Offloading Buoys for Deep Water

Arun Duggal

FMC SOFEC Floating Systems

October 3, 2001

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Outline

- Background
- Offloading Systems Worldwide
  - Offloading systems in shallow water
  - Evolution to deep water
- Deep Water Offloading Systems
  - Characteristics
  - Issues
  - Solutions
- Conclusion

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Shallow Water Offloading Systems

- SALM Buoys
- CALM Buoys
  - Mature technology (in operation worldwide for 20+ years)
  - Standard/Conventional interface with vessels of opportunity
  - Operating guidelines well established
- Other Offloading Systems
  - UKOLS
  - SAL, STL, etc.

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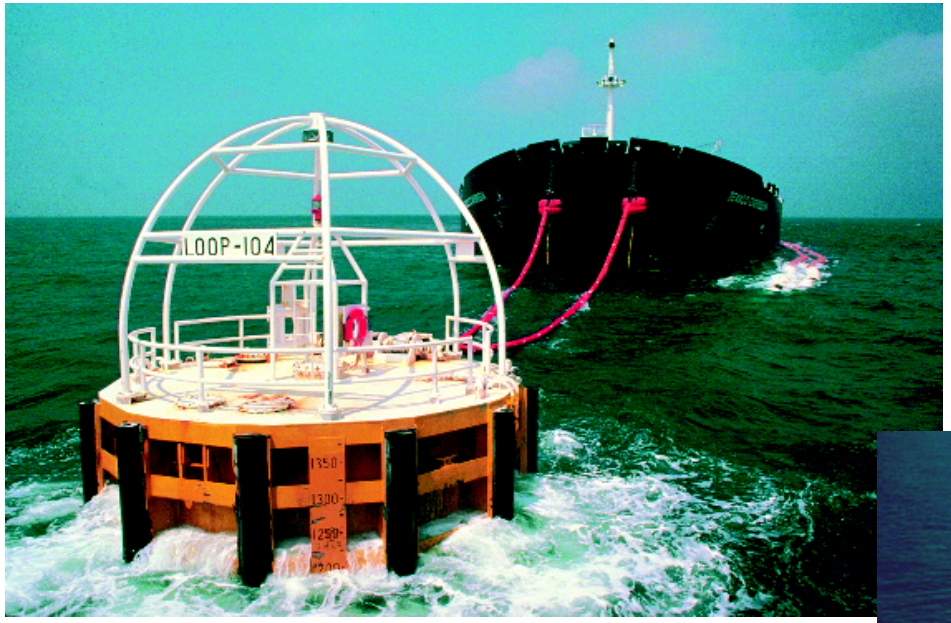
SALM Buoy Offloading System



Single Anchor Leg Mooring
Bearing and Swivel Submerged

Vessels of Opportunity

Gulf of Mexico: LOOP
Since 1978

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CALM Buoy Offloading System

Catenary Anchor Leg Mooring

Most Popular Shallow Water Offloading System

Vessels of Opportunity

Bearing and Swivels above Water Line

Versatile

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Tandem versus SPM Offloading

- Availability (Environment Dependent)
  - SPM (turret-moored FPSO, offloading buoy): 97 - 99%
  - Tandem from spread-moored FPSO: 85 - 95%
- Cost
  - FPSO + Offloading Buoy: Higher CAPEX, Lower OPEX
  - FPSO + Tandem Offloading: Lower CAPEX, Higher OPEX
- Safety/Risk of Collision
  - Location of offloading buoy ~ 2,000 meters from FPSO minimizes risk of collision

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Evolution of Deep Water Offloading Systems

Current Application:

- West Africa & Brazil
- Mild to moderate environment
- Spread-Moored (non-weathervaning FPSO's)
- Long Field Life (20 - 30 years)
- High Rates of Production (> 100,000 bopd)
- Frequent Offloading to Vessels of Opportunity

Current Solution:
Extend Well-Established Shallow Water Systems to Deep Water

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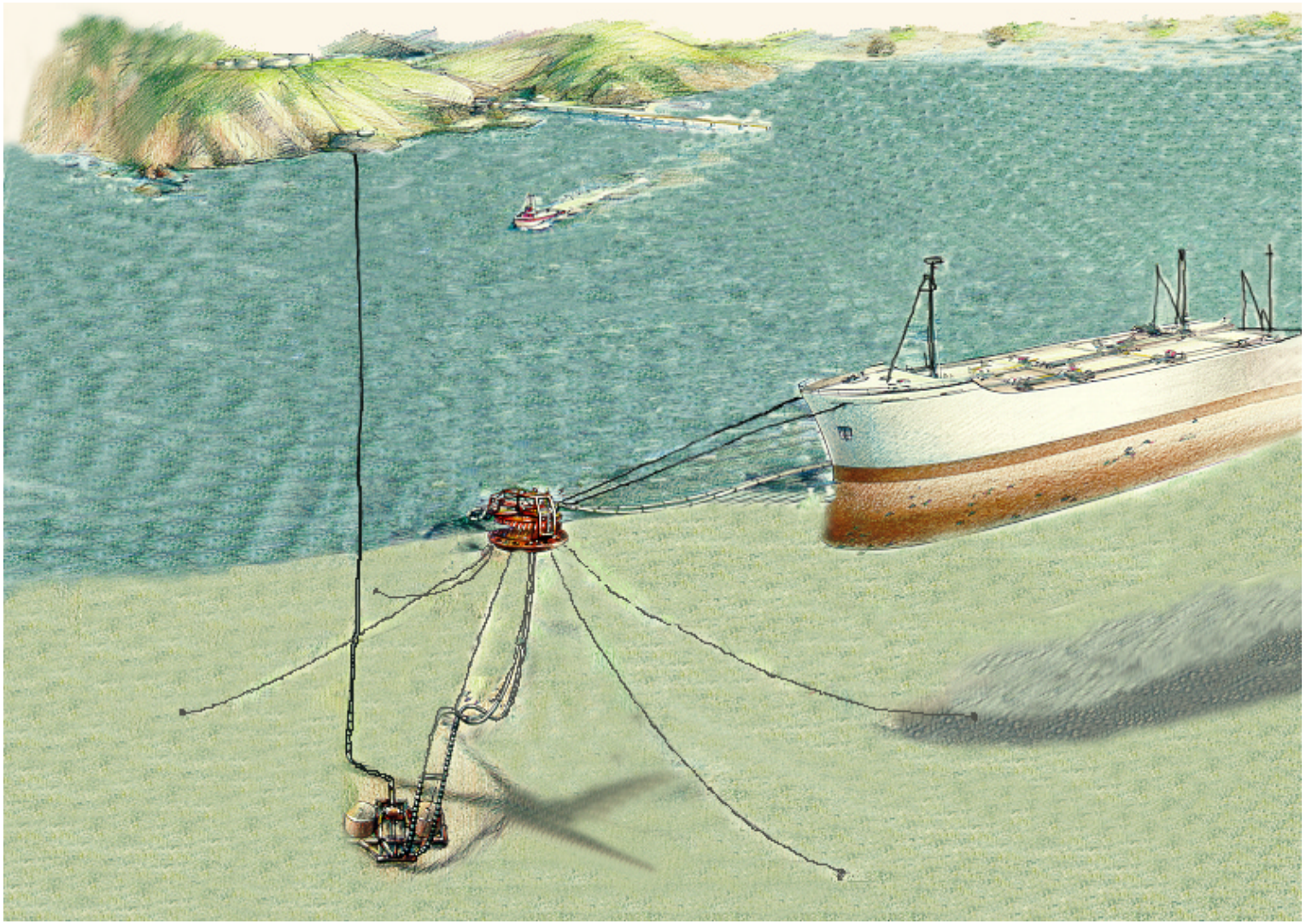
Shallow Water CALM Buoy Offloading System



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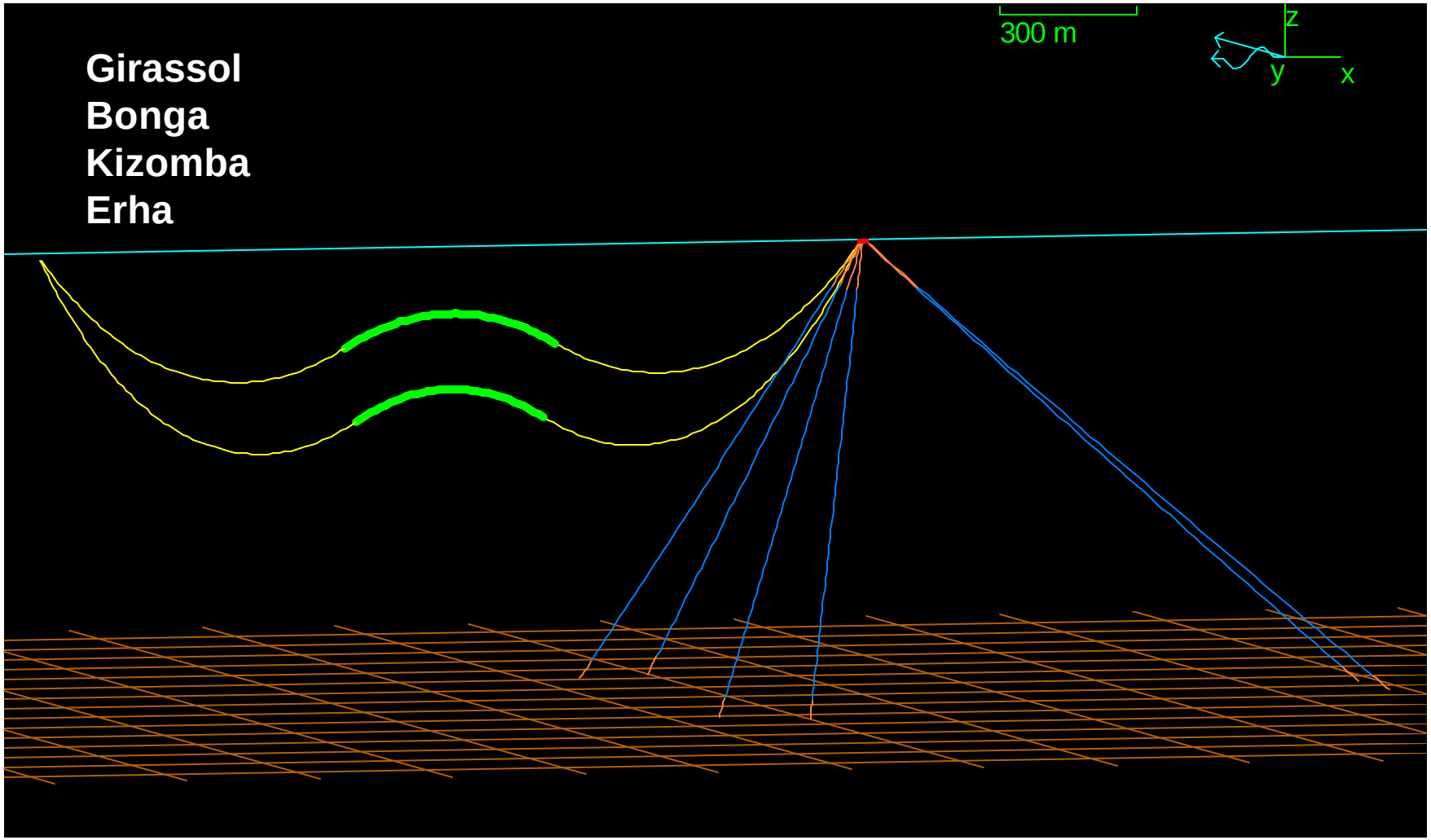
Deep Water CALM Buoy Offloading System



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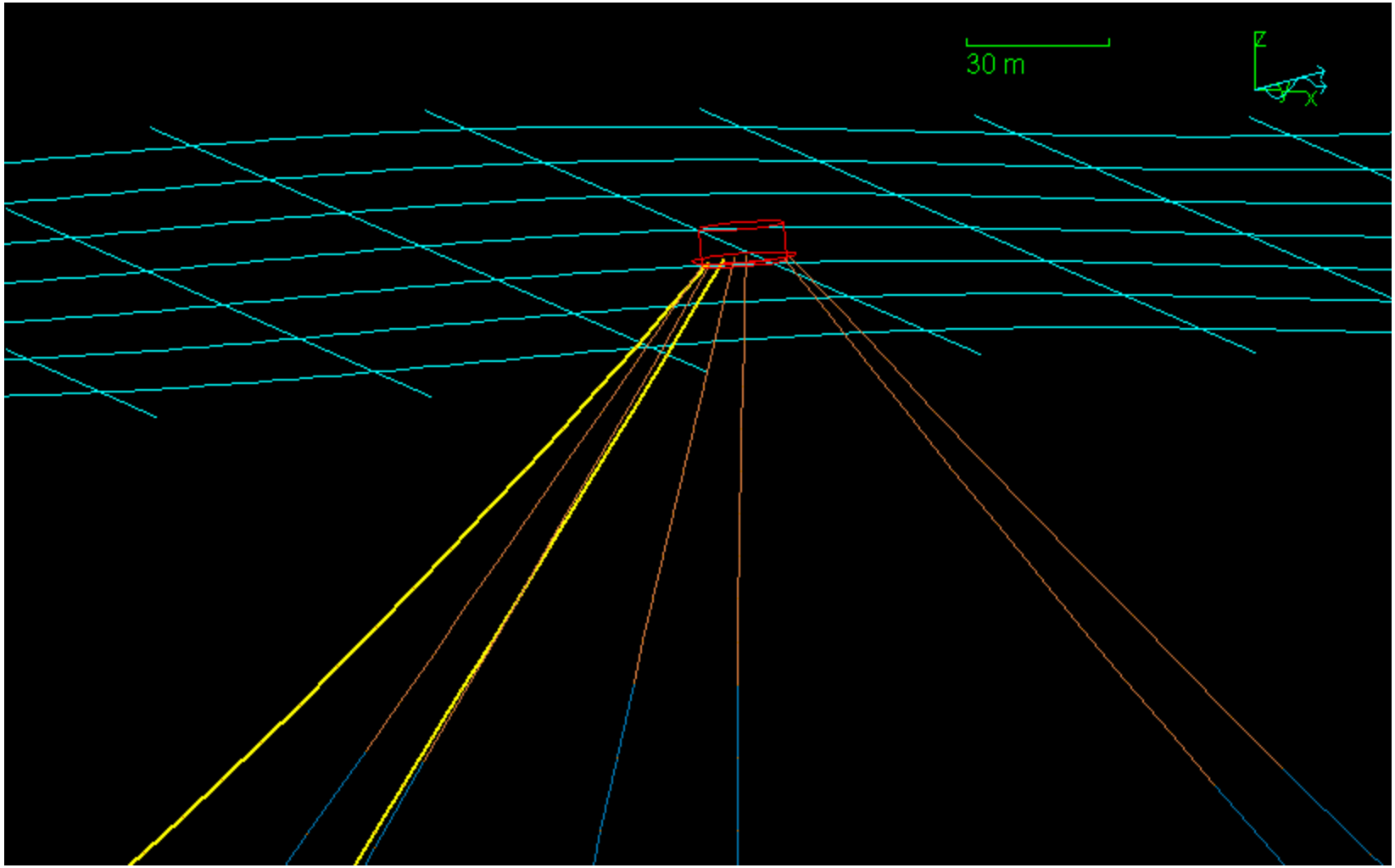
Simulation of CALM/Flowline Motions



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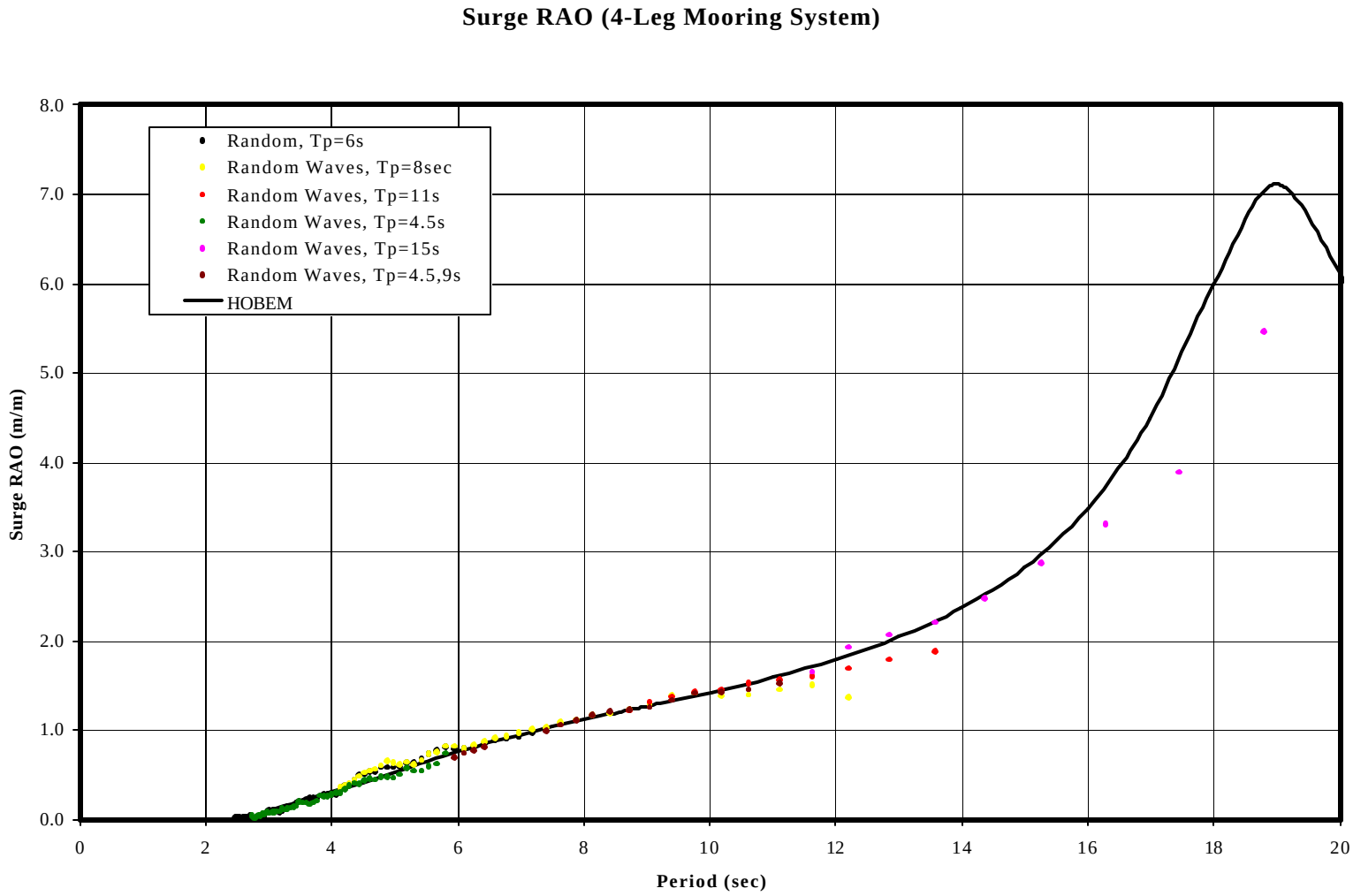
Buoy RAOs: Methodology Verification



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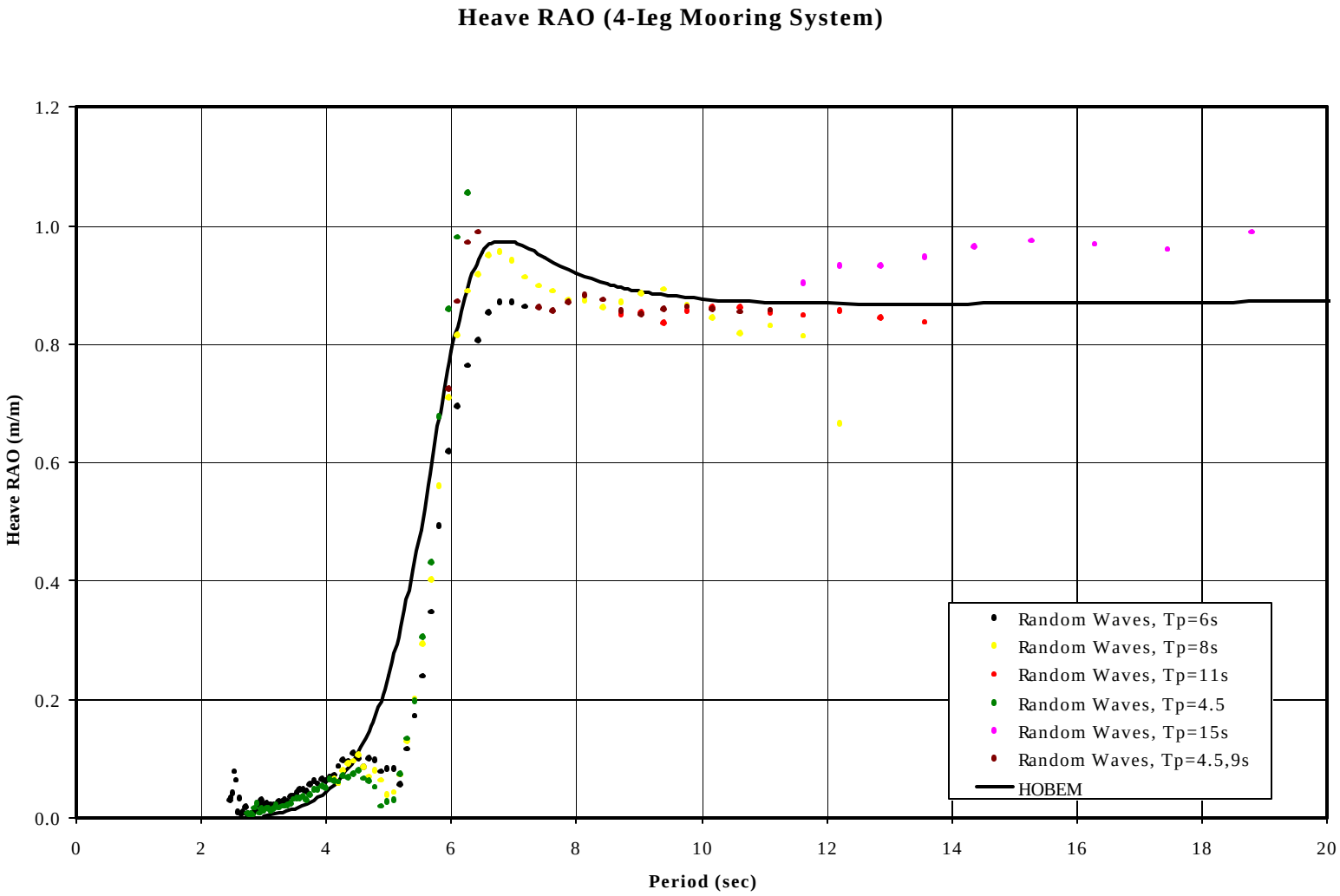

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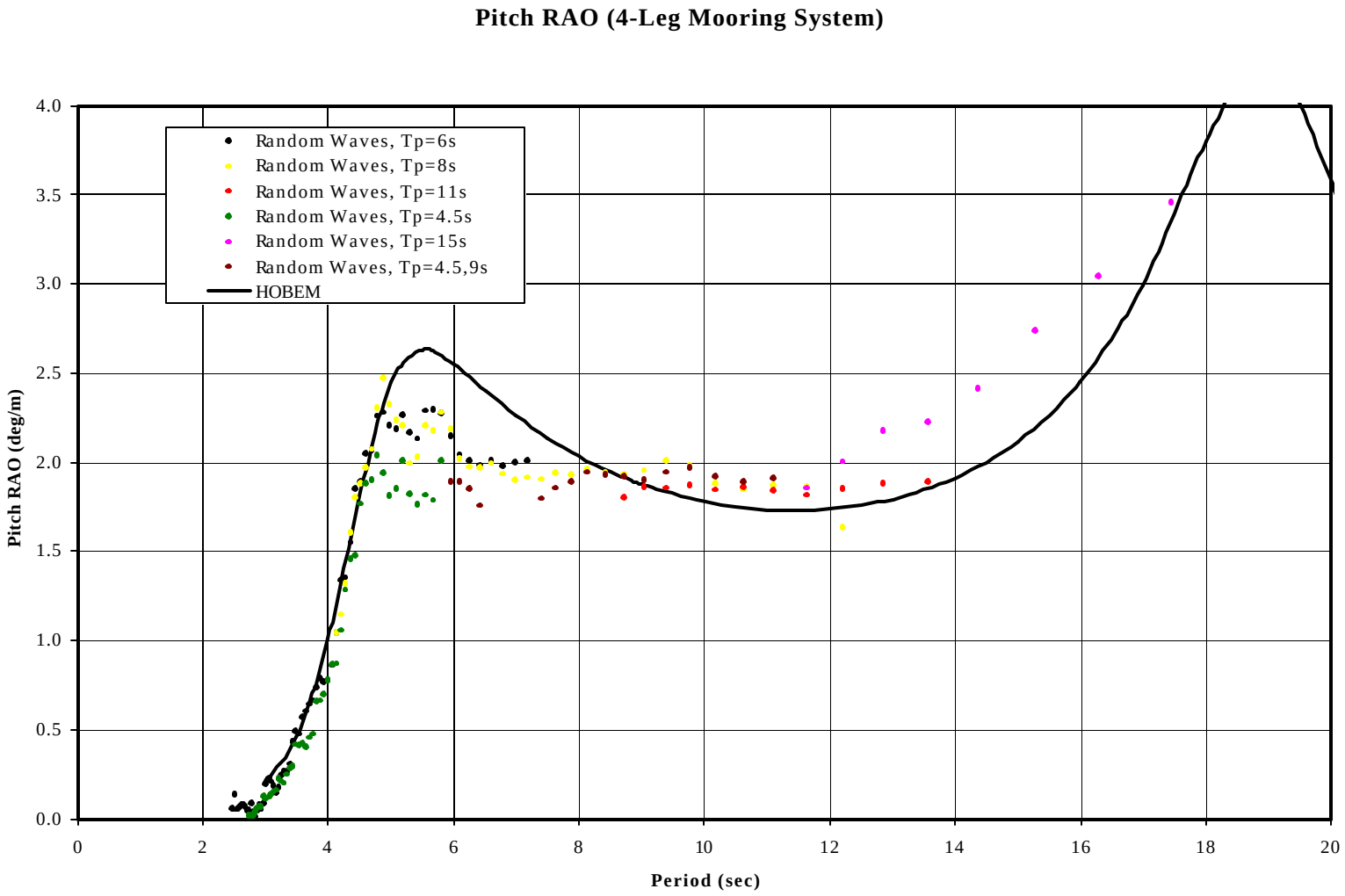

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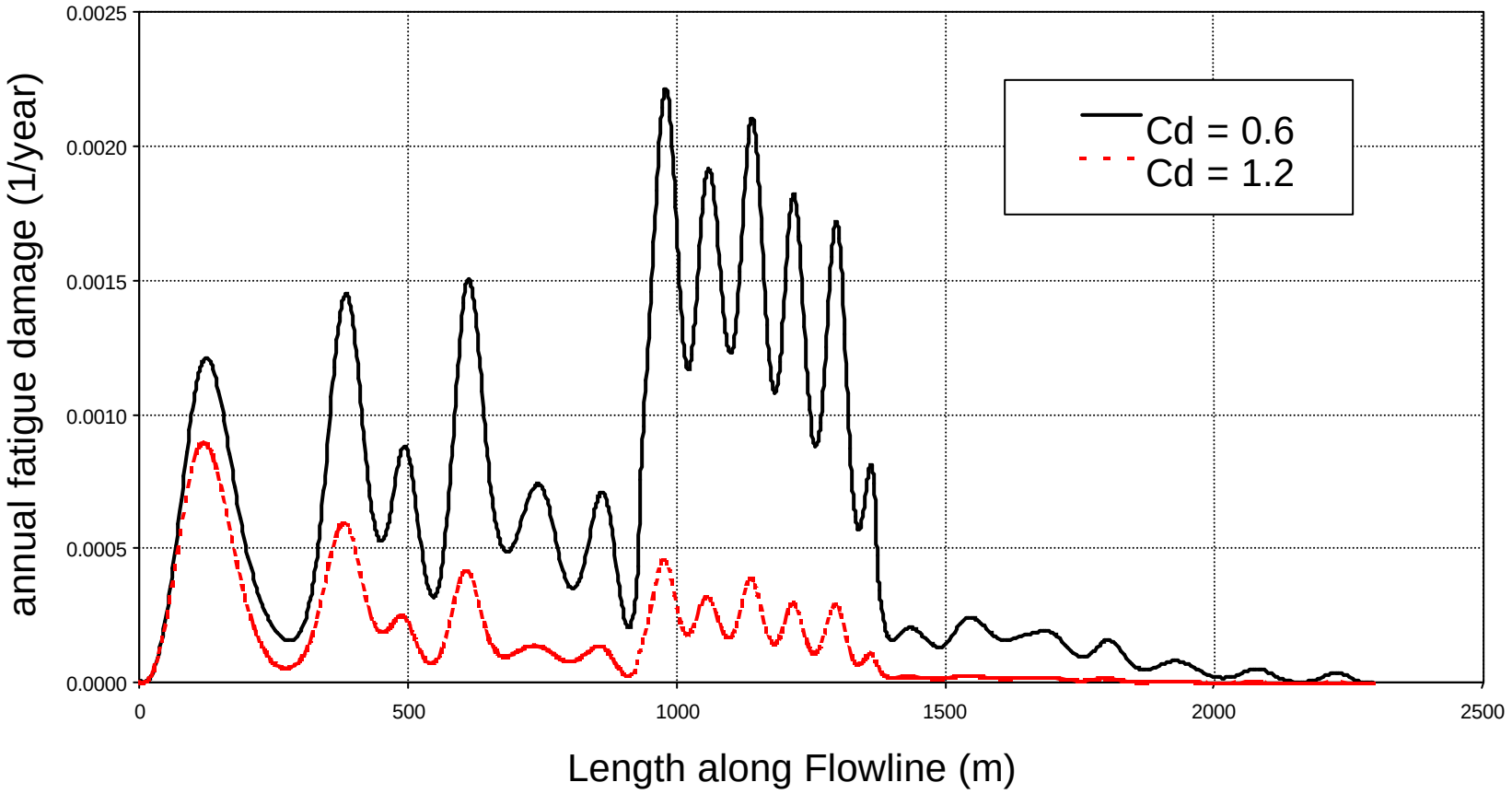
Sensitivity to Drag Coefficient



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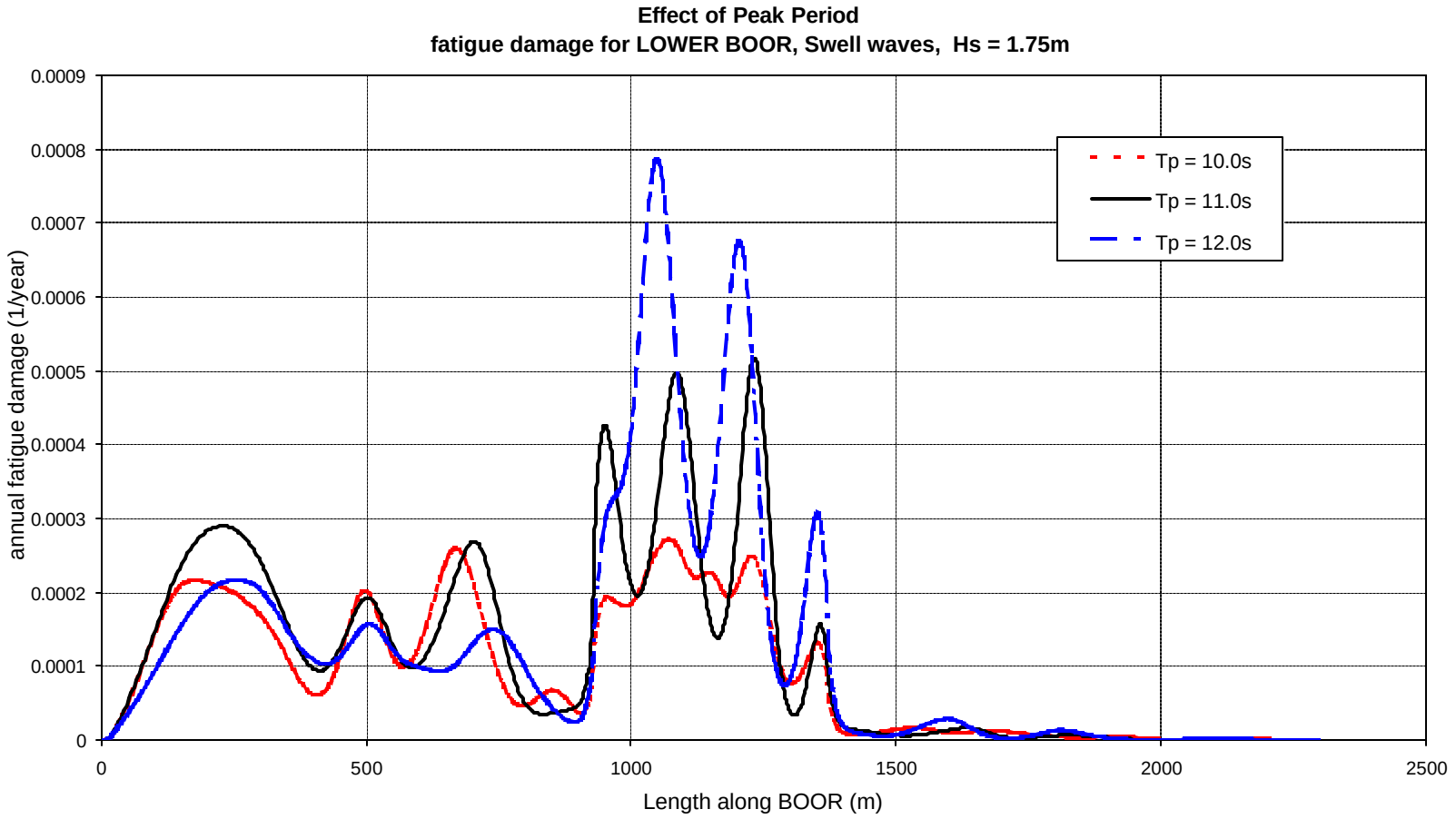
Influence of Swell Bin Width



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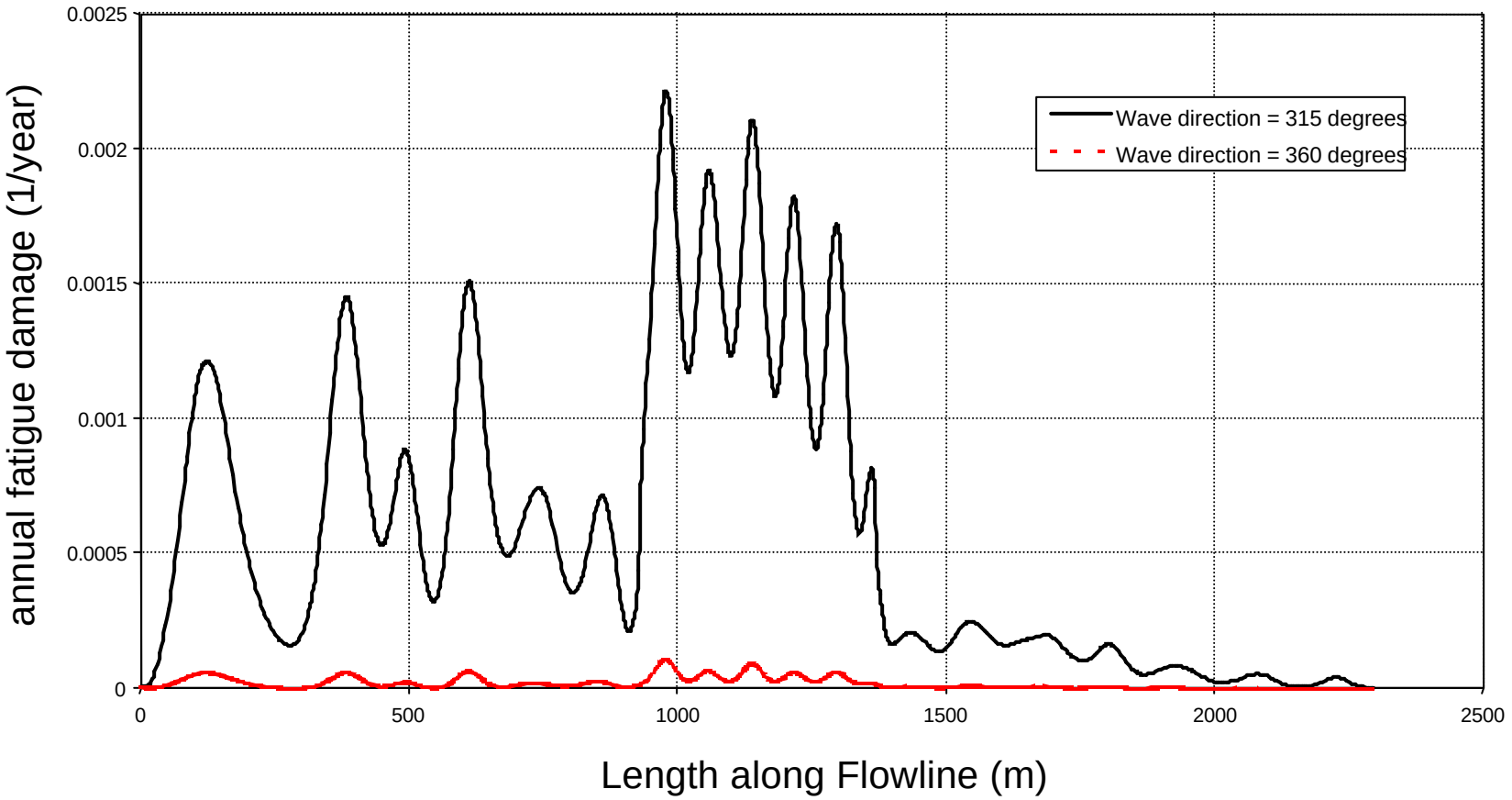
Sensitivity to Wave Direction



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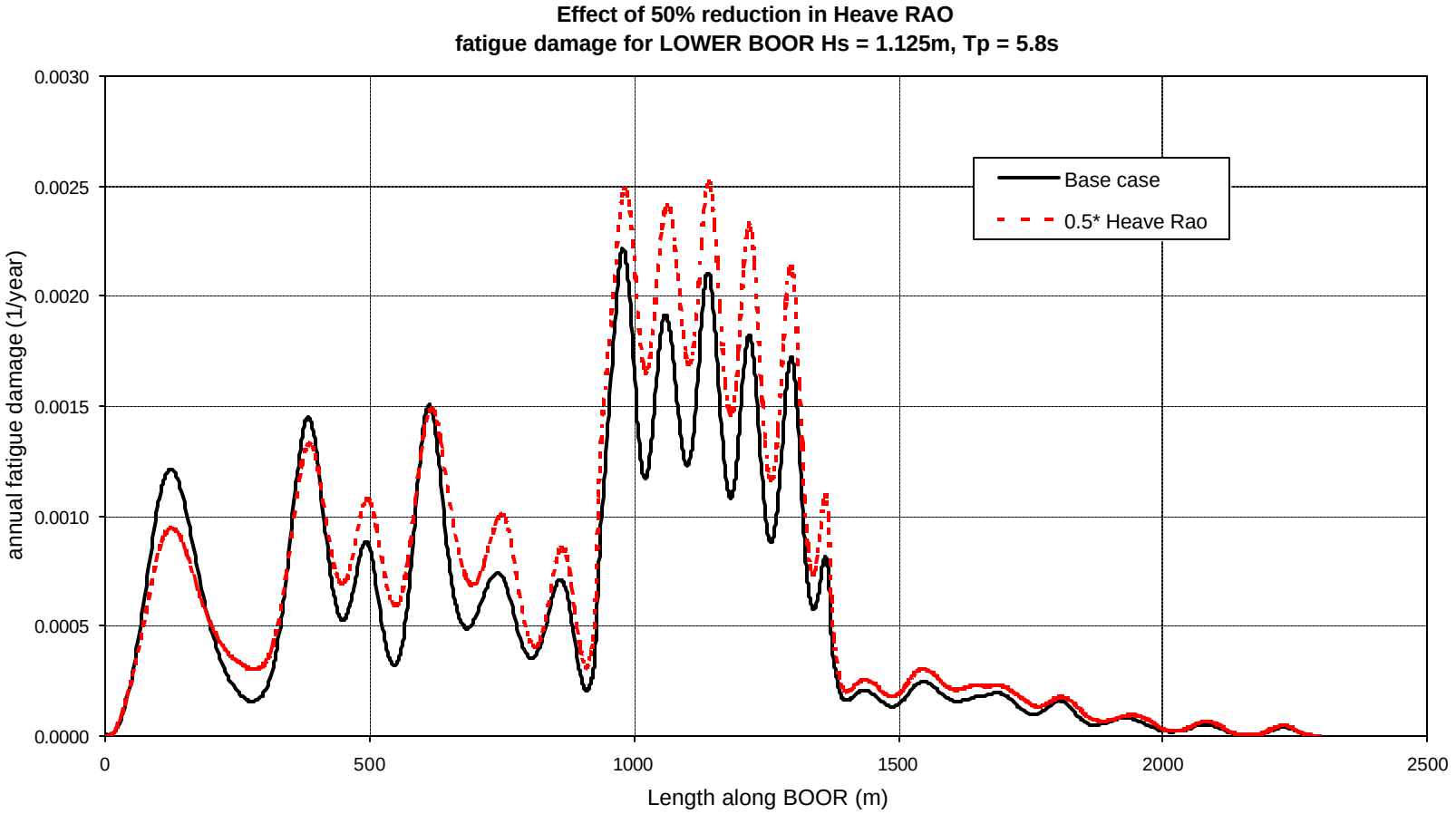
Influence of Heave Reduction



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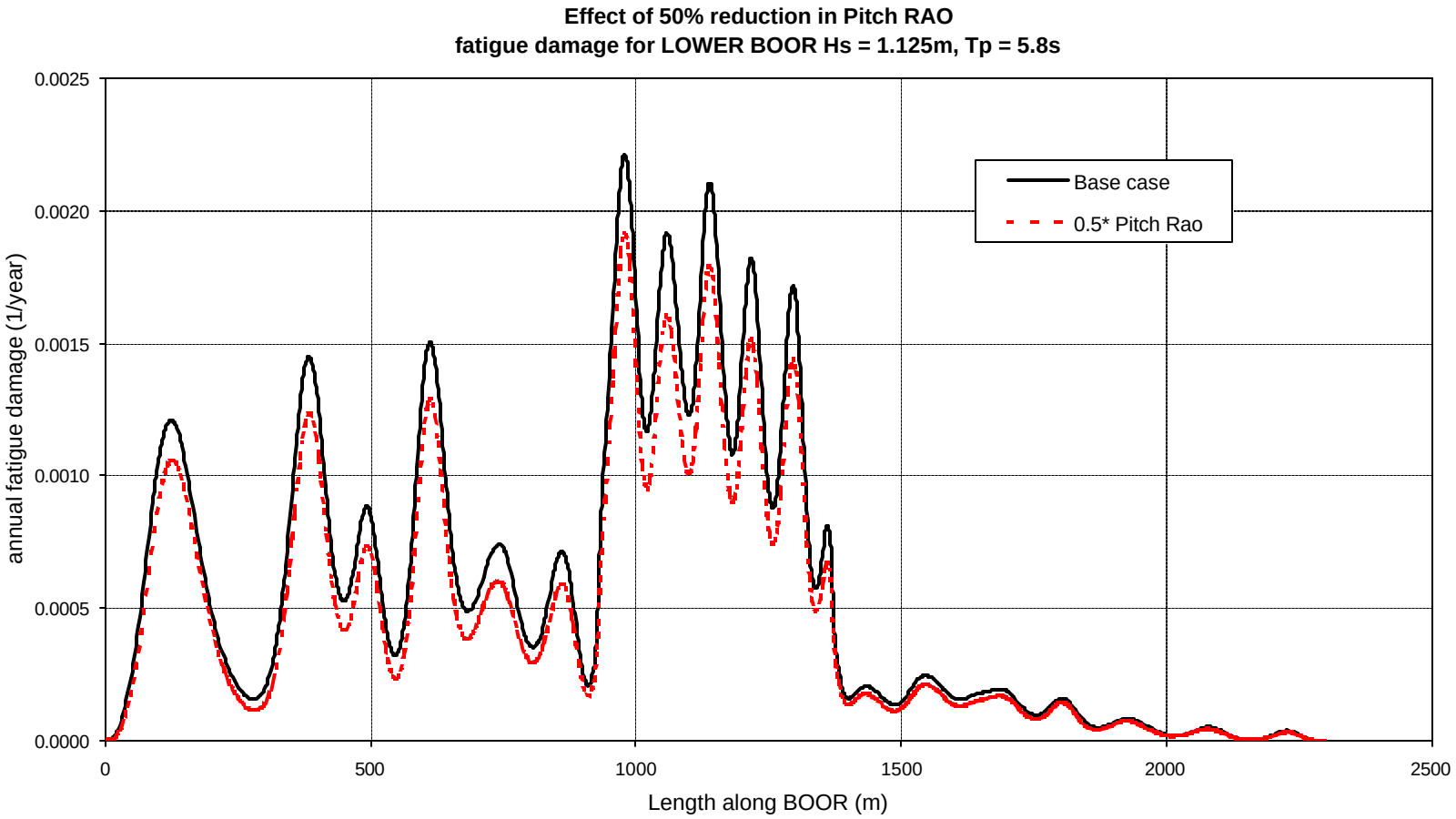
Influence of Pitch Reduction



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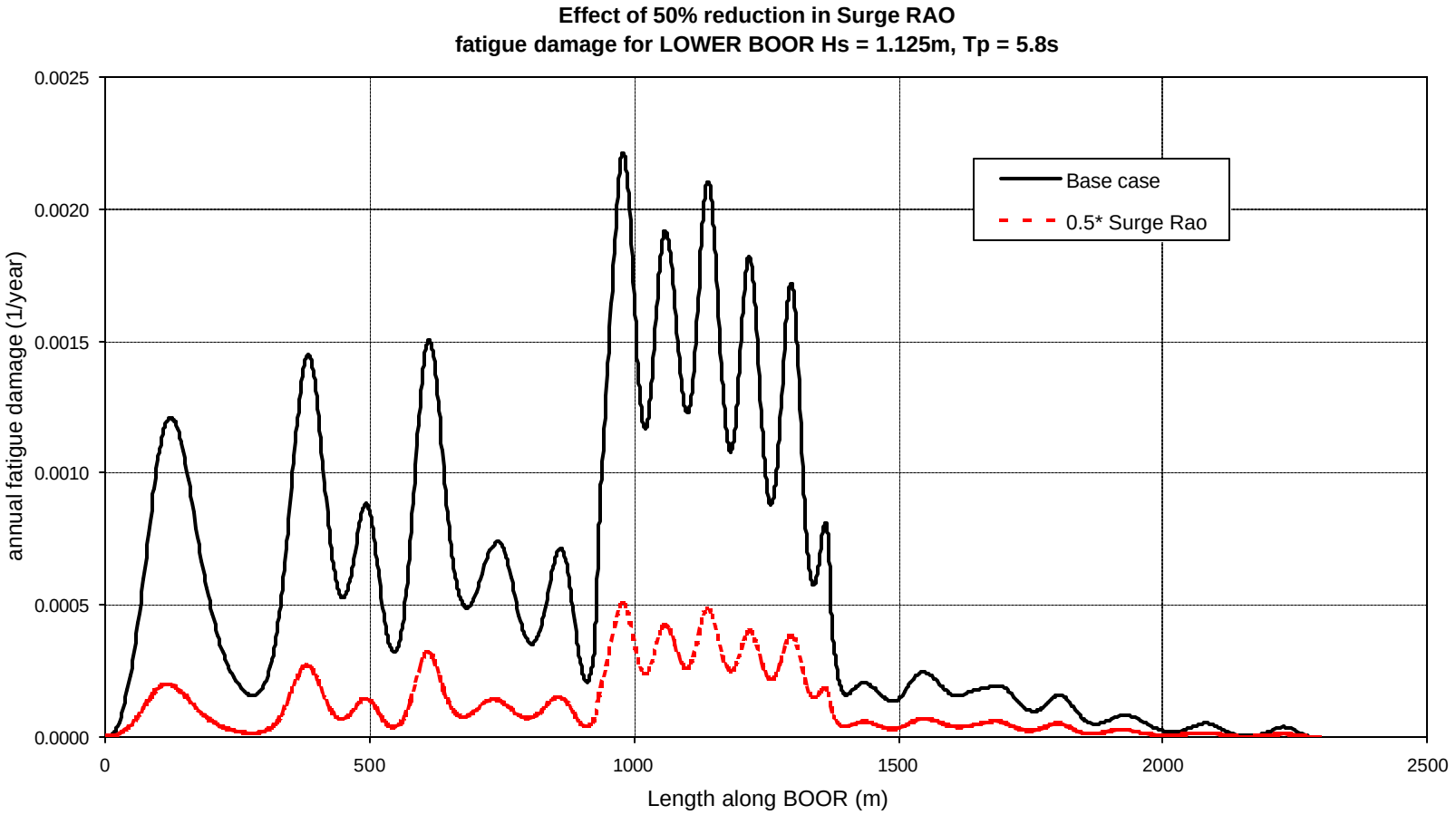
Influence of Surge Reduction



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Issues Related to Deep Water CALM Buoys

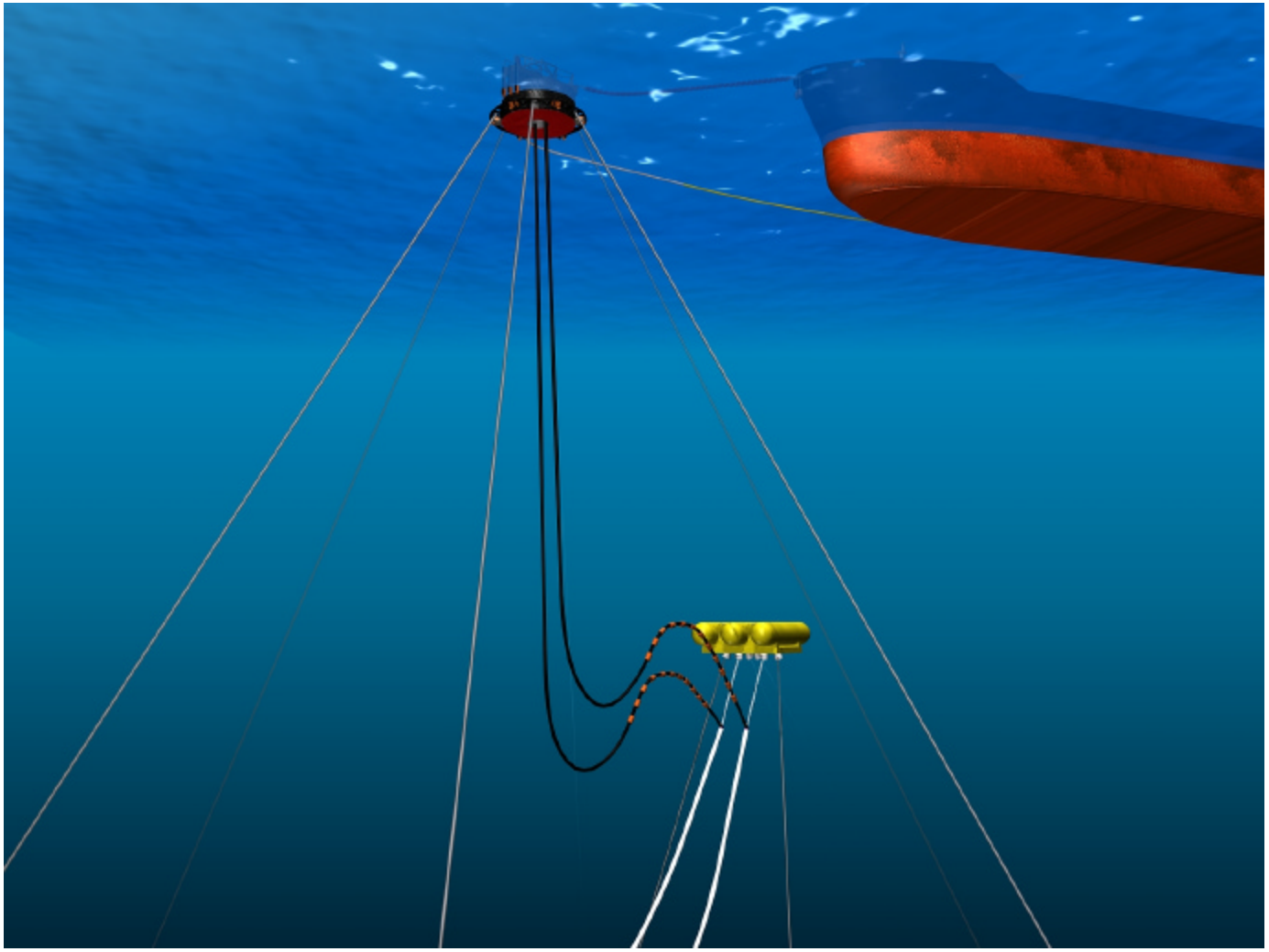
- Flowline Reliability for Life of Field:
  - Buoy motions result in high cycle, low amplitude fatigue damage to flowlines
  - Flowline dynamics sensitive to environment & system damping
  - Flowlines designed to maximize fatigue resistance, not optimal offloading (head loss, pump pressure and flowrate)
- Hawser Loads Increase as Buoy Displacement Increases
  - Requires reduced offloading seastates due to limitation on bow stopper load
- Repair/Replacement of CALM Buoy?
  - Maintenance/Replacement of CALM buoy due to accidental or other damage may compromise the flowline system

Flowline Termination Buoy System

FTB Supports Flowlines 75m Below Water Surface

Flowlines De-coupled from Surface Offloading Buoy

Fatigue Resistant Solution



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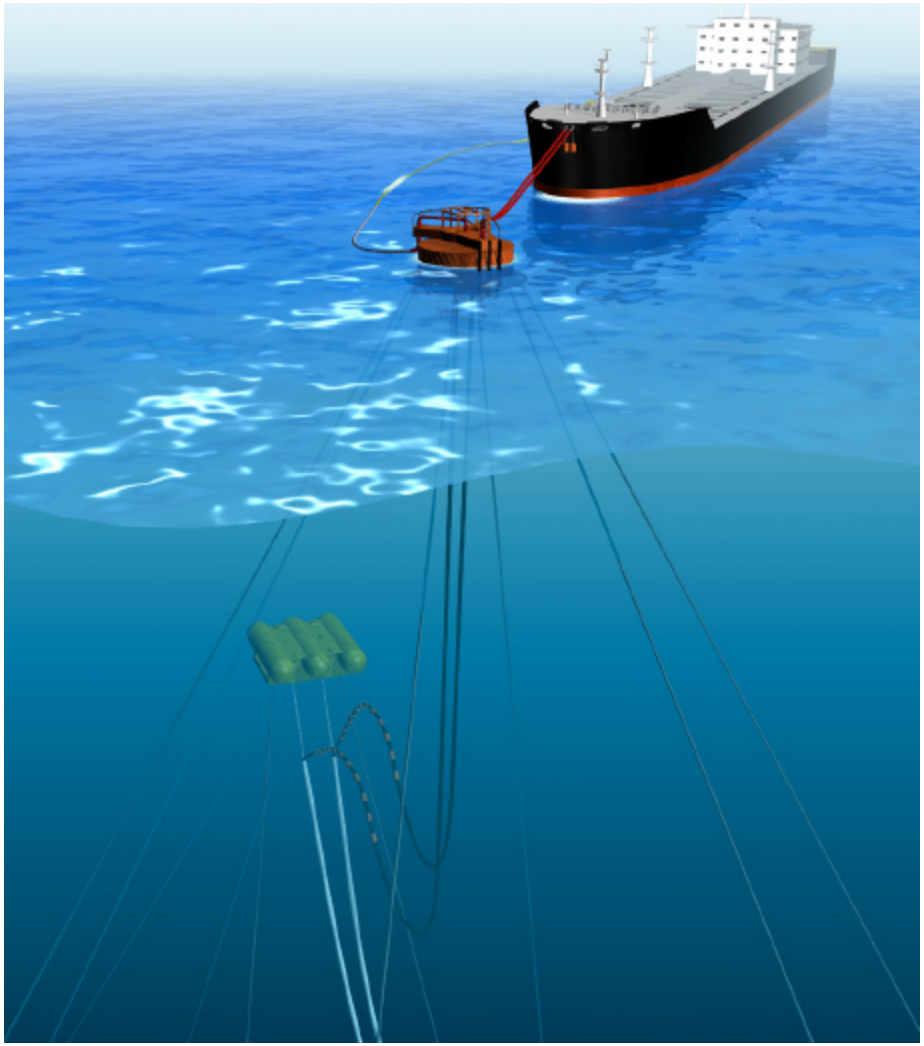
Flowline Termination Buoy System

Standard Offloading Interface for Mariners

All Critical Components (Bearings, Swivels) Above Water Surface

Allows for Easy Maintenance/Repair of Surface Buoy



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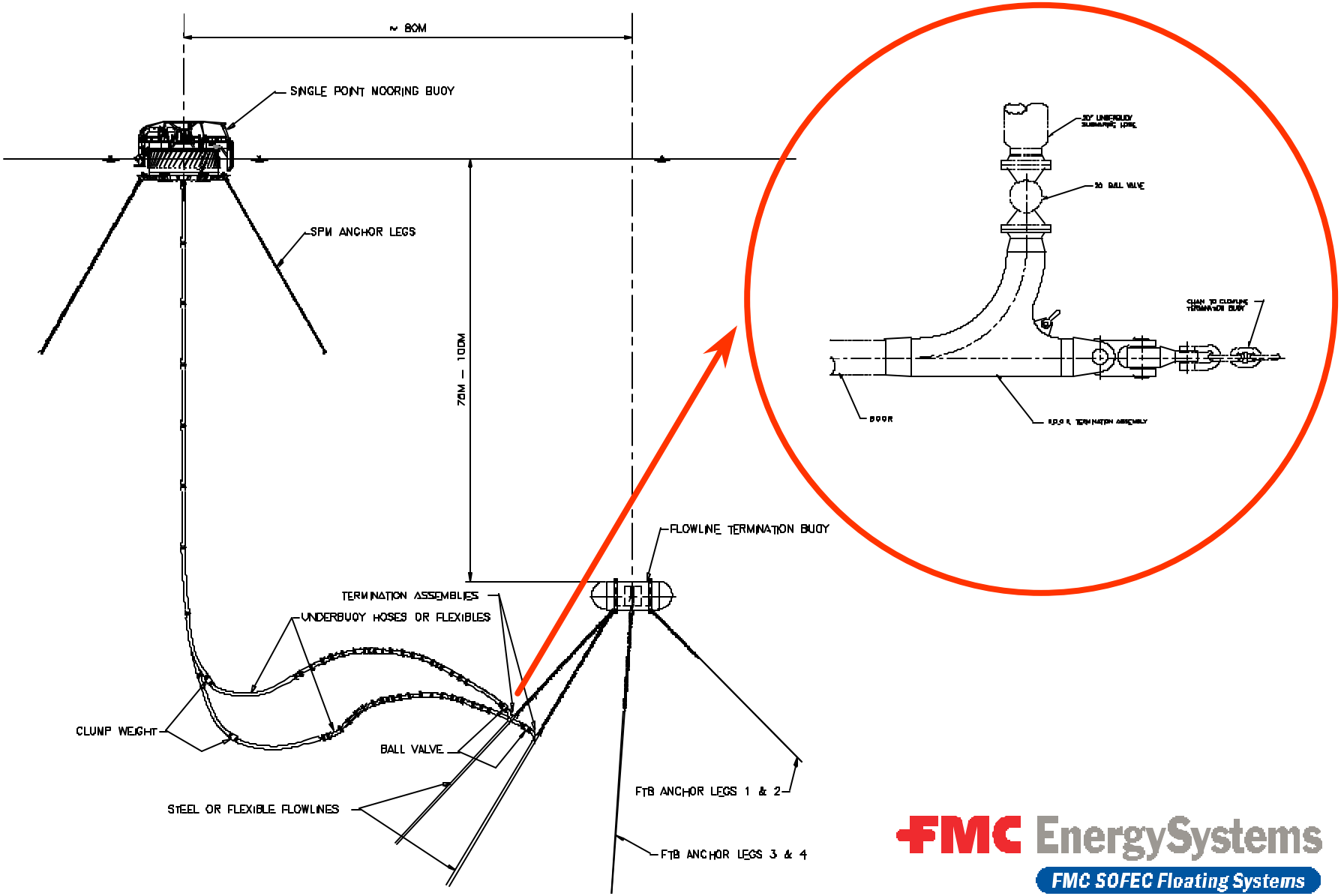
Flowline Termination Buoy System



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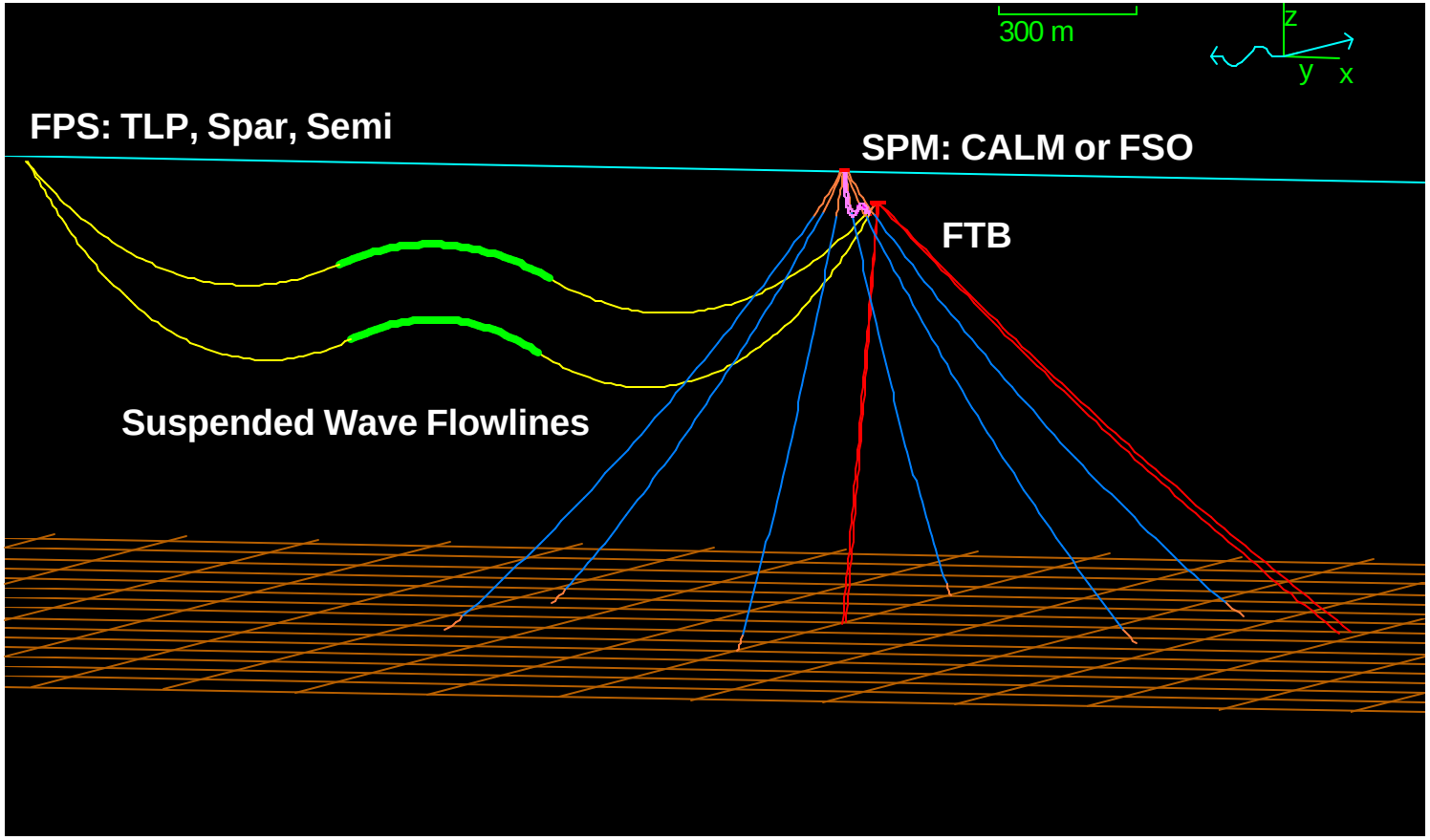
Flowline Termination Buoy System

Flowlines can be Steel Pipe of Flexibles



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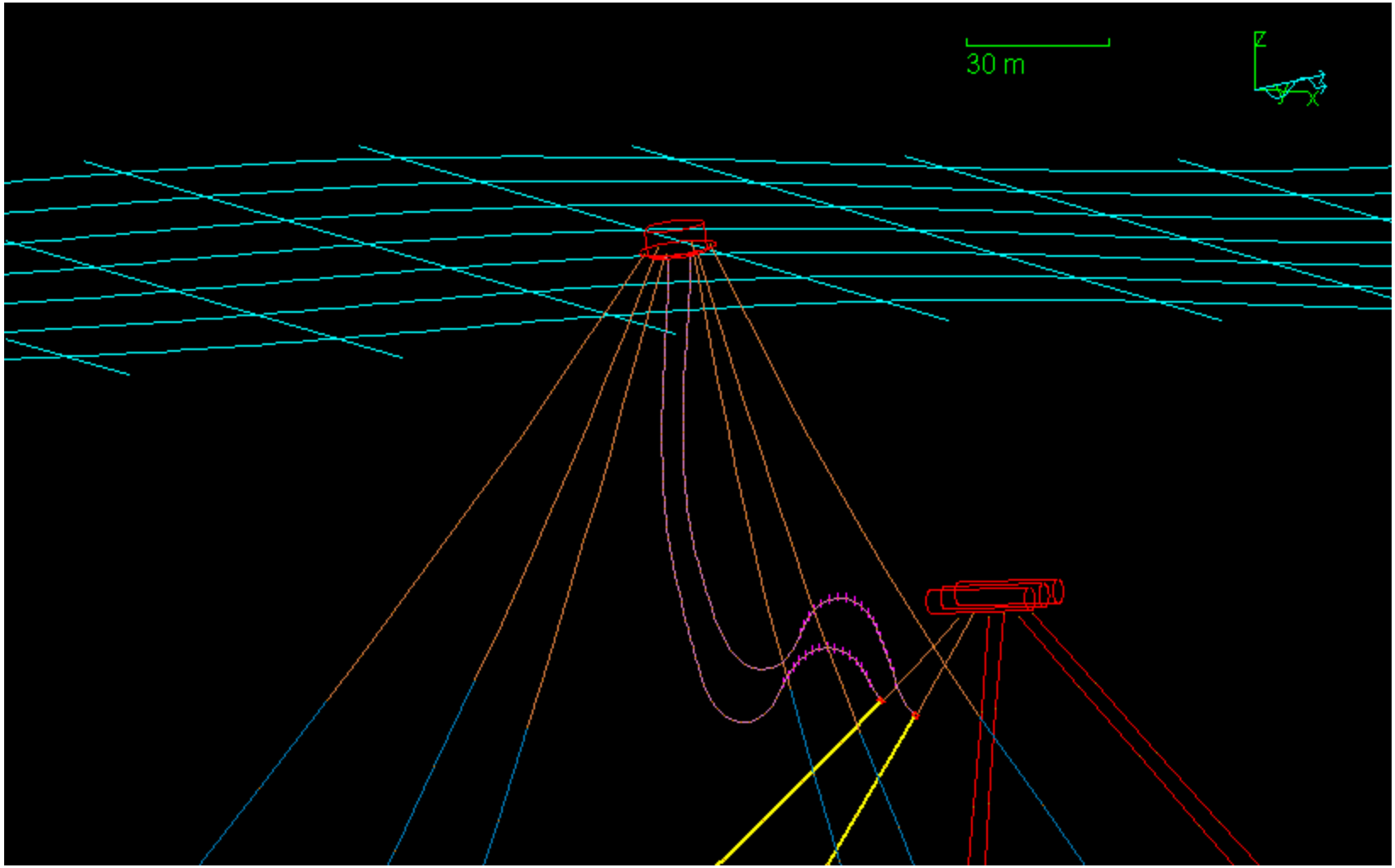
Simulation of FTB/Flowline Motions



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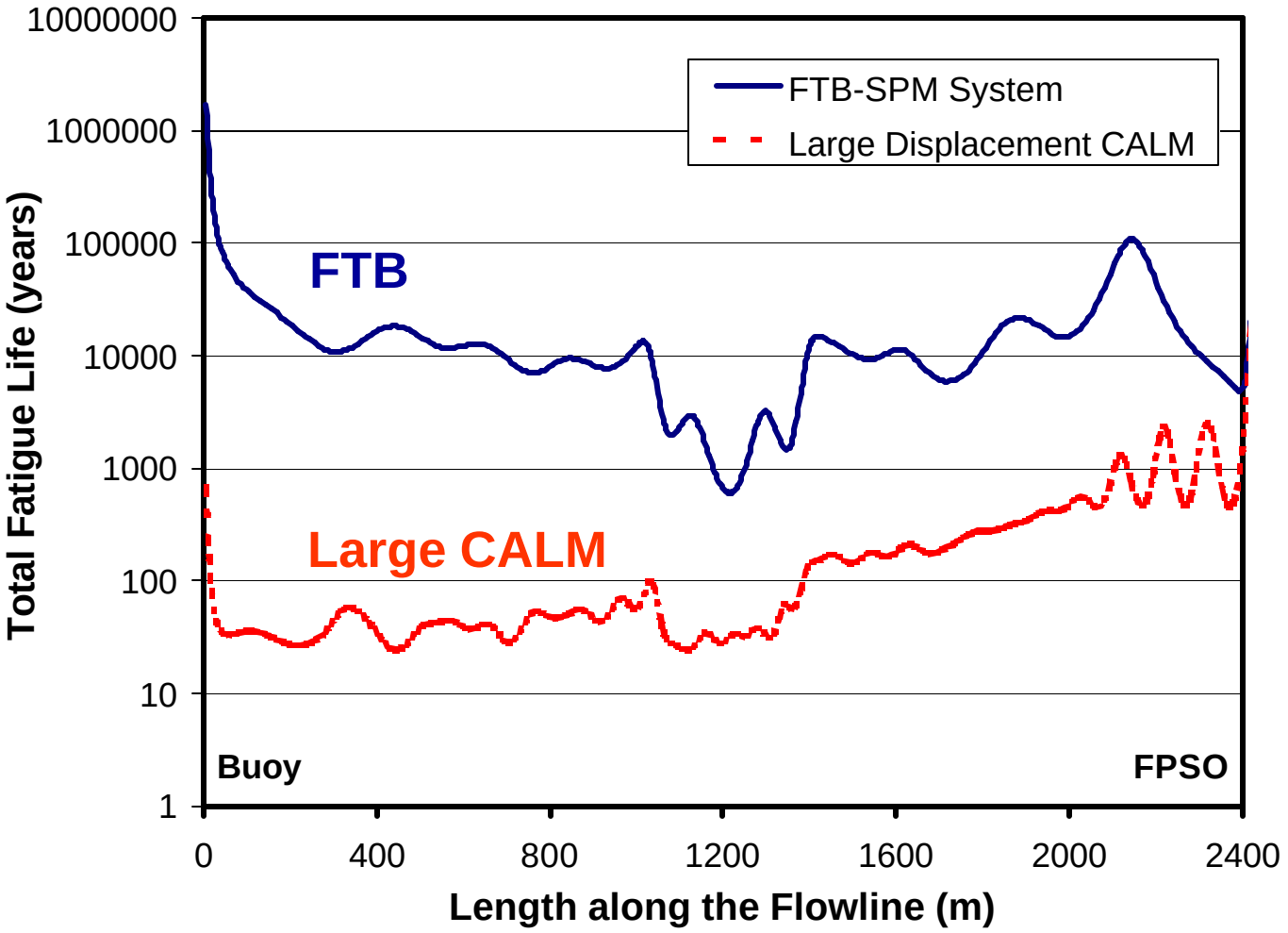
Fatigue Life Comparison



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Summary: FTB Offloading System

- De-couples Flowline Support and Offloading Functions
- Provides Standard Offloading Interface for Vessels of Opportunity
- Flowline Size and Configuration can be Optimized
  - Larger diameter, reduced wall thickness
  - Reduces required pumping pressure/increases flowrate
- Fatigue Life Estimate (West Africa): ~ 1,000 years
- Allows Repair/Replacement of CALM w/o Compromising Flowlines
- Increased Reliability over Life of Field

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Offloading in the Gulf of Mexico

PEMEX, Bay of Campeche (1998)

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