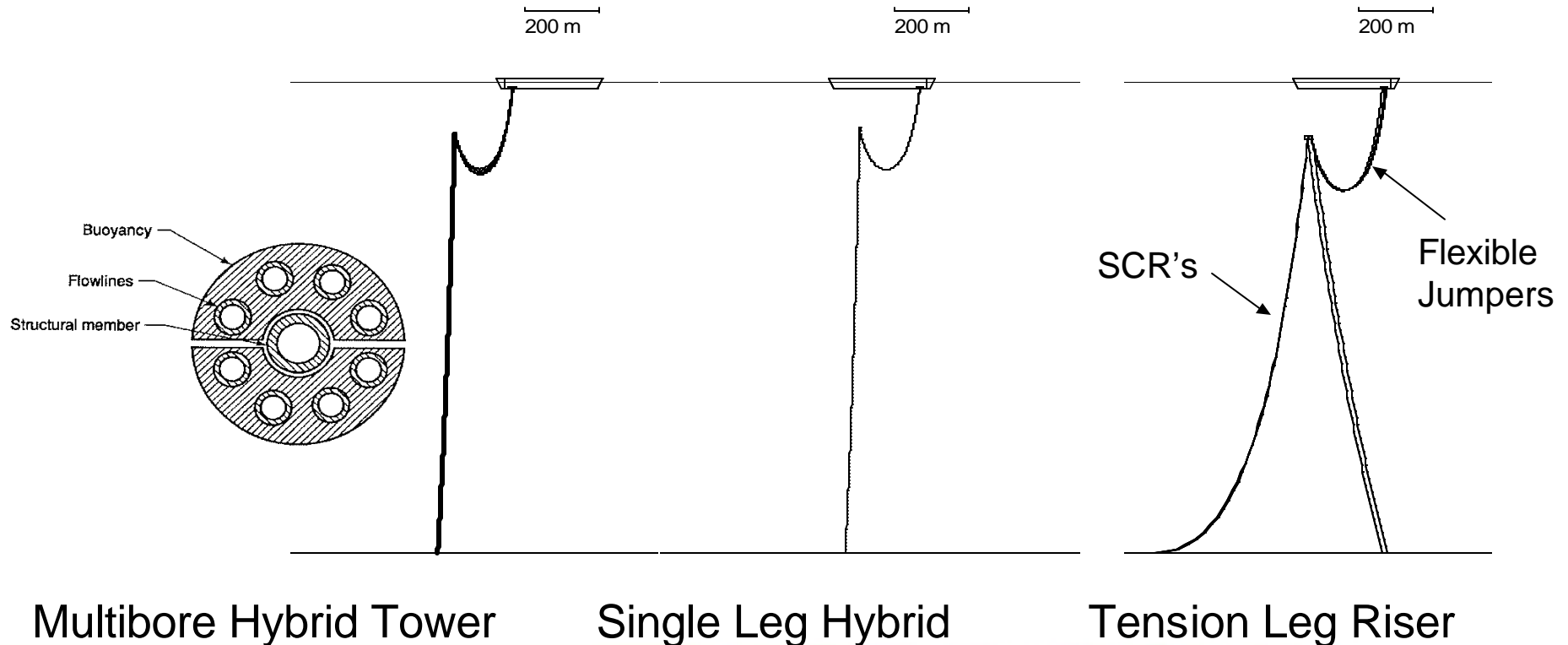


Catenary

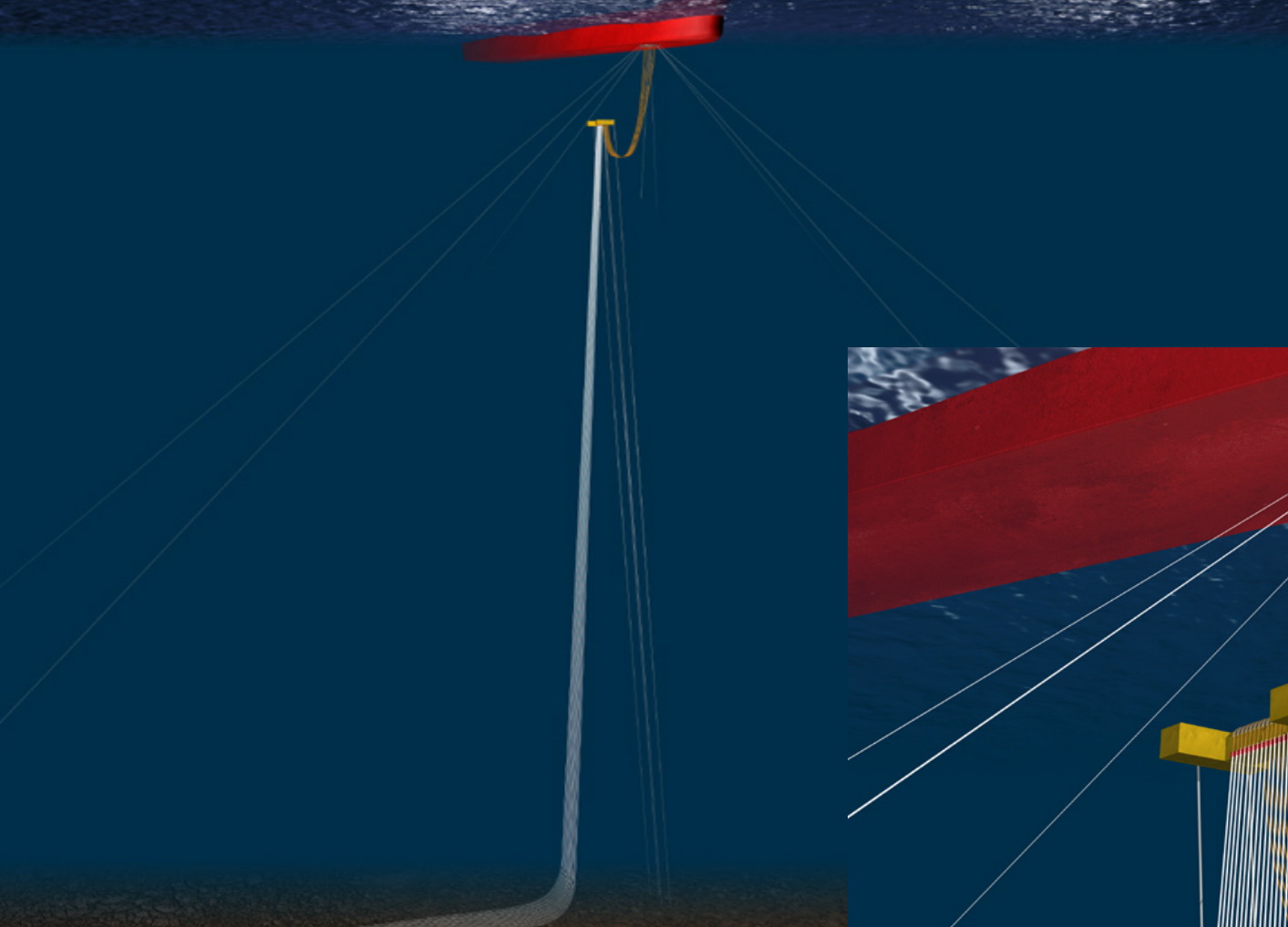
Lazy Wave

Hybrid Riser Systems

- Combination of steel and flexible pipe
- Decouple motions using self-standing risers or buoy
- Connection to the FPSO via flexibles



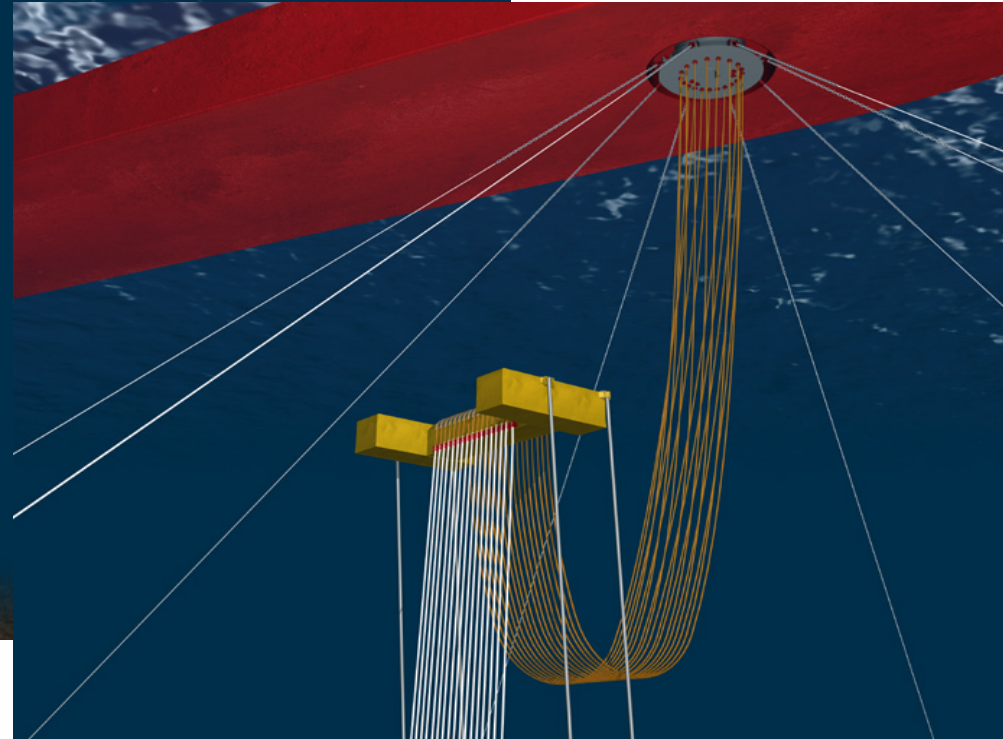
Tension Leg Hybrid System



SCRs decoupled from FPSO motions

Reduces riser load on turret

Allows for pre-installation of riser system



Long-Term Response Analysis of FPSOs

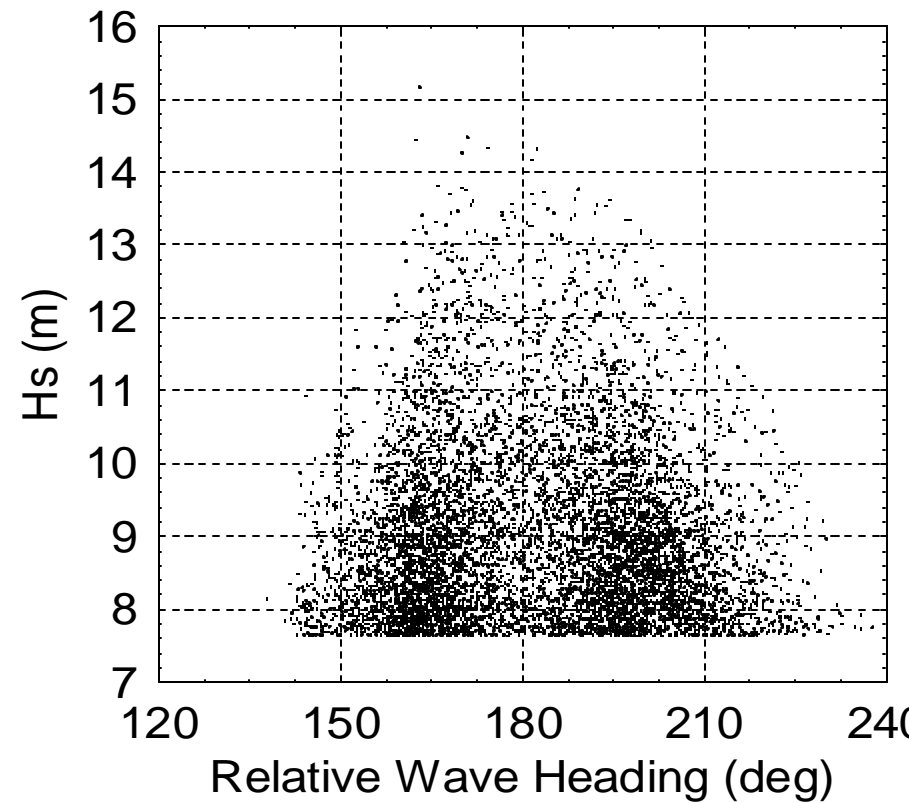
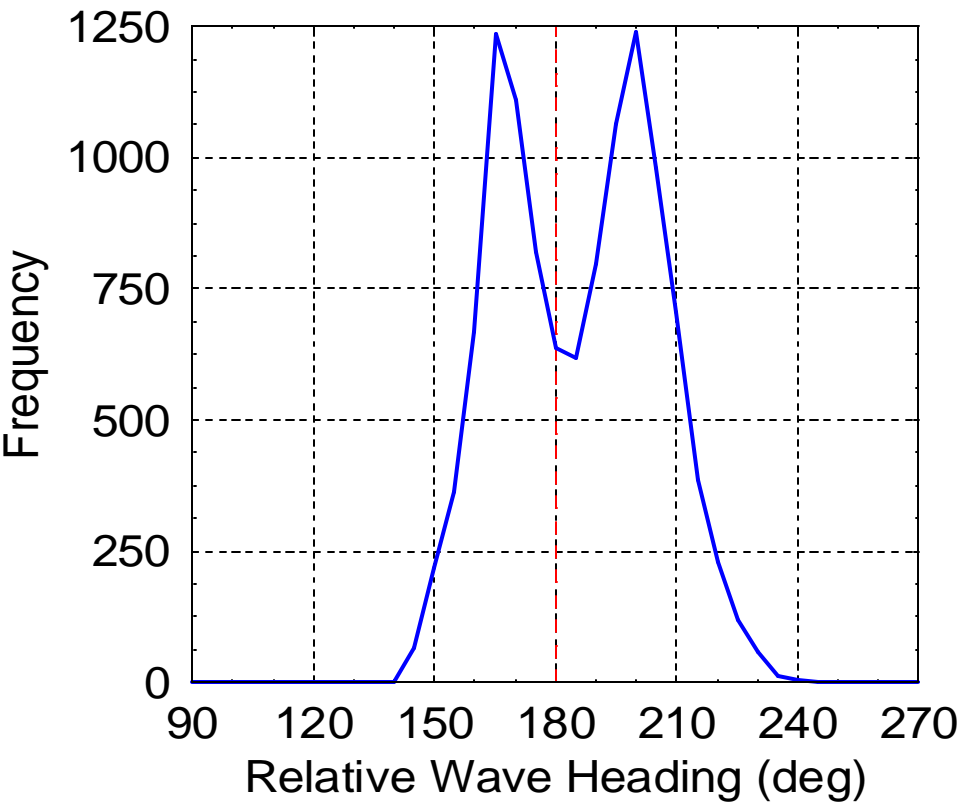
- **Goals**

- Accurate prediction of long-term response levels
- Identify responses that are sensitive to changes in environmental parameters
- Develop design seastates to estimate 100-year responses

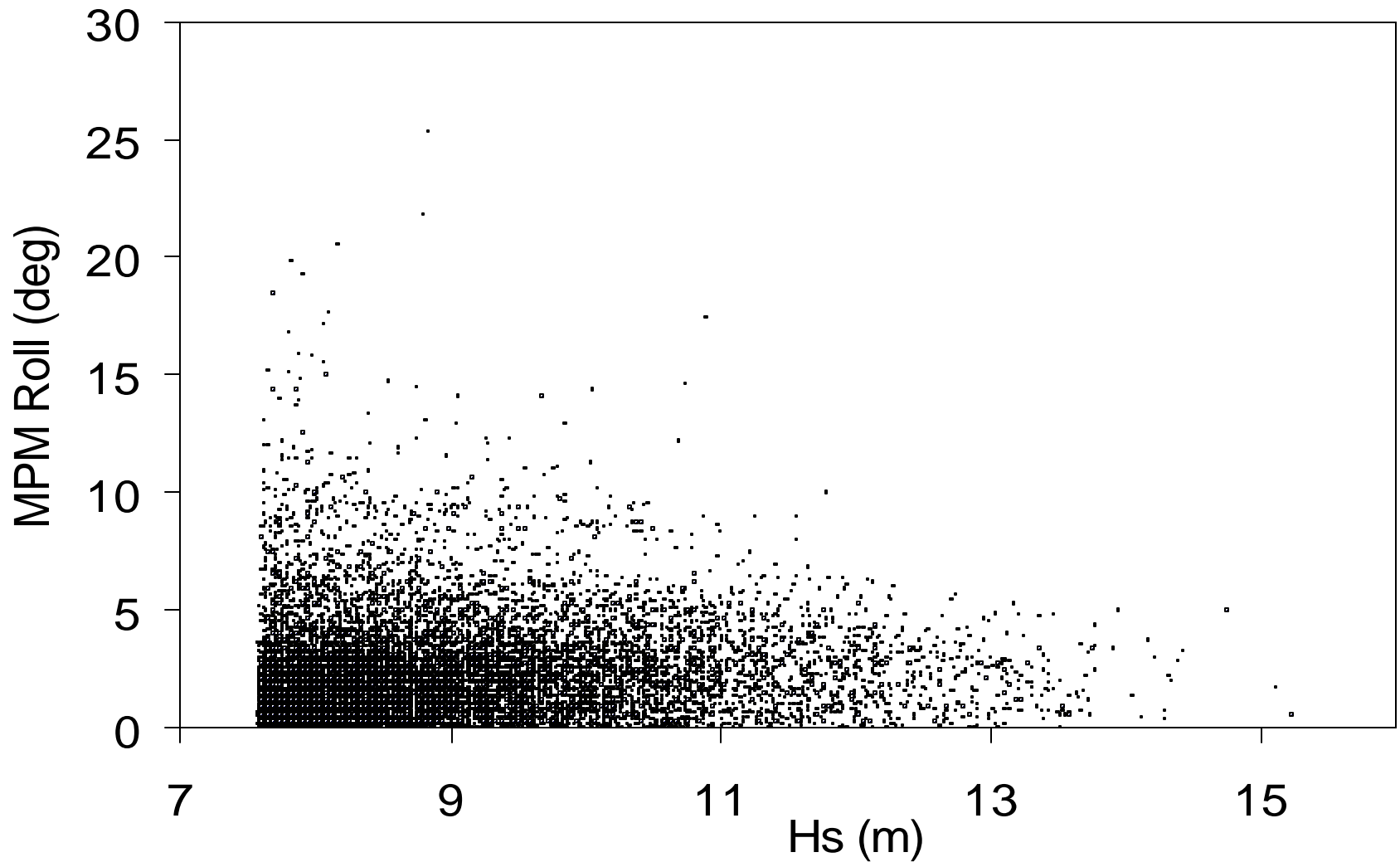
- **Requirements:**

- Joint probability of environmental parameters
- Hindcast database (GUMSHOE, SEAMOS, etc)
- Response model

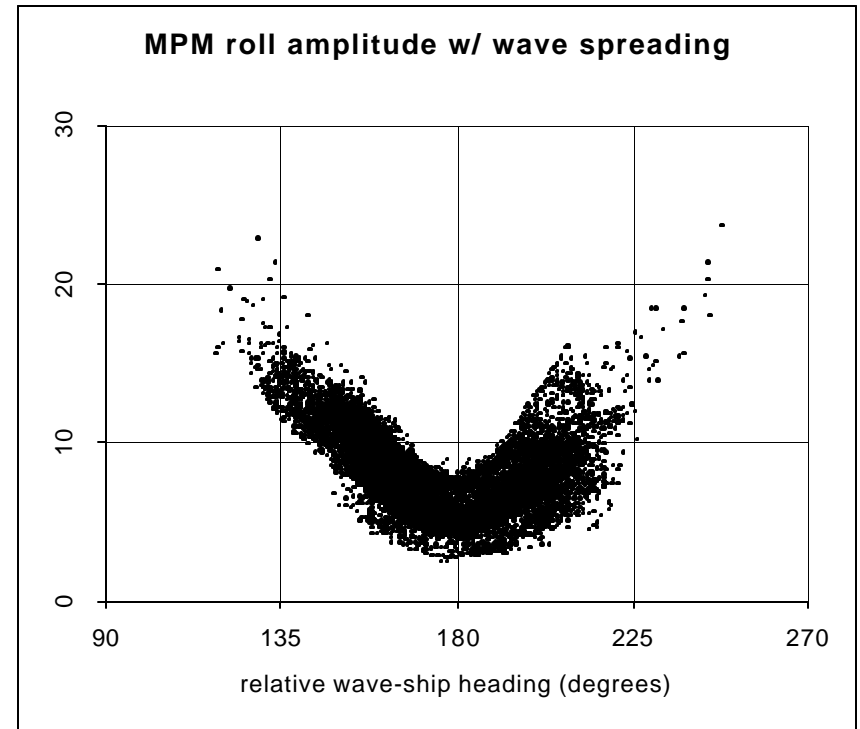
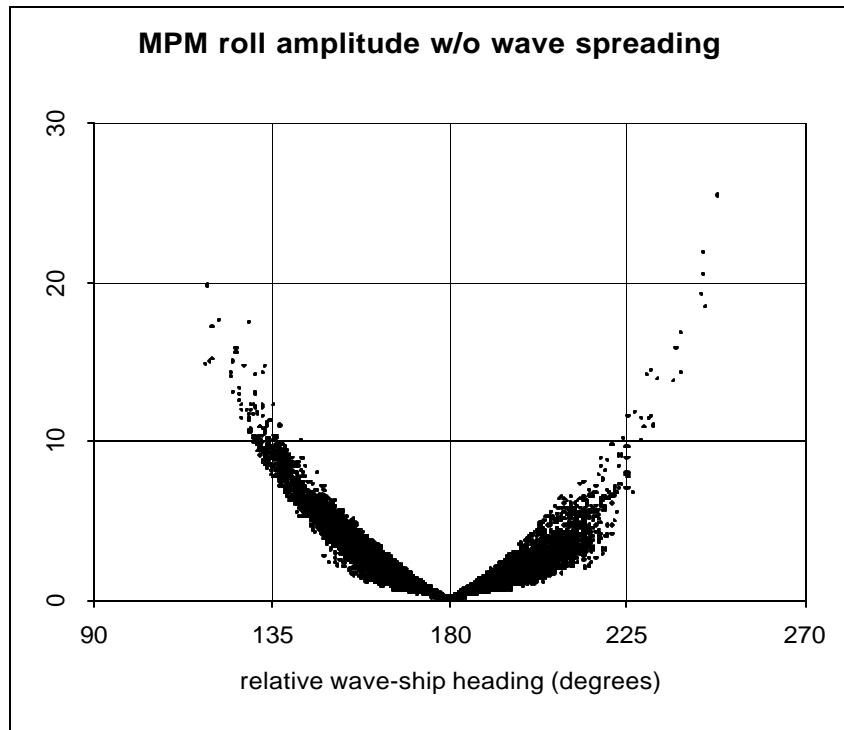
FPSO Relative Wave Heading



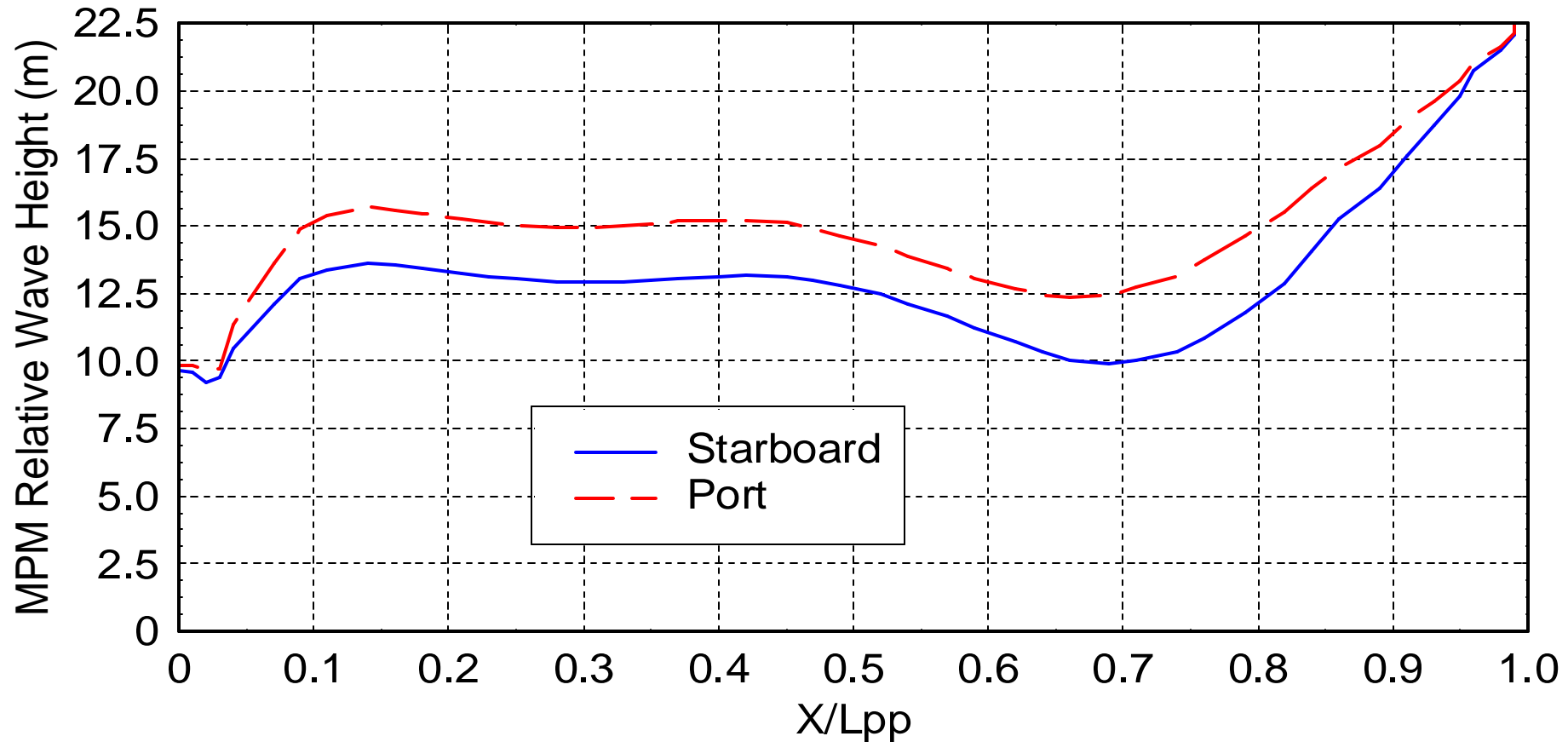
Roll versus Wave Height



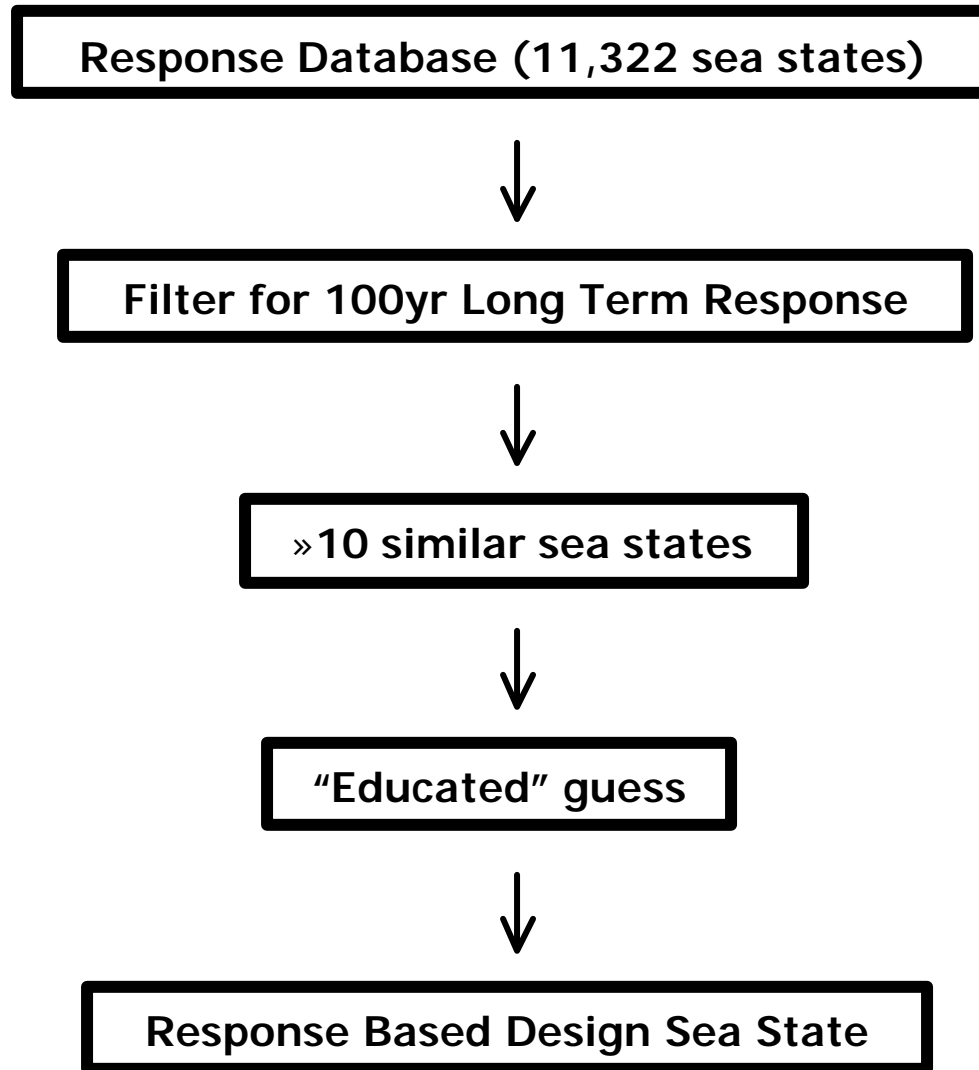
Effect of Wave Spreading



100-year Relative Wave Height (Greenwater)



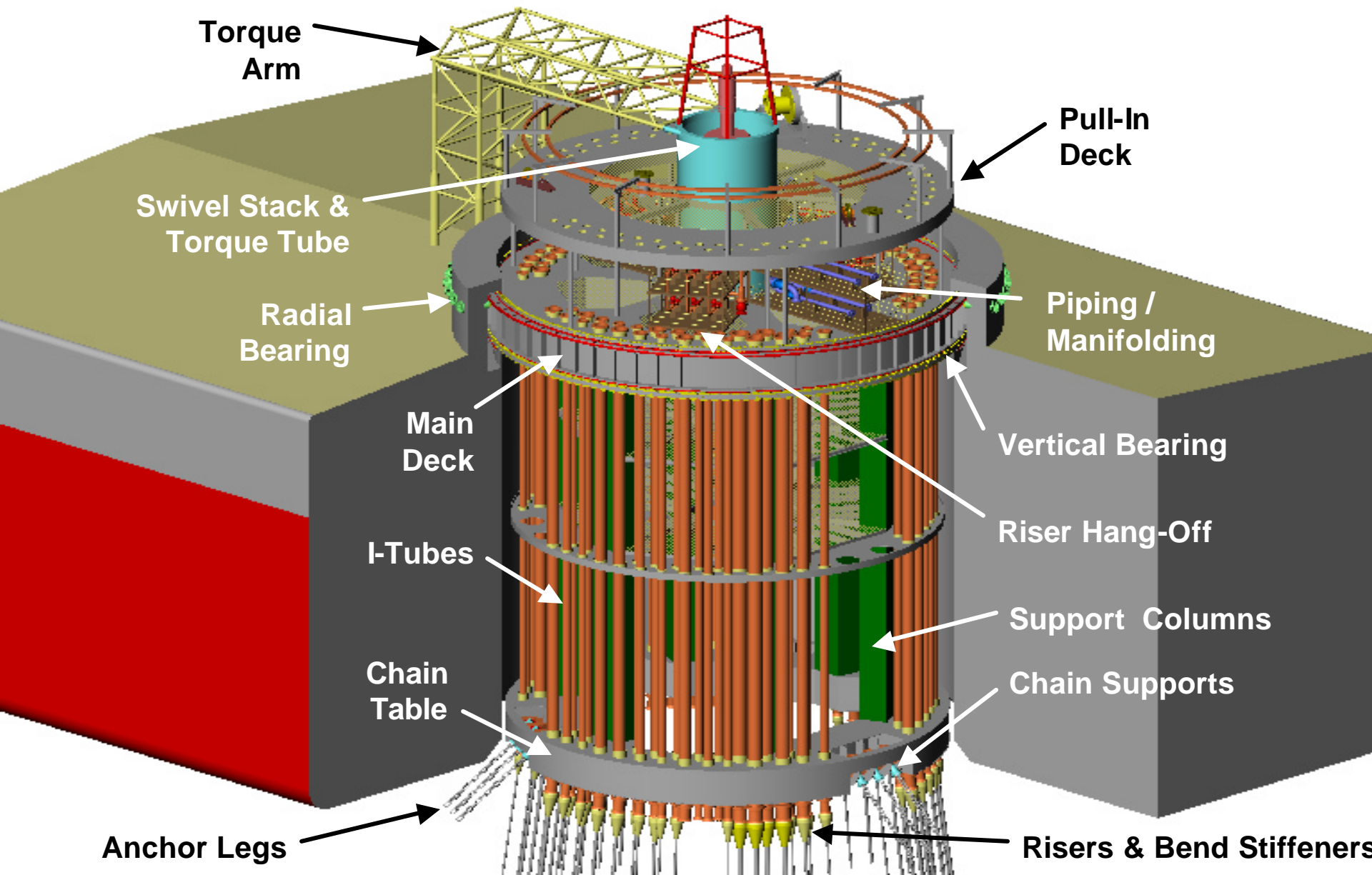
Design Criteria - Methodology



Response-Based Design Sea State

Parameter	Units	Offset	Tension	Heave	Roll	Pitch	Relative Wave		Design
							Bow	Side	
Hs	m	10.4	13.0	12.9	8.9	13.2	14.6	10.0	12.2
Tp	s	12.3	15.3	14.9	14.5	14.5	15.0	11.9	14.2
g		2.7	2.0	2.7	1.4	2.8	2.0	2.9	2.4
Heading	deg	45.0	130.0	162.0	134.0	165.0	175.0	220.0	?
Wind	m/s	30.9	38.1		27.5				36.5
Heading	deg	45.0	160.0		215.0				?
Current	m/s	2.2	1.8		0.8				1.8
Heading	deg	-25.0	140.0		147.0				?

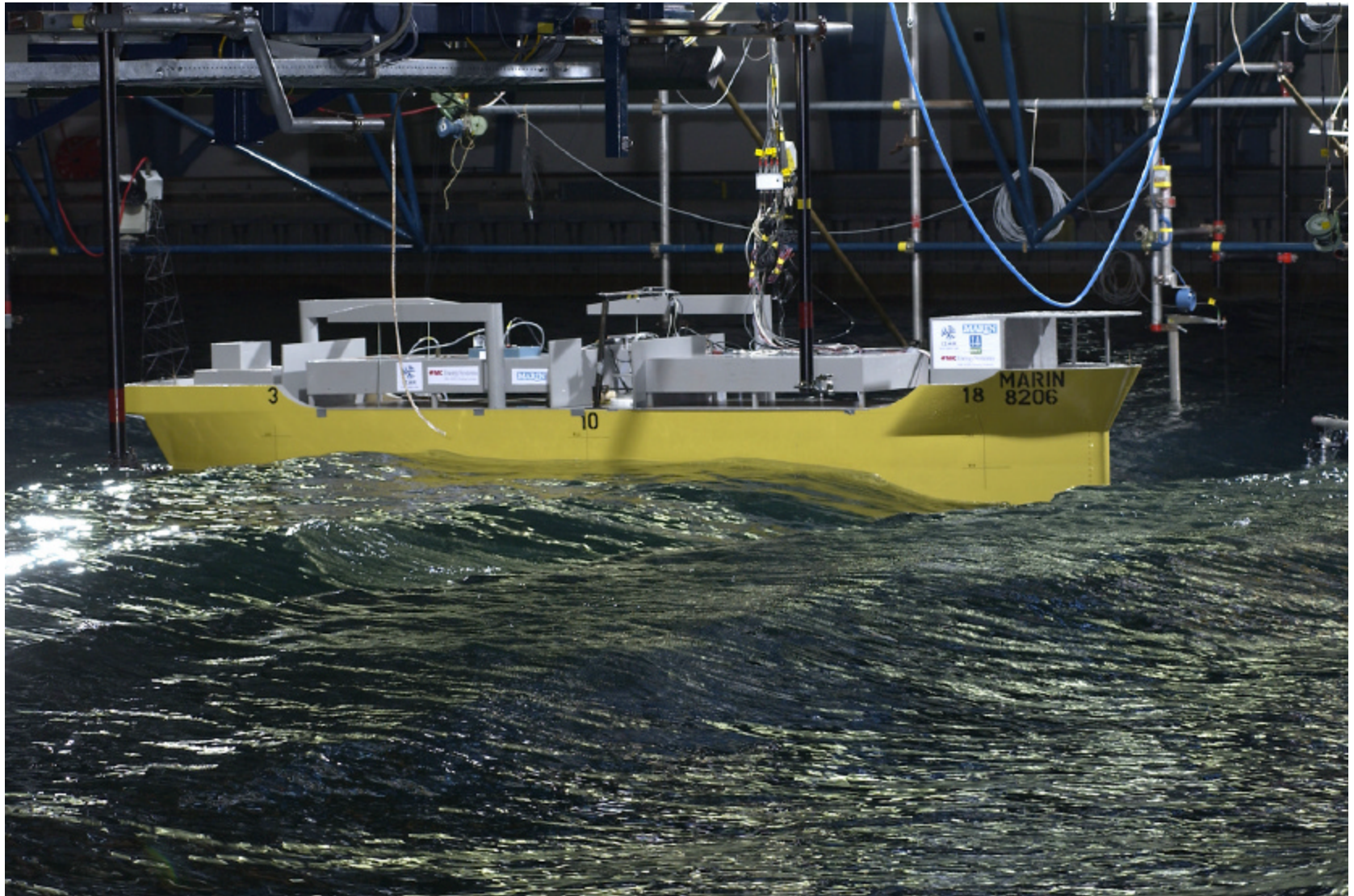
VLT: Deep Water, Large Capacity Internal Turret



DP FPSOs for the GoM

- **Joint Engineering Study**
 - IZAR, Spain (Vessel, DP-Thruster Systems, etc.)
 - FMC SOFEC (Turret & Riser System)
 - MARIN (Analysis & Model Testing)
 - DNV (Risk Assessment, Regulatory Requirements, Code Compliance)
- **GoM FPSO**
 - 2,500 meter water depth
 - 200,000 ton displacement FPSO, 6x5 MW thrusters
 - 16 risers
 - 125,000 bbl/day
 - Designed to stay on station for 10-year hurricane

DP FPSO (10-year Hurricane)



Summary & Conclusions

- **Turret-Moored FPSOs are an effective option for ultra-deep waters in the GoM**
 - **Uses existing technologies with demonstrated performance in several locations worldwide**
 - **Efficient station-keeping system**
 - **Compatibility with several deepwater riser systems**
 - **Competes with other FPS with subsea wellheads w/o storage requirement**
 - **Cost-effective and reliable FPS system**