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Stationkeeping Technology for Frontier Deepwater Floating Systems

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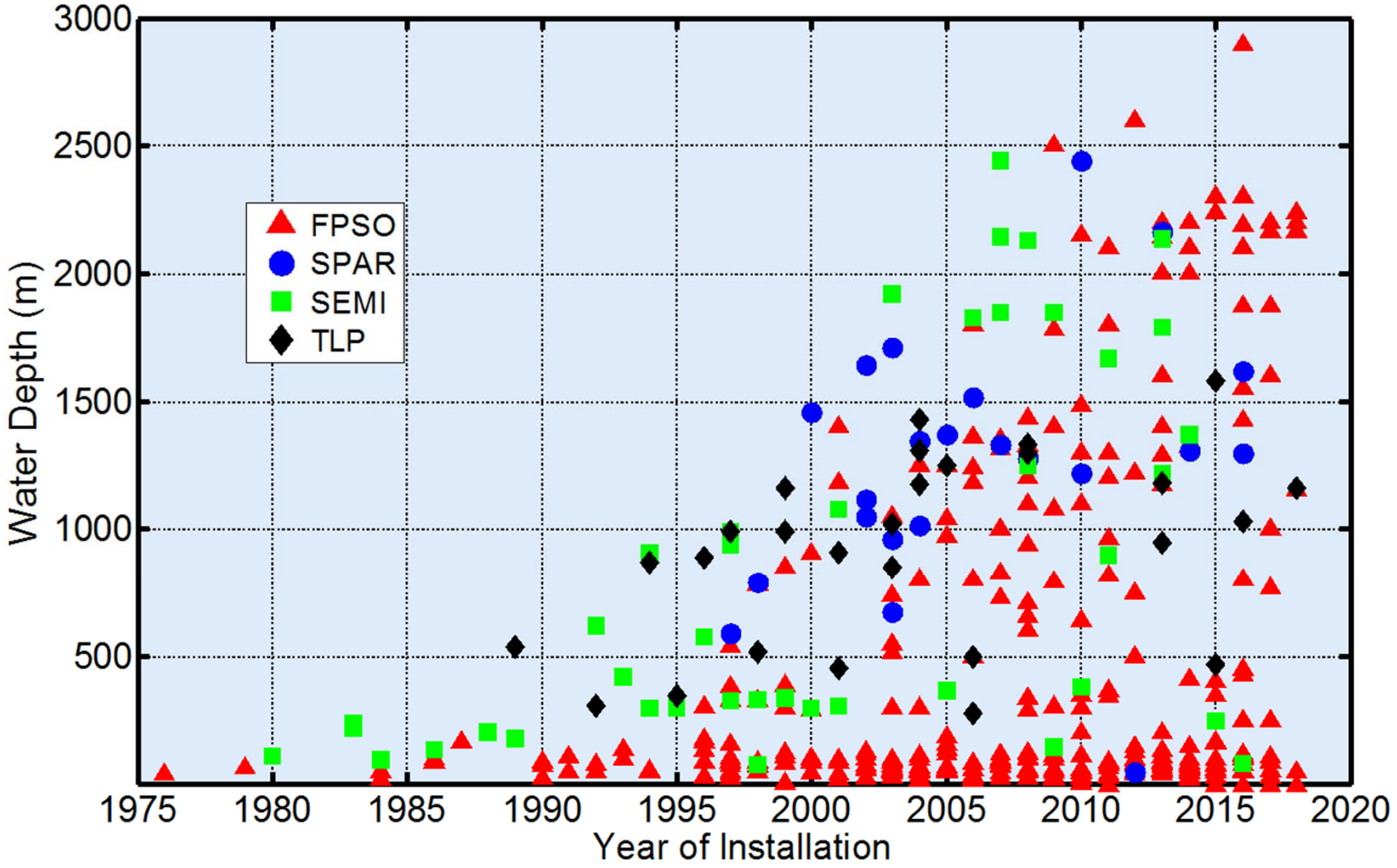
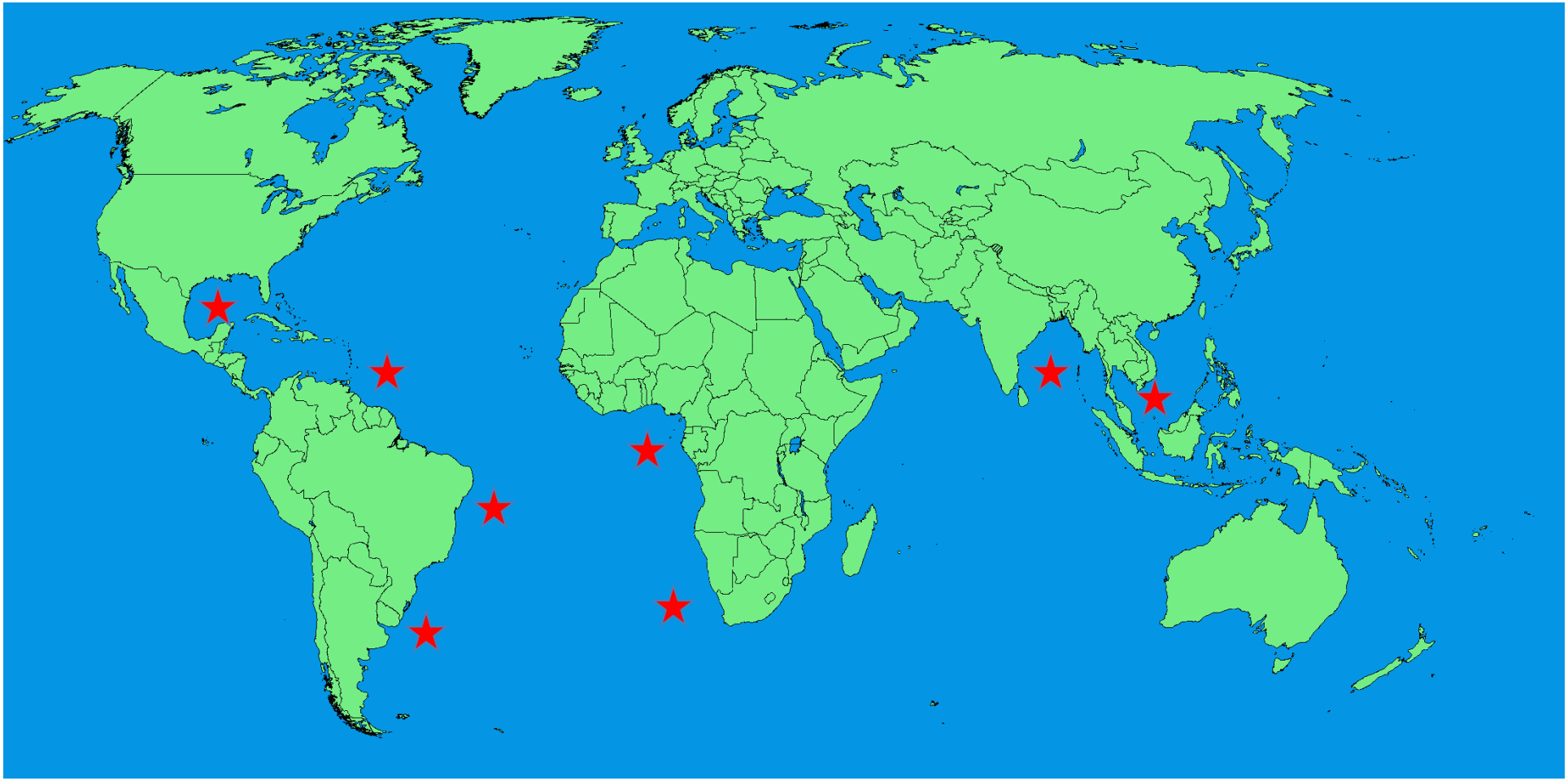
SOFEC

Overview

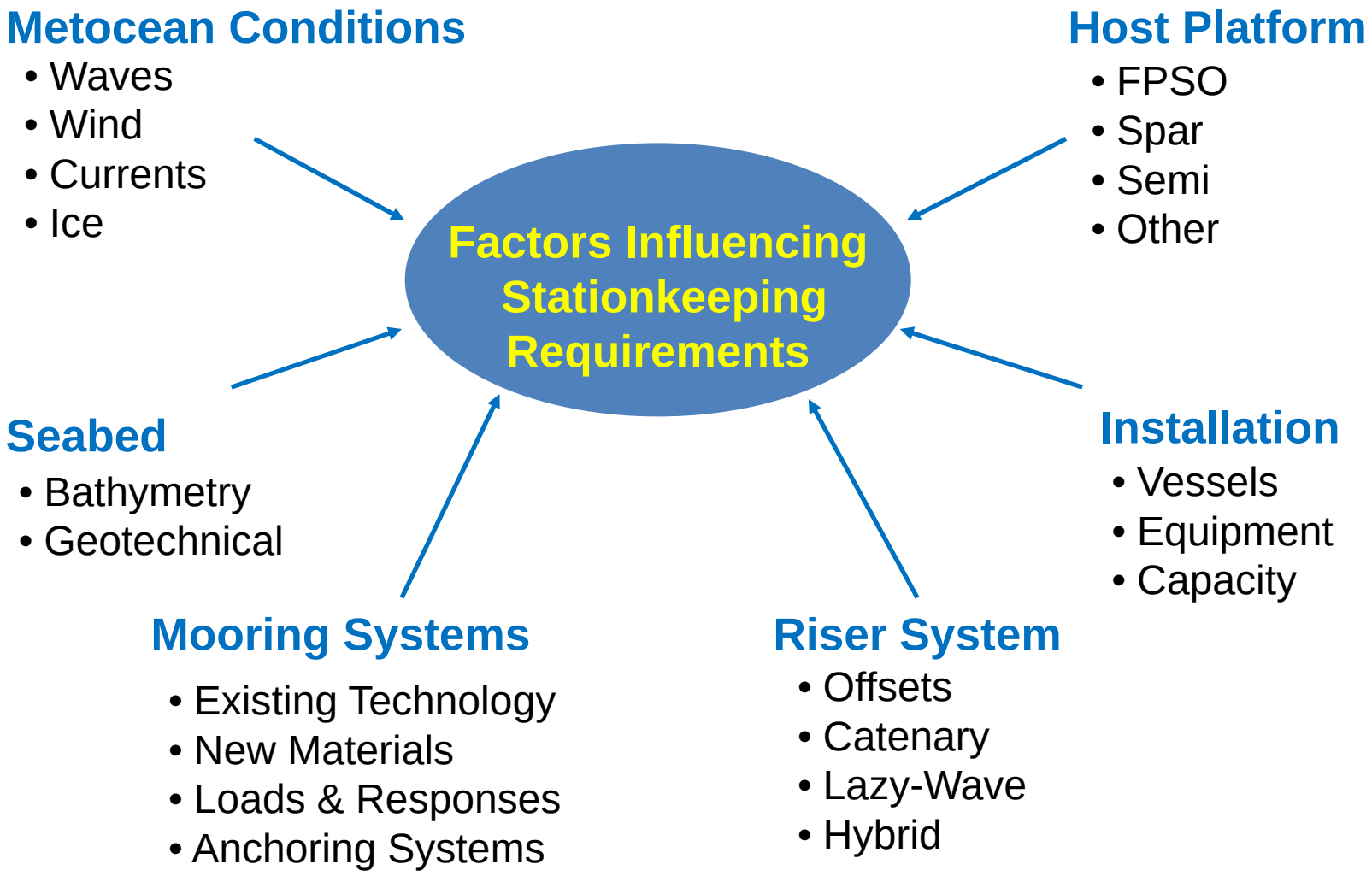
- Floating Systems Production Systems Water Depths from 20m to 3,000m
  - Various host production platforms
  - Various riser & mooring systems
- New Frontier for Deepwater:
  - 3,000 to 4,500 meters
- Key Drivers for Stationkeeping Technology Selection
- Focus on Mooring Technology Required
- Case Study:
  - FPSO in varying water depths
  - Focus on mooring response as a function of mooring line stiffness
- Summary


3000
2500
2000
1500
1000
500
Water Depth (m)
FPSO
SPAR
SEMI
TLP
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year of Installation

Frontier Deepwater Regions of the World

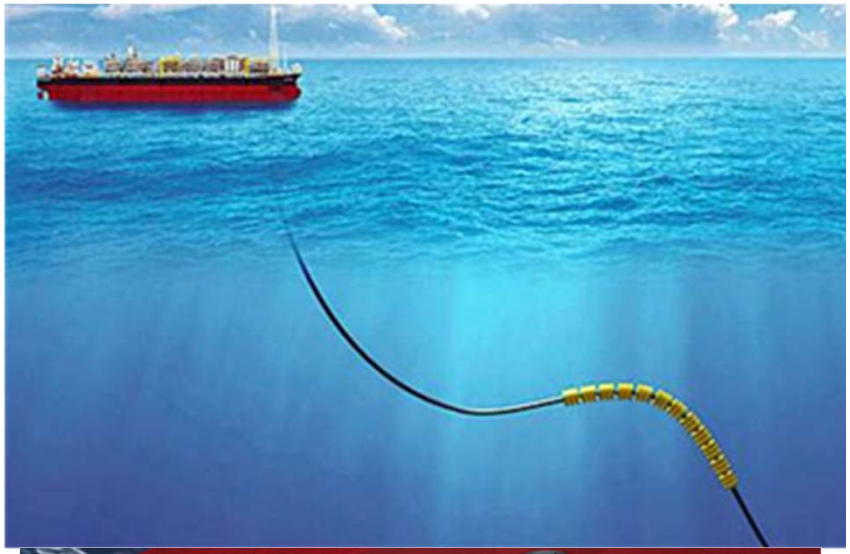


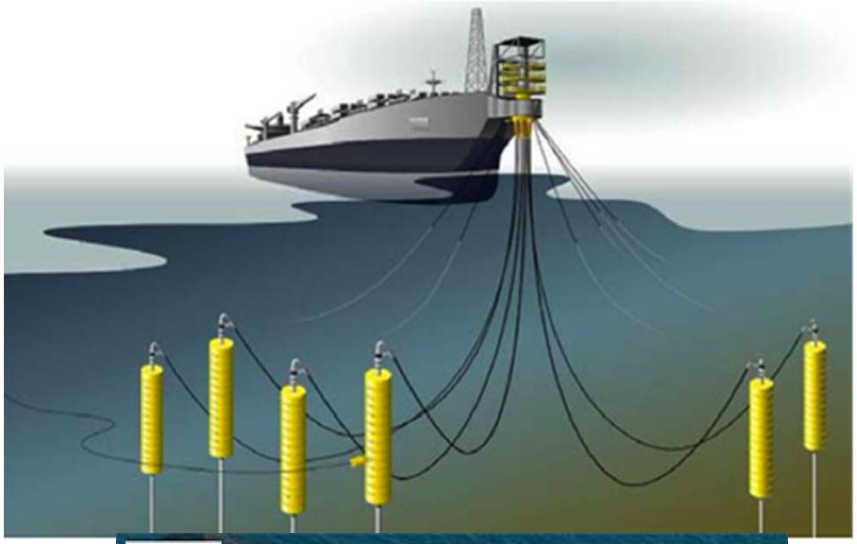
Key Drivers for Stationkeeping Design

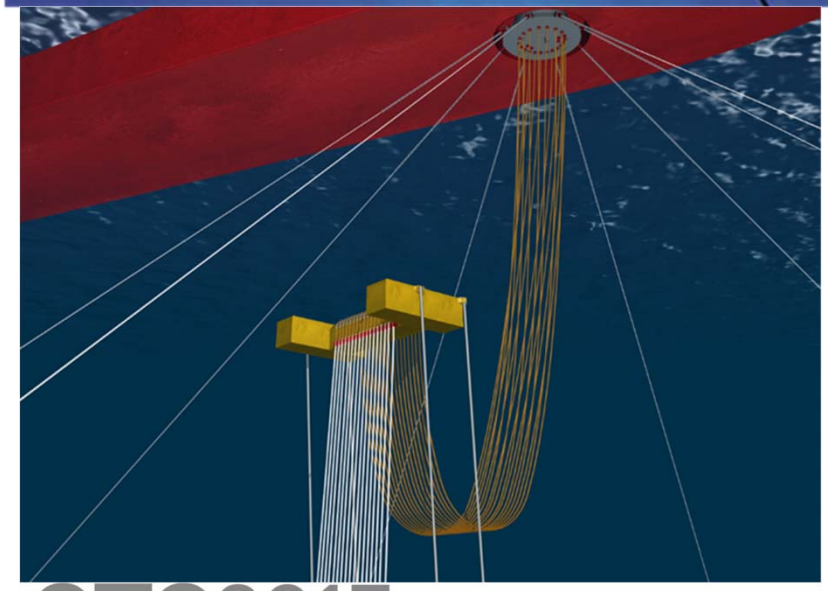


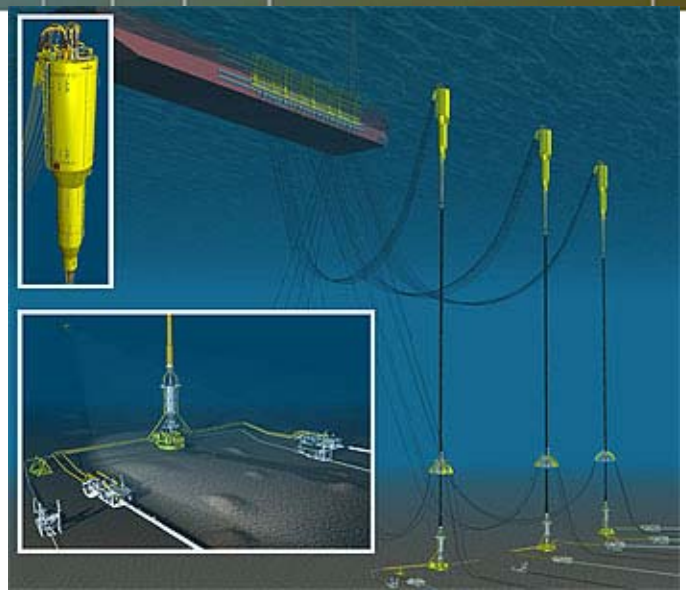
Floating Production Platforms

Riser Systems









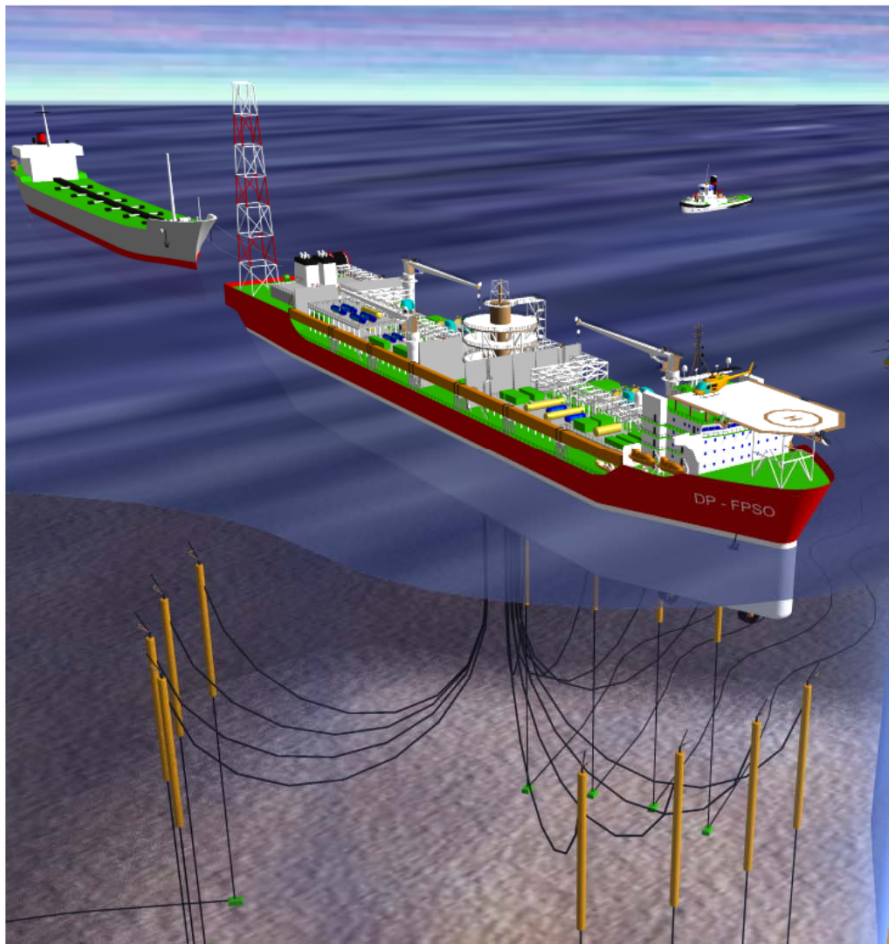
Stationkeeping Technology

- Host Floating Production System Dependent
  - Motion characteristics
  - Degree of coupling between floater, mooring and risers
- Riser System Requirements
  - Offsets and motions (Floater dependent)
- Spread Moored Systems
  - All floater types including FPSOs
- Turret Moored (FPSOs) Systems
  - Internal; External; Disconnectable
  - Thruster-Assisted or DP

DP or Thruster Assisted FPSOs

- Several Deepwater Drillships in Operation for over 10 years
  - Long track record of performance
  - Designed for maintain station up to 10-year hurricane conditions
- Several Early Production / Well Test DP Vessels
  - MV Seillean
  - Pipa II
- DP FPSOs
  - Munin
  - Helix Producer 1
- Thruster-Assisted FPSOs
  - Several in the North Sea

DP FPSOs



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Deepwater Mooring Design (2,000 to 3,000 meters)

- Riser Offset Requirements
  - Typically range from 5 to 10% of water depth
  - Depends on environmental conditions, riser type, etc.

- Mooring Components
  - Chain: Grades up to R5
  - Polyester rope
  - Suction piles, torpedo piles or plate anchors

Frontier Deepwater Design (3,000 to 4,500 meters)

- Offsets tend to be smaller (mooring system is typically more efficient)

- Offsets very dependent on Riser Type
  - Conventional coupled risers (Lazy-wave): ~ 5 to 10%
  - Decoupled risers (Hybrid): ~5% or less

- Offset Control
  - Larger number of anchor legs (also controls anchor loads)
  - Higher pretension
  - Introduce stiffer mooring components, e.g. high modulus fiber ropes

- Installation Equipment
  - Mooring design should consider installation requirements
  - Could limit maximum component sizes and lengths
  - Should also allow for easy maintenance / replacement in the future

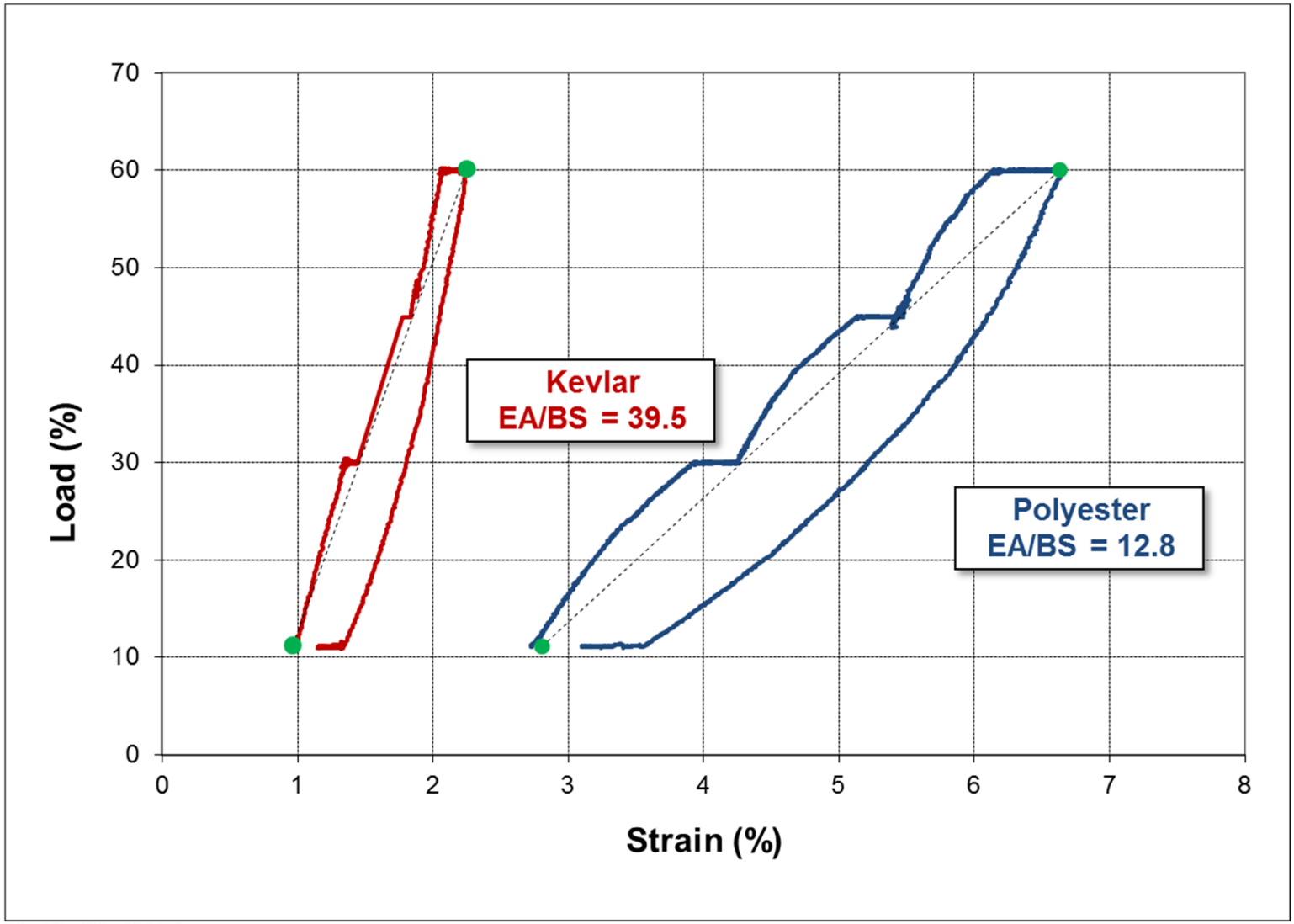
High Modulus Synthetic Mooring Rope

- Most Ultra-Deepwater Mooring Systems use Polyester Rope
  - High strength to weight ratio
  - High reliability / very good long-term performance
  - Relatively low cost

- High Modulus Fiber Ropes:
  - Effective axial stiffness 3 to 4 times that of polyester
  - Higher strength to weight ratio
  - Higher cost (2 to 4 times that of polyester rope)

- High Modulus Fiber Ropes being considered:
  - HMPE (DM20)
  - LCP (Vectran)
  - Aramid (Kevlar)

Static Modulus: Polyester Rope and Kevlar

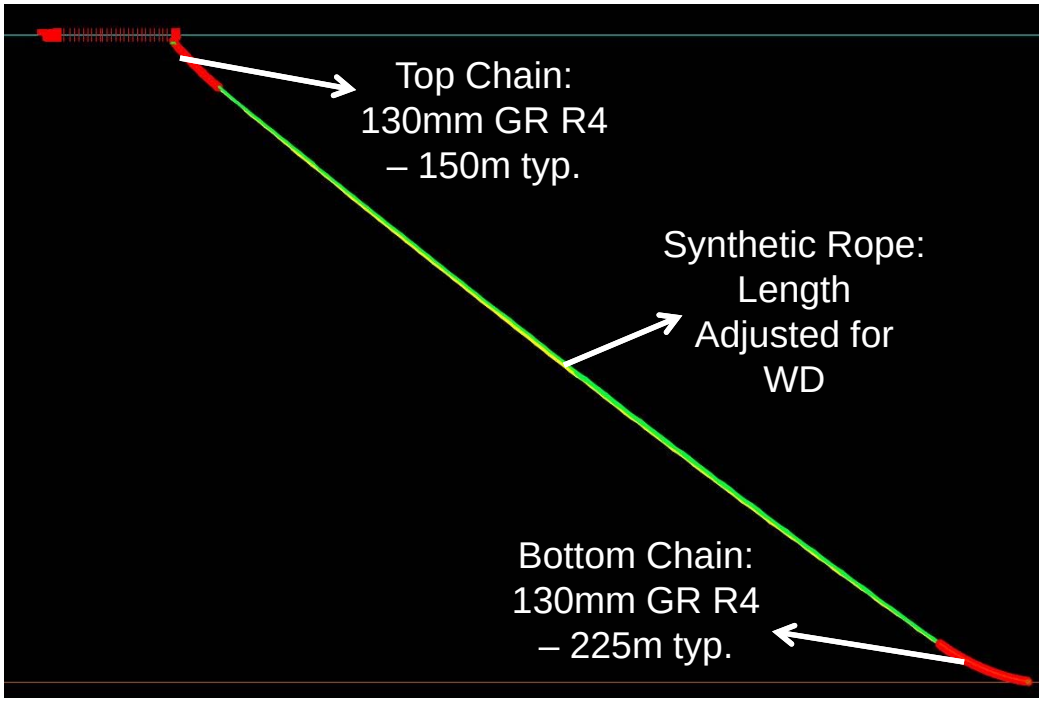


Courtesy of Whitehill Manufacturing

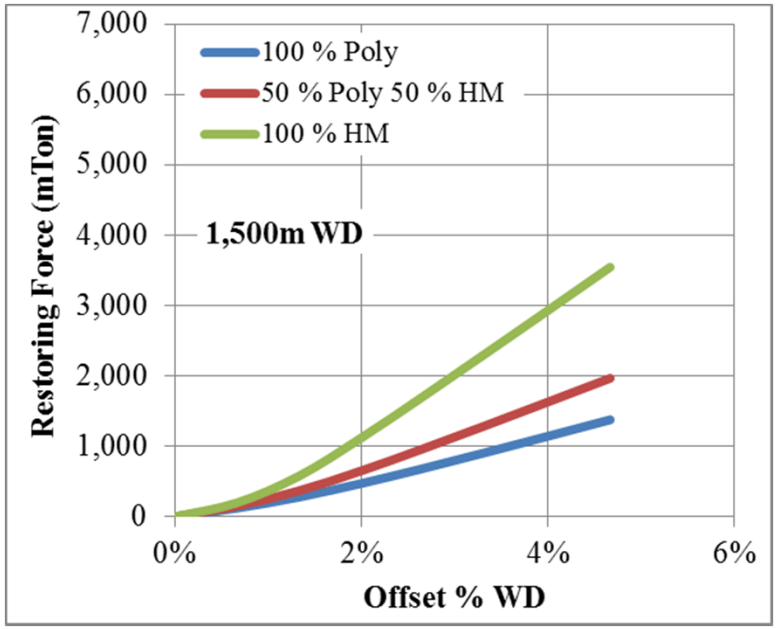
Case Study: FPSO with Internal Turret Mooring System

- **Stationkeeping System:** Internal Turret
- **Anchor leg system:** 9 taut legs (3 groups of 3 legs)
- **Anchor leg components:**
  - Top chain
  - Synthetic Rope
    - 100% Poly
    - 50% Poly + 50% HM
    - 100% HM
  - Bottom chain
- **Vessel:** Typical VLCC vessel
- **Water Depth:**
  - WD = 1,500m, Anchor Leg R = 1,982m, Top T = 175MT
  - WD = 3,000m, Anchor Leg R = 3,215m, Top T = 200MT
  - WD = 4,500m, Anchor Leg R = 5,005m, Top T = 225MT

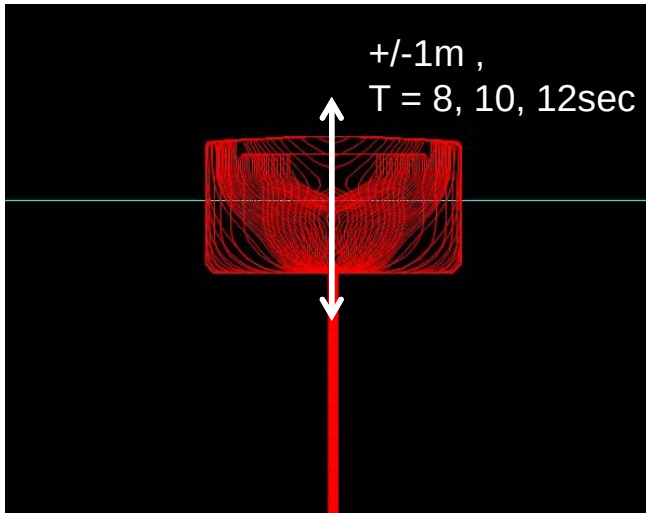
Case Study: Mooring System Details



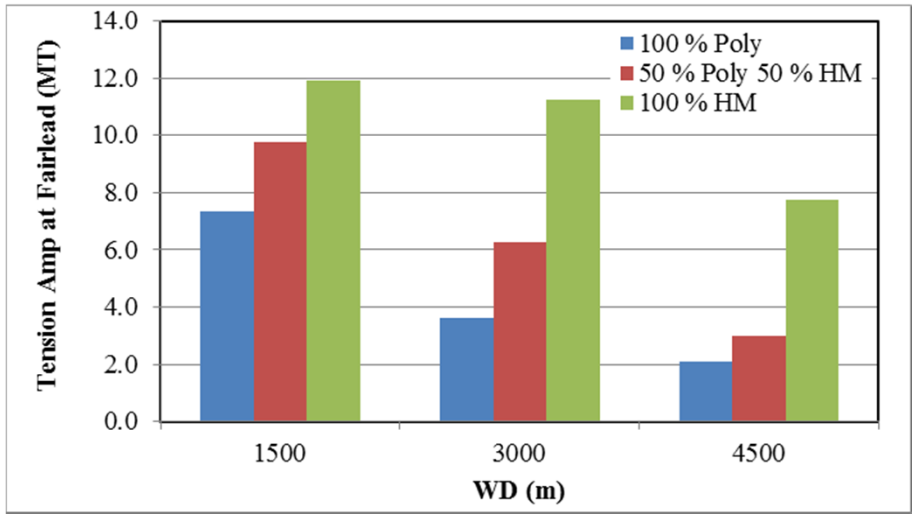
Restoring Force vs. Normalized offset
– almost the same for all WDs

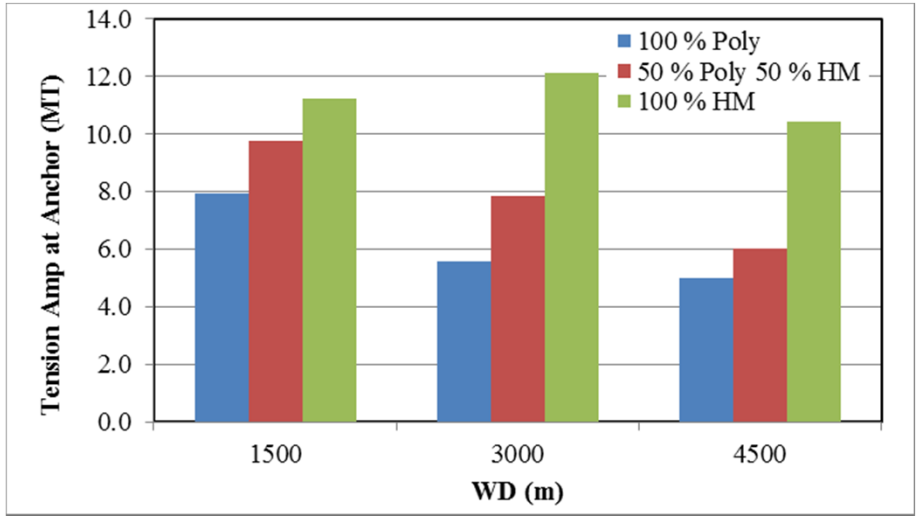


Case Study: Dynamic Characteristics

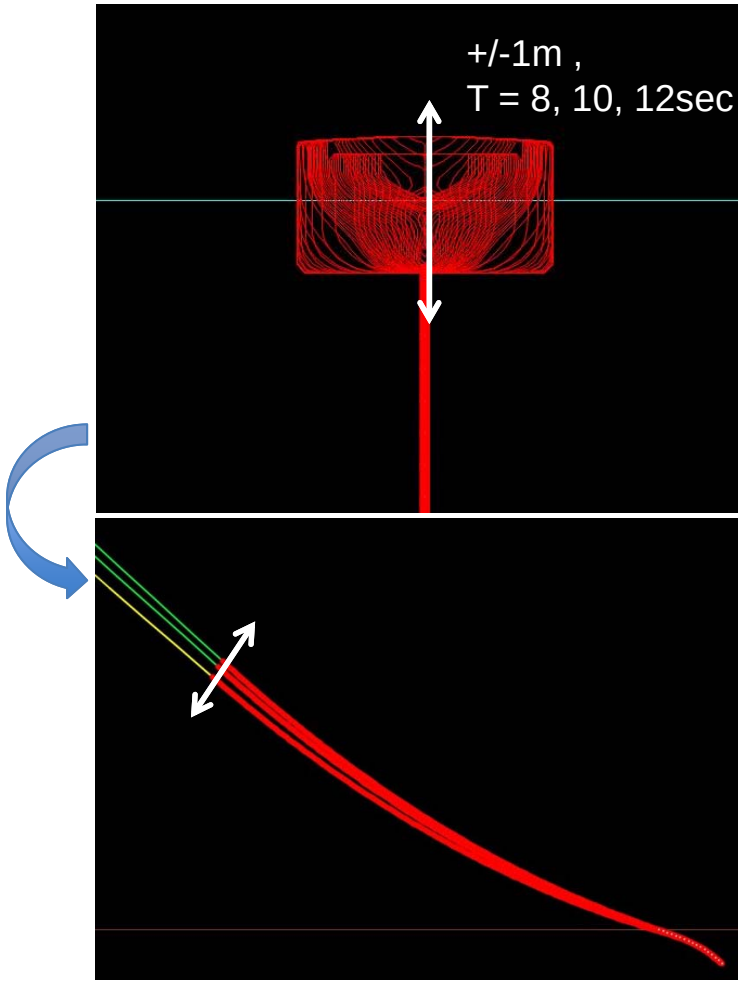


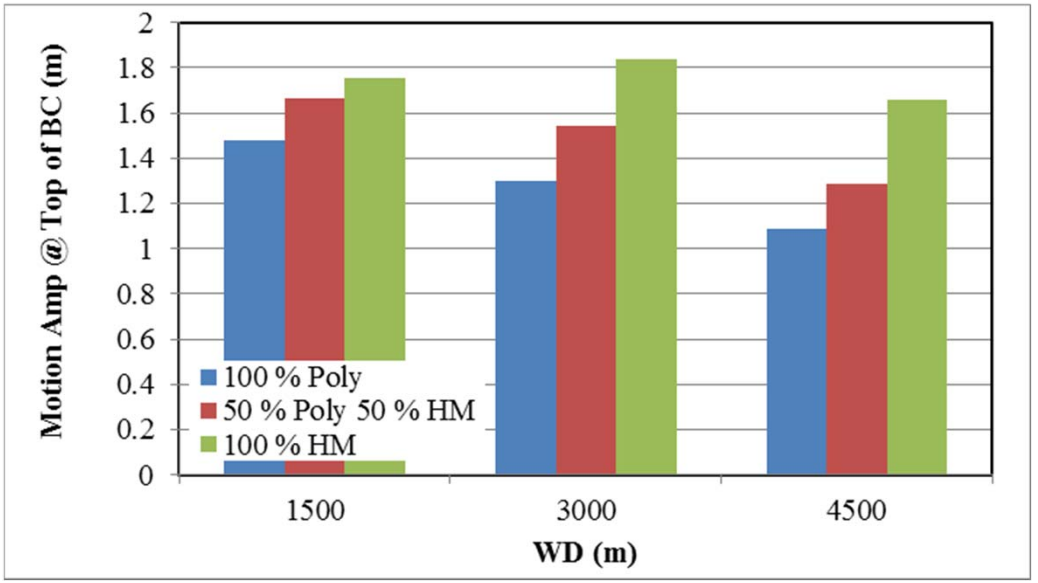
Regular Forced Motion Analysis





Case Study: Dynamic Characteristics

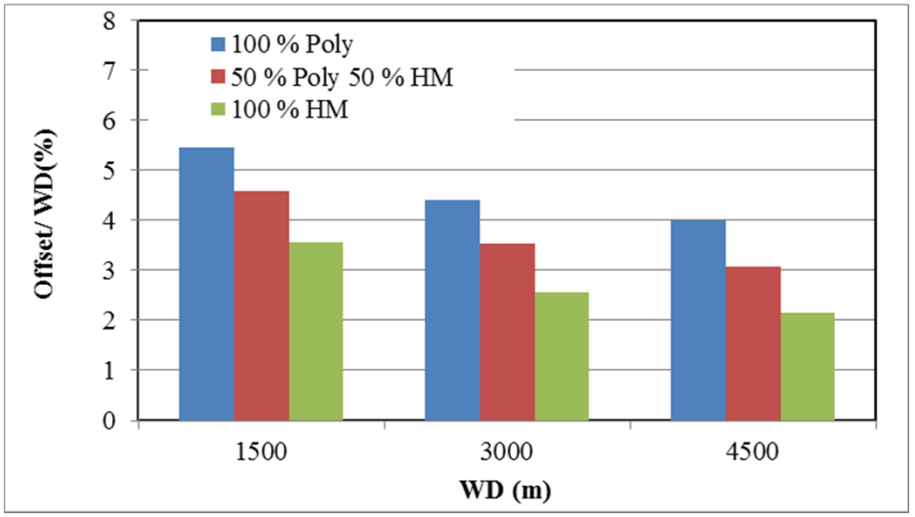


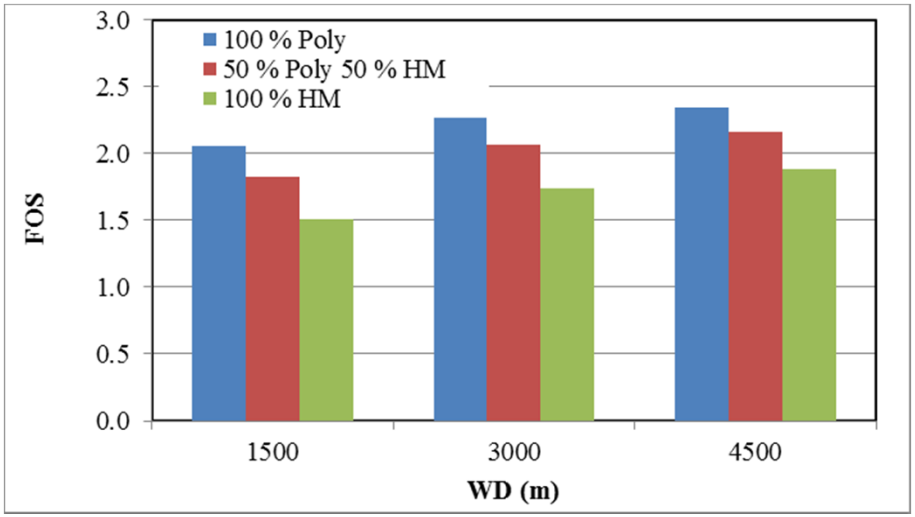


Case Study: Extreme Analysis

Hs = 13.0m
Tp = 14sec
Ws = 36m/sec
Vc = 1m/sec

Dynamic Global Analysis

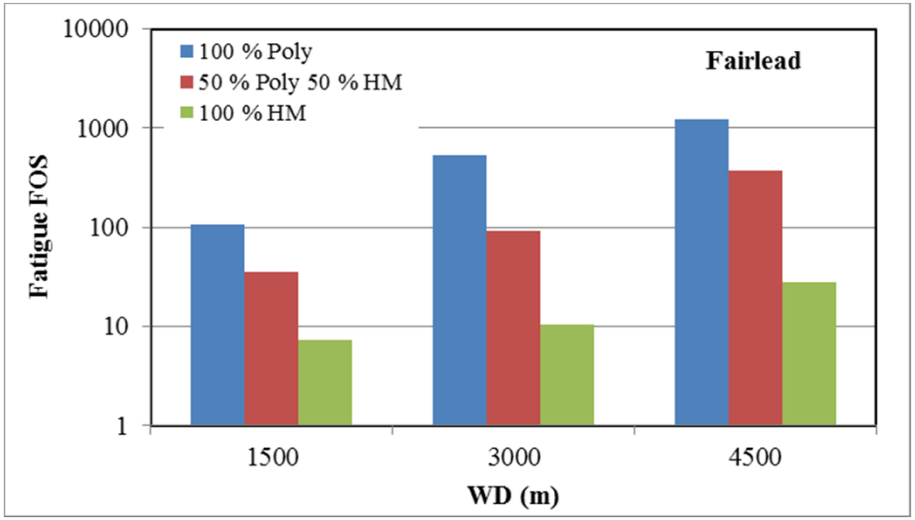


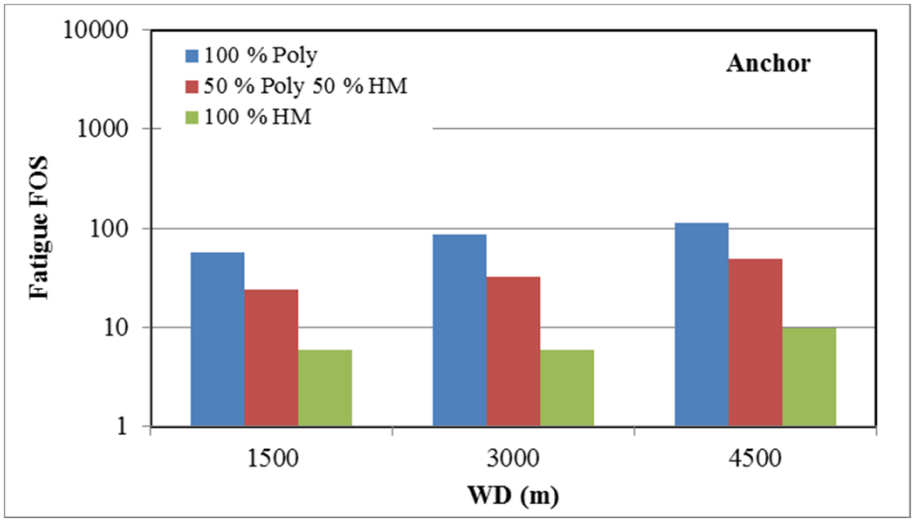


Case Study: Fatigue Analysis

LC	Primary Wave			Secondary Wave			Wind data		Current data		Prob.
	Hs	Tp	Dir	Hs	Tp	Dir	Ws	Dir	Vc	dir	
	(m)	(sec)	(deg.)	(m)	(sec)	(deg.)	(m/sec)	(deg)	(m/sec)	(deg)	
1	2.2	6.8	195	0.8	7.0	131	9.8	180	0.2	220	5.2%
2	2.1	6.9	180	0.9	8.3	102	9.9	180	0.3	206	26.0%
3	2.0	6.7	165	0.8	8.1	101	9.7	180	0.3	195	21.2%
4	1.9	7.1	150	0.6	5.3	141	8.2	180	0.3	199	10.1%
5	1.7	8.6	135	0.4	4.0	204	5.7	180	0.2	205	5.4%
6	1.6	8.7	120	0.6	4.0	192	5.8	180	0.3	211	4.7%
7	1.6	9.2	105	0.7	4.1	176	5.8	180	0.3	195	5.5%
8	1.6	10.0	90	0.8	4.6	175	6.0	180	0.3	212	4.8%
9	1.8	10.9	75	1.0	4.7	172	6.7	180	0.3	211	4.5%
10	2.0	11.6	60	1.1	5.1	168	7.2	180	0.3	215	4.6%
11	2.0	11.8	45	1.1	4.9	168	7.1	180	0.2	216	3.4%
12	2.2	12.1	30	1.1	4.9	170	7.2	180	0.2	194	4.1%
13	2.3	11.4	15	1.0	4.3	188	7.0	180	0.2	239	0.5%
14	1.7	6.6	300	0.5	4.5	218	4.7	180	0.2	227	0.1%

Dynamic Global Analysis





Summary

- Stationkeeping Technology for Frontier Deepwater:
  - Extension of existing technology is possible
  - Understand the seabed conditions / soil strength
  - Pay attention to the system dynamics
    - Study anchor leg dynamics along the line length
    - Study anchor leg – seabed interaction
  - Integrated design of host production facility, mooring and riser systems

- Offset Control for Riser Systems:
  - Understand the trade-offs!
  - Tune the mooring stiffness to optimize the performance
    - Offset
    - Maximum Loads
    - Fatigue Loading

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Thank You!

Questions?

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