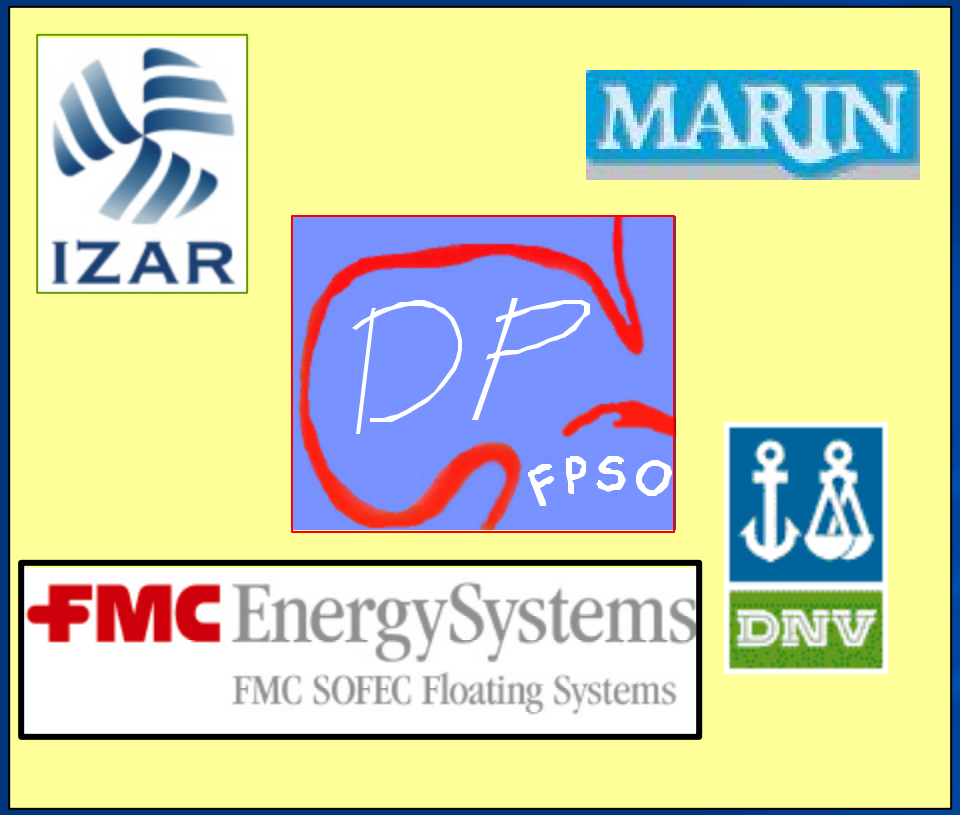
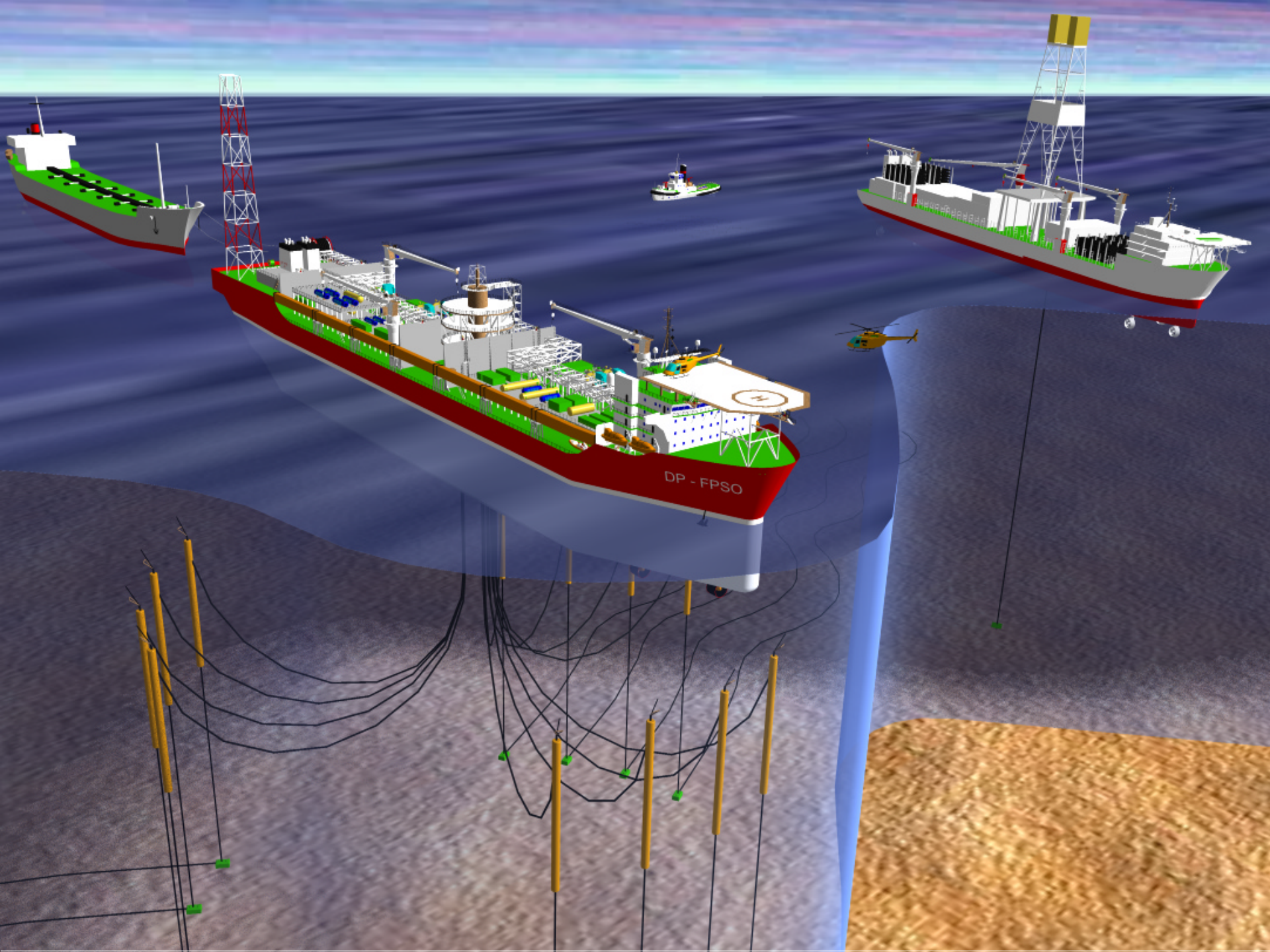
# DP FPSO: A Dynamically Positioned FPSO for Ultra Deep Waters

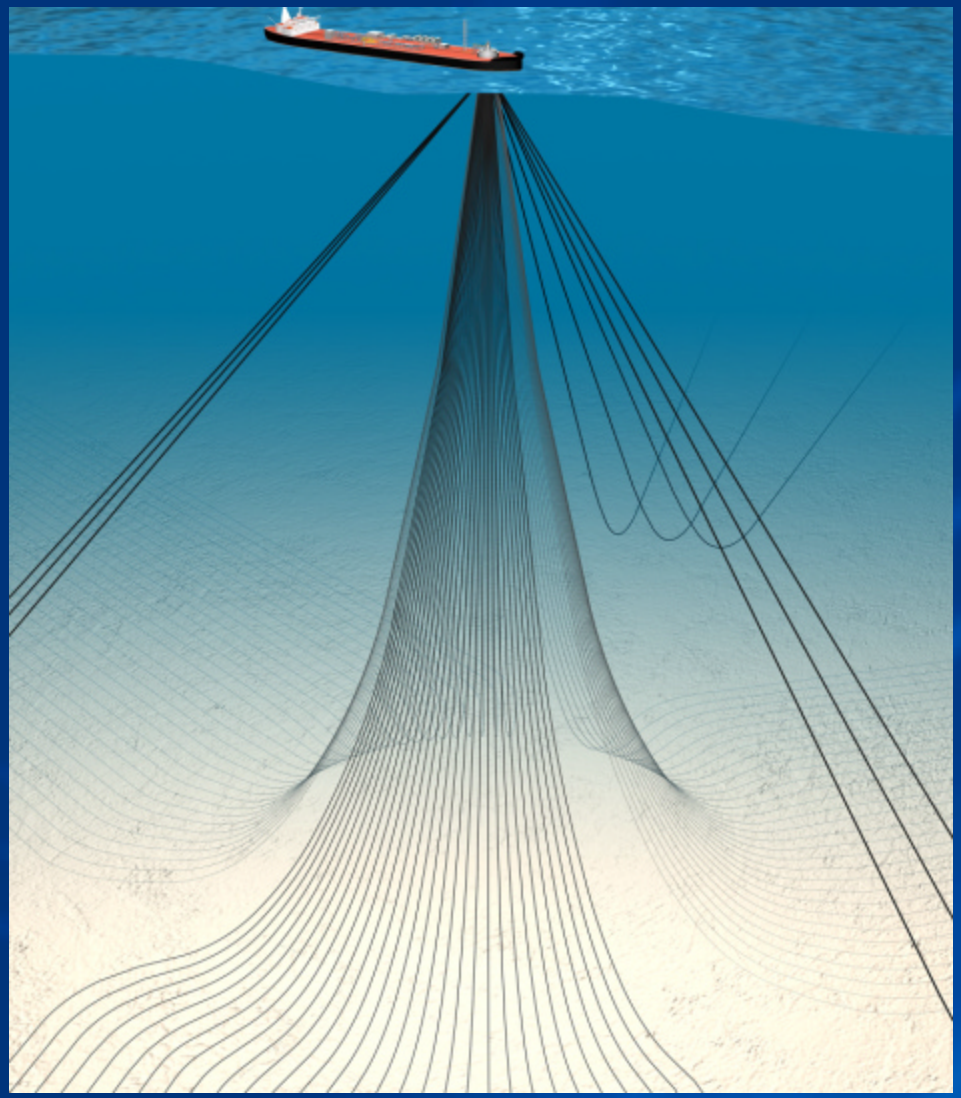



*Joaquin Cortijo*
**IZAR**
*Arun Duggal*
**FMC SOFEC**
*Radboud van Dijk*
**MARIN**
*Sergio Matos*
**DNV**

**ISOPE 2003**


DP - FPSO

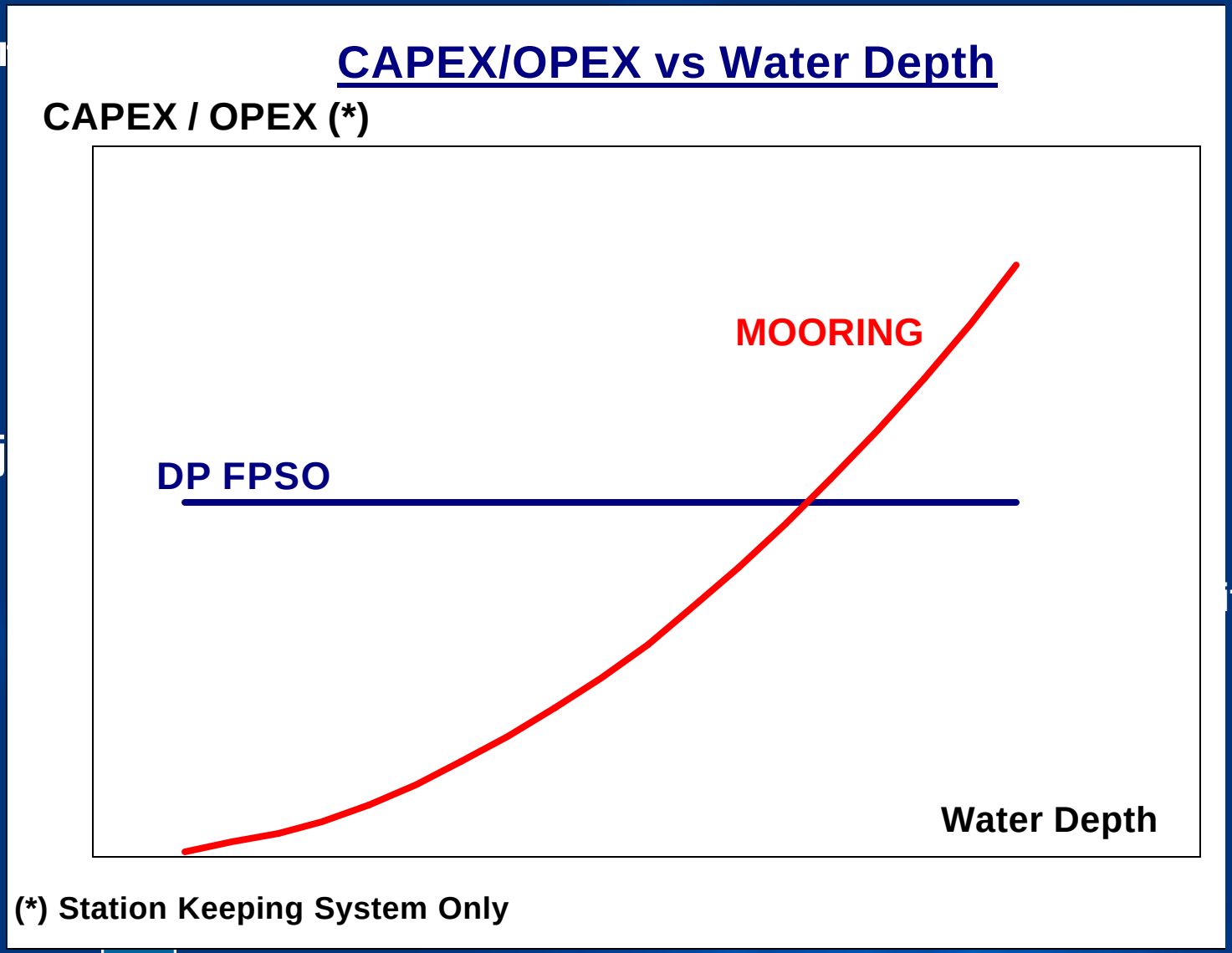
# Turret Moored FPSOs for Deep Water



IZAR MARIN DNV FMC EnergySystems

# DP FPSOs for Ultra Deepwater

- Joi
  - –
  - –
  - –
  - –
- Obj
  - –
  - –
  - –
  - –
  - –




ity

IZAR MARIN DNV FMC EnergySystems

# DP FPSO: Pros & Cons

## Advantages:

- Utilizes Proven Offshore Technology
- Adapts to Ultra-Deepwater
  - No anchor leg system
  - No interference with equipment on seabed
  - Deepwater allows large offsets – easier control
  - Hybrid riser system suited for ultra deep water
- Candidate for an Early Production System
- Diconnectability allows for Easy Evacuation during Hurricanes

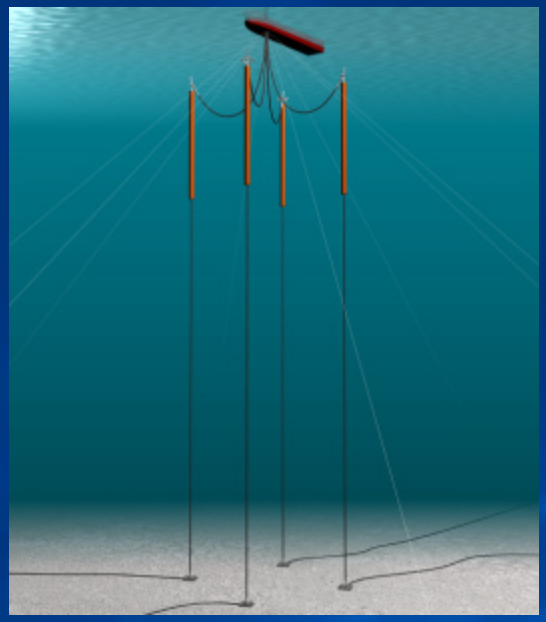
## Issues:

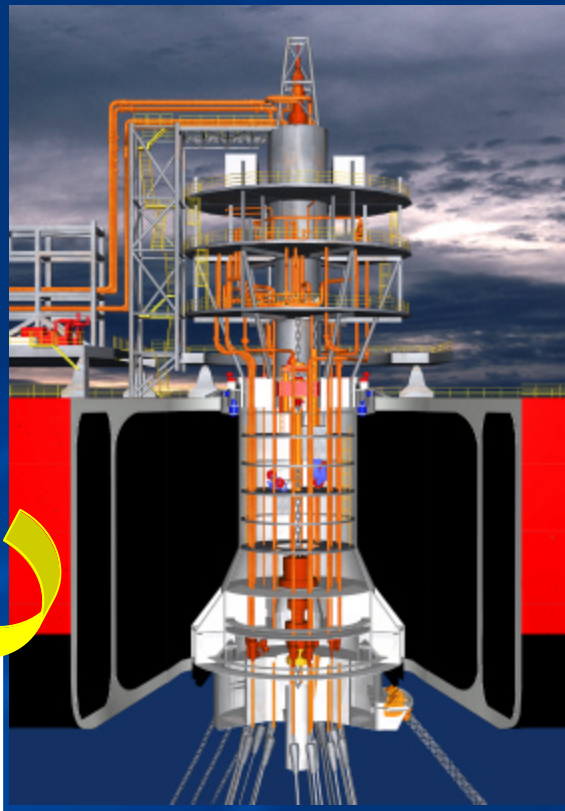
- Stationkeeping Reliability
  - Power generation system
  - Thrusters
  - Control system
  - Operators
- Disconnectable Riser System
- Maintenance
- Life of Field Costs

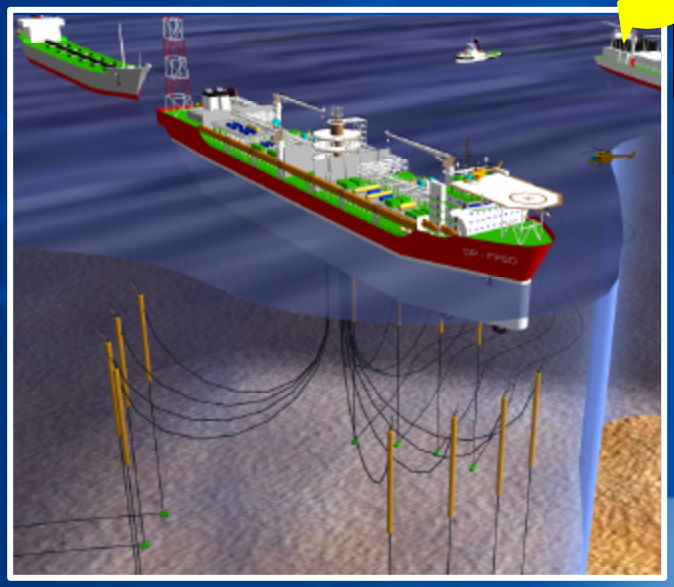
IZAR MARIN DNV

FMC EnergySystems

# DP FPSO: Integration of Proven Technology





IZAR MARIN DNV

FMC EnergySystems

# Hypothetical Field Design Basis

| Gulf of Mexico | |
|---|---|
| Water Depth | 2,500 m (8,200 ft) |
| Drill Centers | 3 |
| Oil Production Rate | 125,000 barrels/day |
| Production Risers | 6 x 12” PIP |
| Water Injection | 3 x 10” |
| Gas Injection / Gas Lift | 2 x 10” |
| Gas Export | 1 x 12” |
| Umbilicals | 4 |

IZAR MARIN DNV FMC EnergySystems

# Design Basis (continued)

- Vessel – 1,000,000 bbl storage
  - 20-year service life w/o dry-docking
- Offloading tankers around 500,000 bbl capacity
- Disconnectible Riser Turret
  - Controlled Disconnect: 12 hours
  - Emergency Disconnect: 15 – 30 minutes
- Environments representative of the Gulf of Mexico, West Africa & Brazil

IZAR MARIN DNV FMC EnergySystems

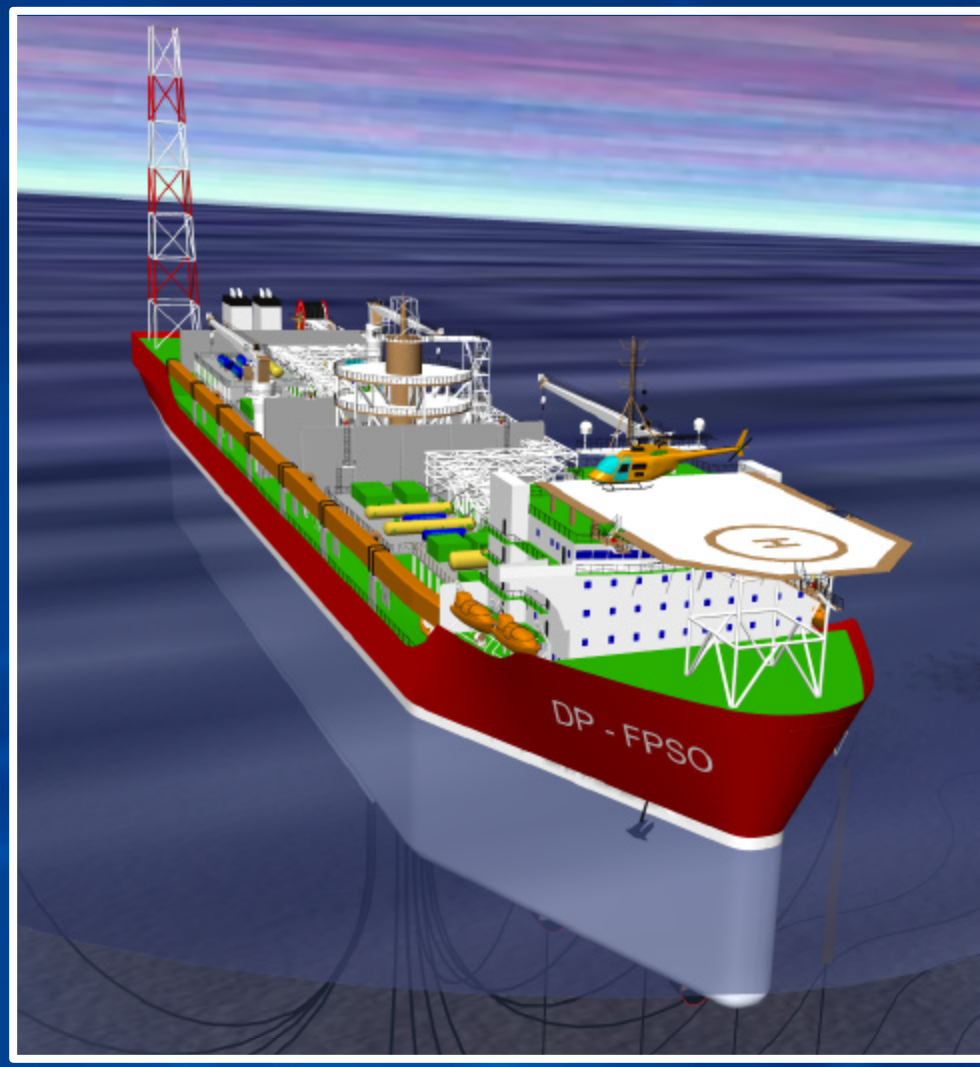
# Metocean Data for Design

| ENVIRONMENTAL CONDITIONS | NORMAL OPERATION | EXTREME OPERATION | | | OFFLOADING | DISCONNECTION | RECONNECTION |
|---|---|---|---|---|---|---|---|
| *Description* | 99% Exceedance GOM | Loop Current GOM | 10-year hurricane GOM | Squall WOA | 99% Exceedance GOM | 10-year hurricane GOM | 99% Exceedance GOM |
| *Significant Wave Height* | 4,0 m | 3,8 m | 8,6 m | 2,0 m | 4,0 m | 8,6 m | 4,0 m |
| *Peak Period* | 9,0 s | 9,0 s | 12,3 s | 6,0 s | 9,0 s | 12,3 s | 9,0 s |
| *Wind Speed* | 15 m/s | 15,0 m/s | 29,5 m/s | 30,0 m/s | 15 m/s | 29,5 m/s | 15 m/s |
| *Current Speed* | 0,35 m/s | 2,13 m/s | 1,0 m/s | 0,35 m/s | 0,35 m/s | 1,0 m/s | 0,35 m/s |

IZAR MARIN DNV FMC EnergySystems

# DP FPSO Vessel

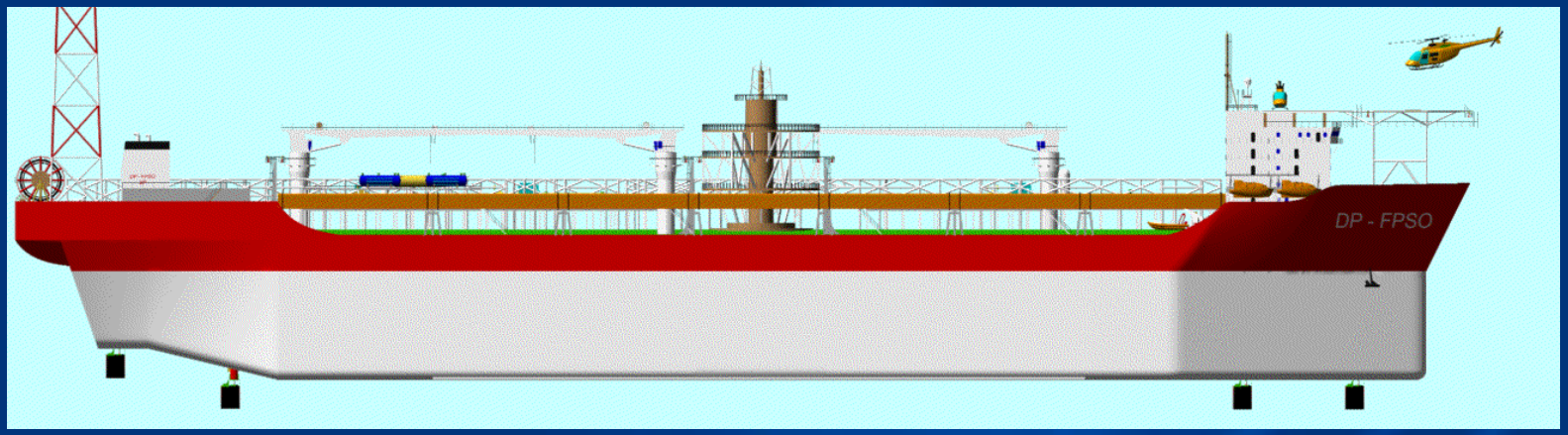
- Displacement: 190,000 MT
- Length: 260 meters
- Breadth: 46 meters
- Depth: 28 meters
- Storage: 1 million bbls




IZAR MARIN DNV

FMC EnergySystems

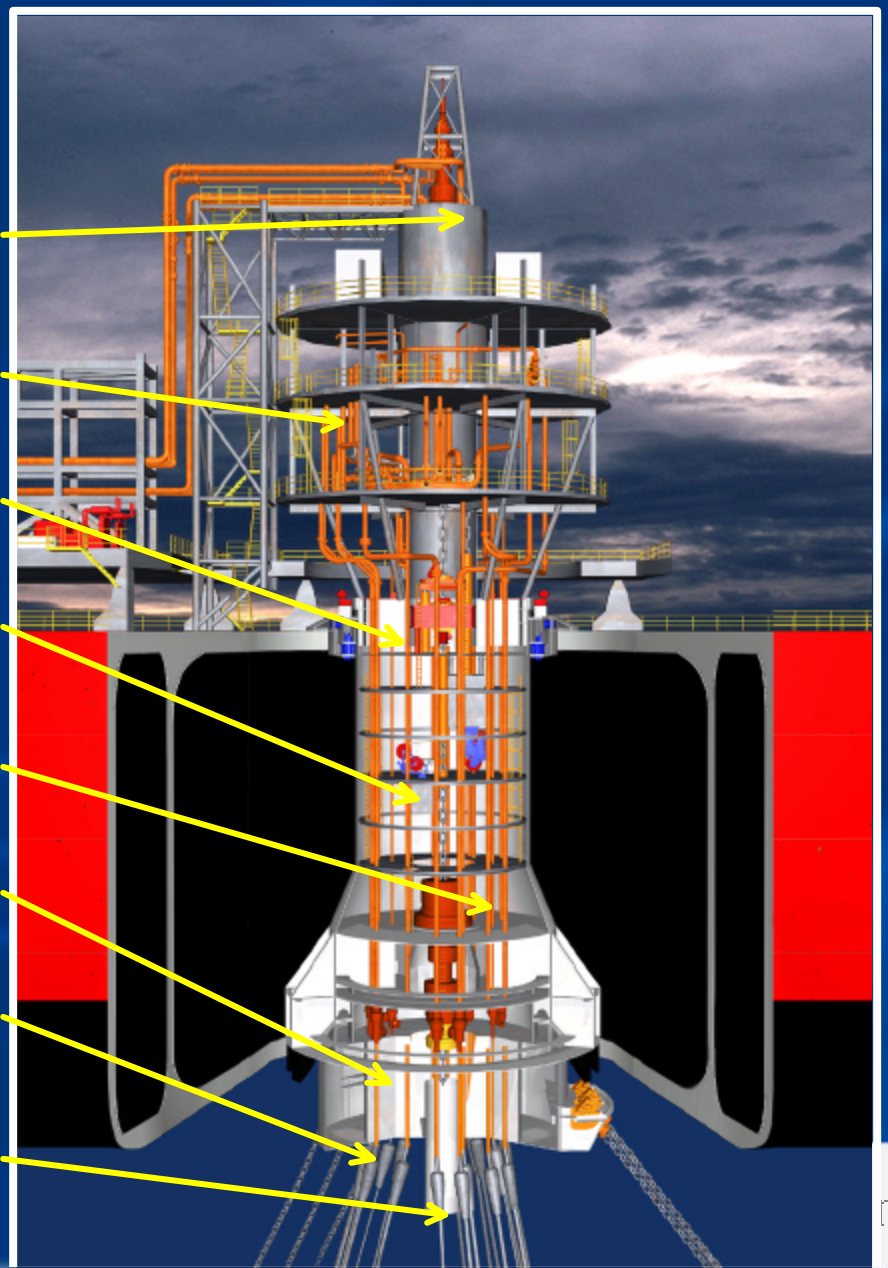
# StationKeeping System




- DNV Notation “DYNPOS AUTRO” (IMO Class 3)
- 6 Azimuthing Thrusters (5 MW each)
  - Single failure results in 2 forward and 2 aft thrusters available
  - Overhauling of all thrusters possible in machinery space
- Redundant  Power Generation and Switchboards
  - Dual Fuel Turbines and Dedicated  Diesel Generators

IZAR MARIN DNV FMC EnergySystems

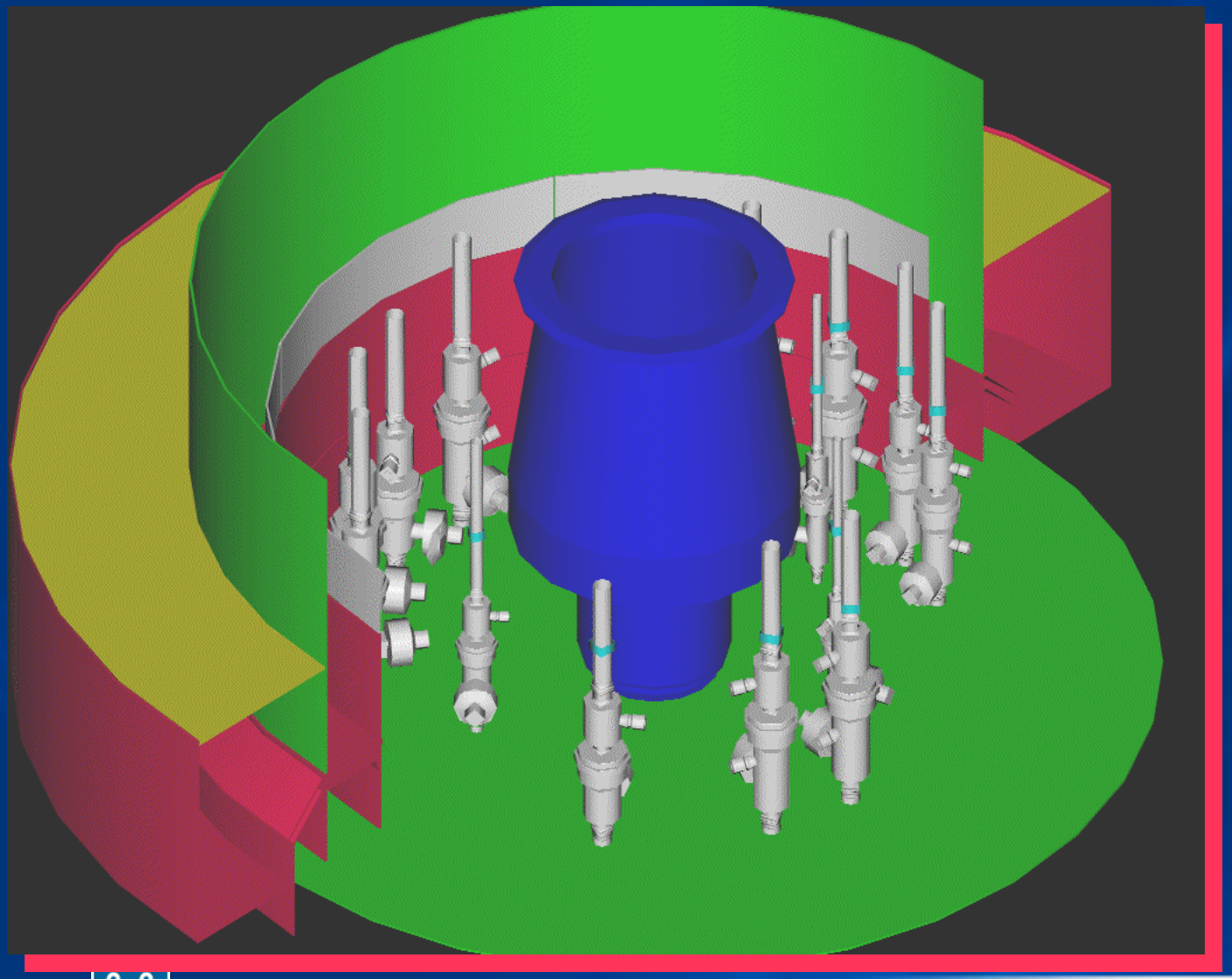
# Terra Nova Disconnectable Turret System




IZAR MARIN DNV

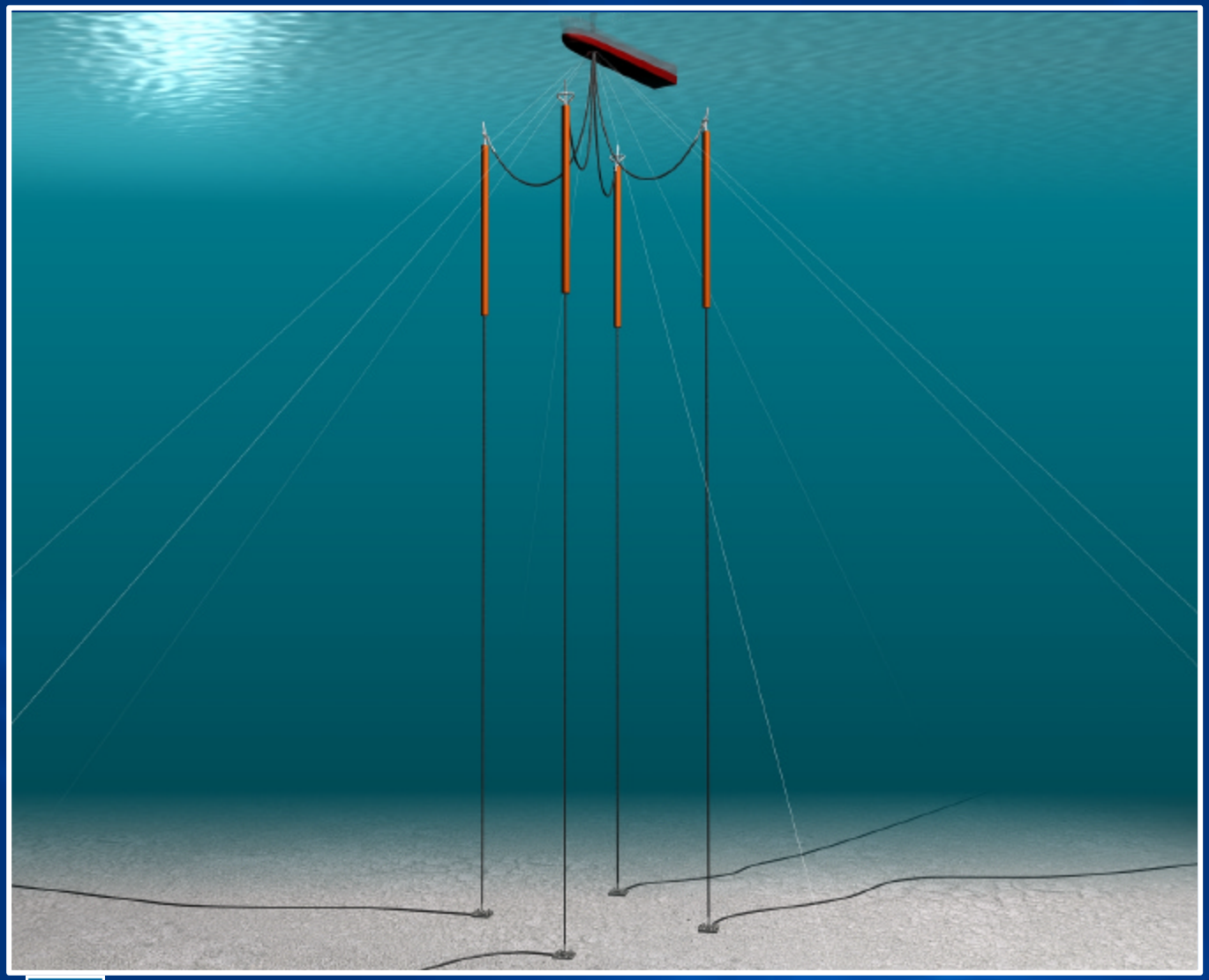
nergySystems

# Turret – Buoy Interface



IZAR MARIN DNV FMC EnergySystems

# Single Leg Riser System



IZAR MARIN DNV FMC EnergySystems

# System Feasibility & Stationkeeping Performance Evaluation

- Numerical Simulations
  - MARIN program DPSIM for System Stationkeeping
  - FE program OrcaFlex for Riser Buoy System performance
- Model Tests
  - Conducted at MARIN's deepwater Offshore Basin
  - Complete Physical Model including DP-thruster system
- Workshops with Industry
  - Feedback on Offshore Operations
  - Concerns & Focus

IZAR MARIN DNV FMC EnergySystems

# Stationkeeping Time Domain simulations

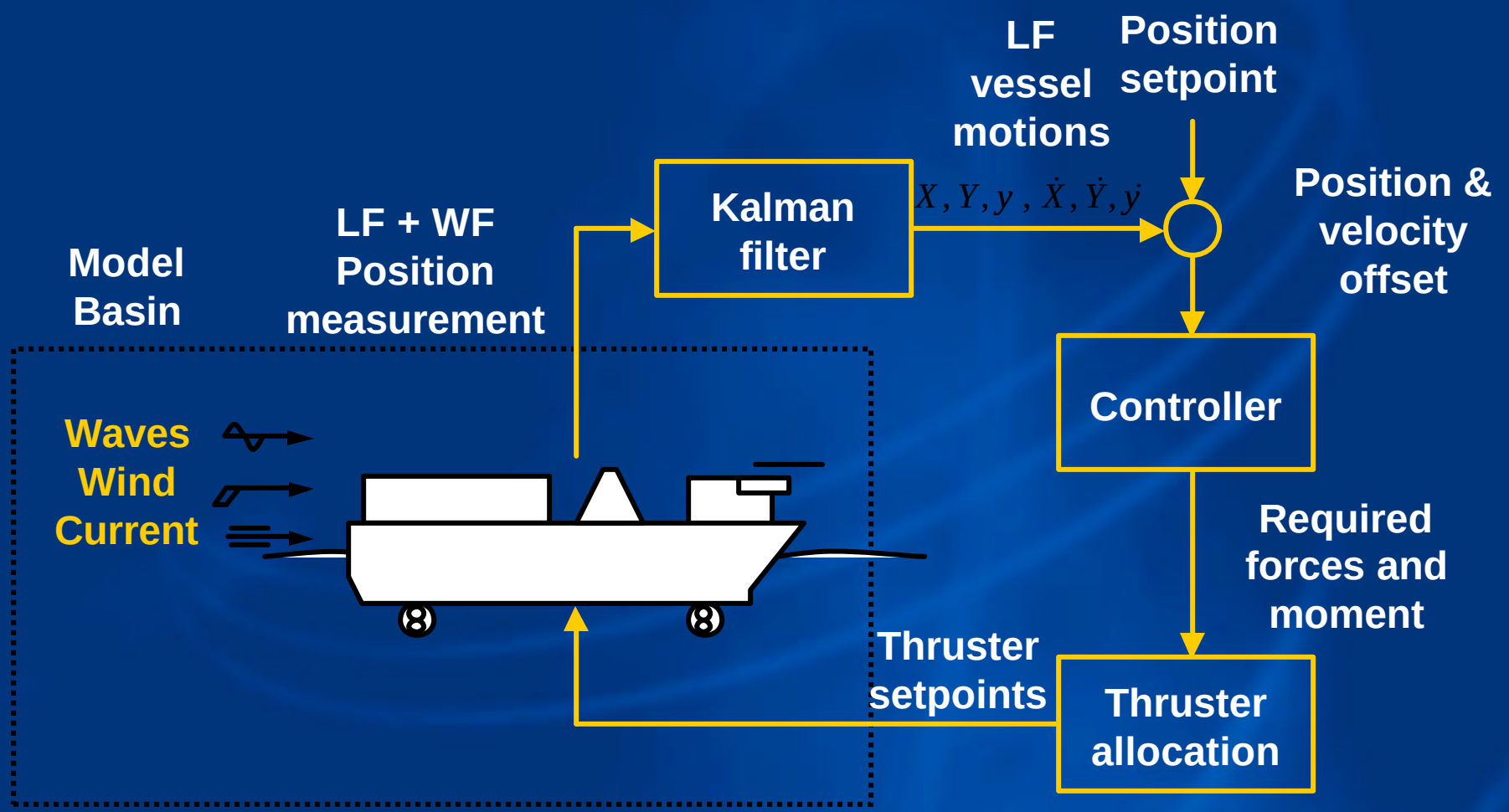
- Initial Evaluation of DP-Thruster System Performance
  - Thruster lay-out and allocation
  - Evaluation of stationkeeping performance
  - Focus model test program
- Initial settings for DP control coefficients
- Comparison with model test results
- Final Design simulations after input data updated

# DP FPSO Model Tests

- Full Physical Model
- Waves, Wind and Current (collinear and crossed)
- DP Control System including Kalman filter (RUNSIM)
- Six Azimuthing Thrusters
- Riser System and Buoy Modelled
  - Disconnect and Reconnect of Buoy-Riser System
- Tandem Offloading to tankers of opportunity
- Measurement of LF & WF vessel motions, Thruster loads and Riser loads

IZAR MARIN DNV FMC EnergySystems

# DPSIM/RUNSIM Control Loop



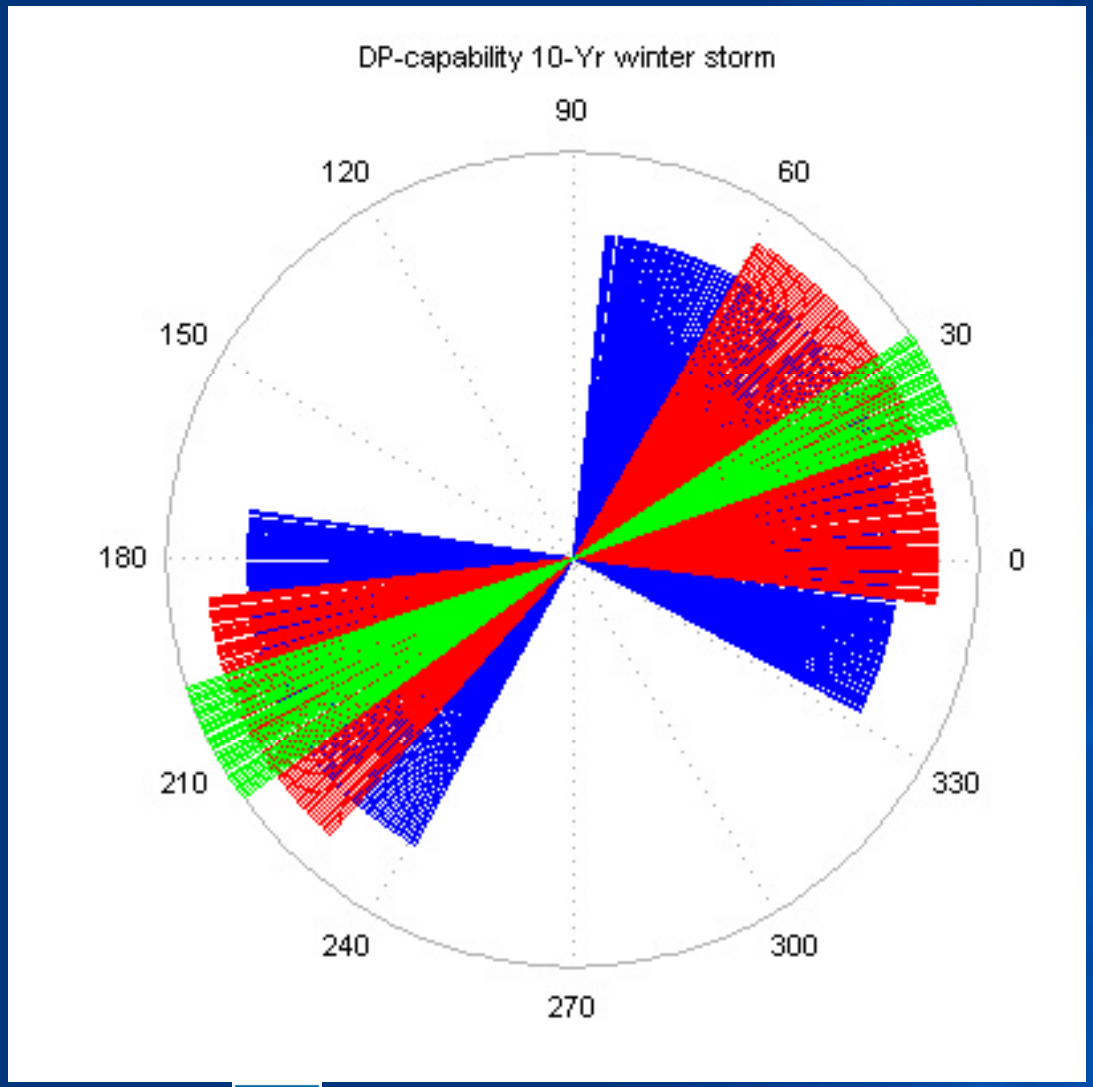

IZAR MARIN DNV

FMC EnergySystems

# Thruster Allocation Algorithm

- Minimum power (minimum emissions)
- Delivery of required forces and moment
- Based on LaGrange multipliers
- Forbidden zones applied to minimize thruster interaction effects and interaction with risers

# Theoretical DP Capability Plot: 10-Year Winter Storm




- 6 Thrusters
- 4 Thrusters
- 2 Thrusters

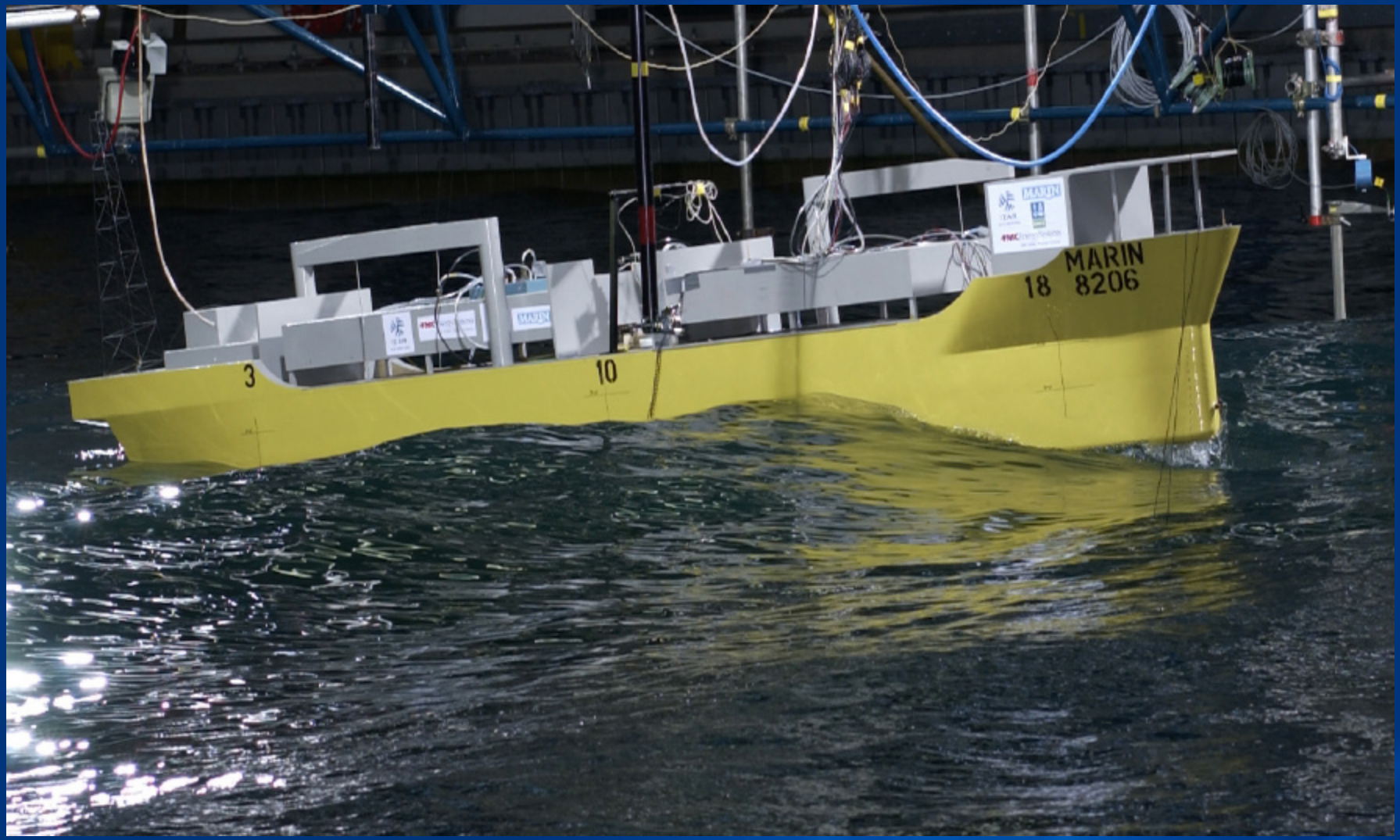
**Hs=5.8m, Tp=10.6s**
**Wind = 20 m/s**
**Current = 0.6 m/s**

IZAR MARIN DNV FMC EnergySystems

# DP FPSO Model (1:60)

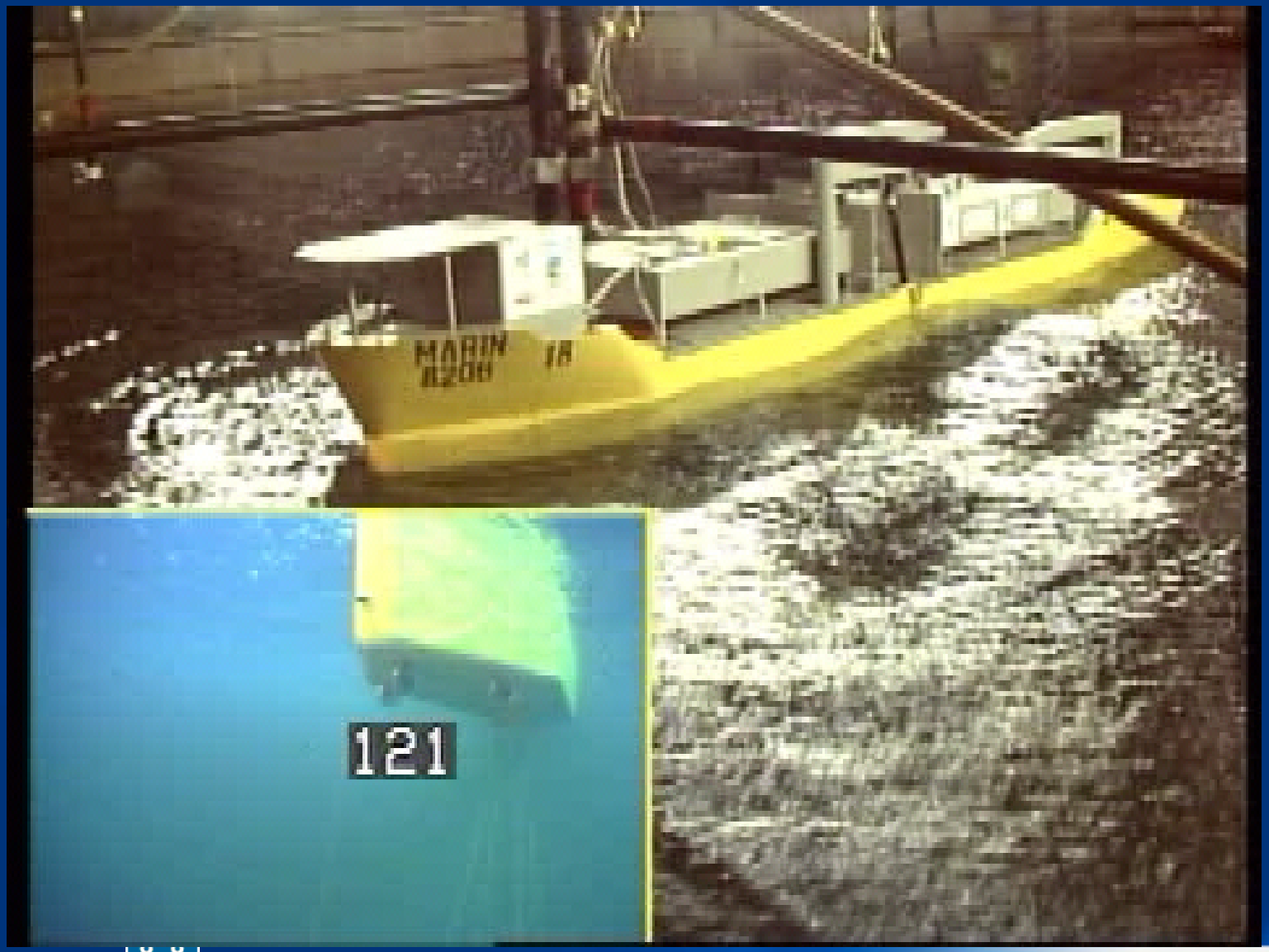

IZAR MARIN DNV FMC EnergySystems

# DP FPSO in 10-Year Hurricane Condition



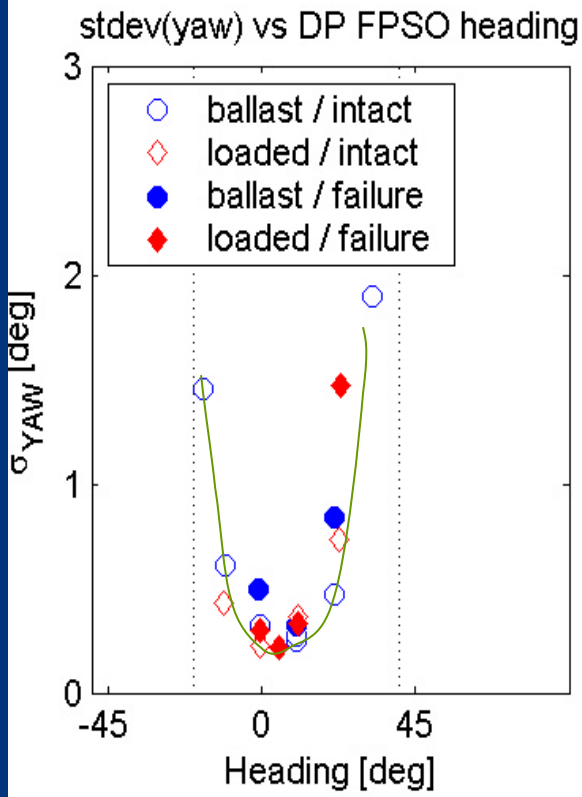

IZAR MARIN DNV FMC EnergySystems

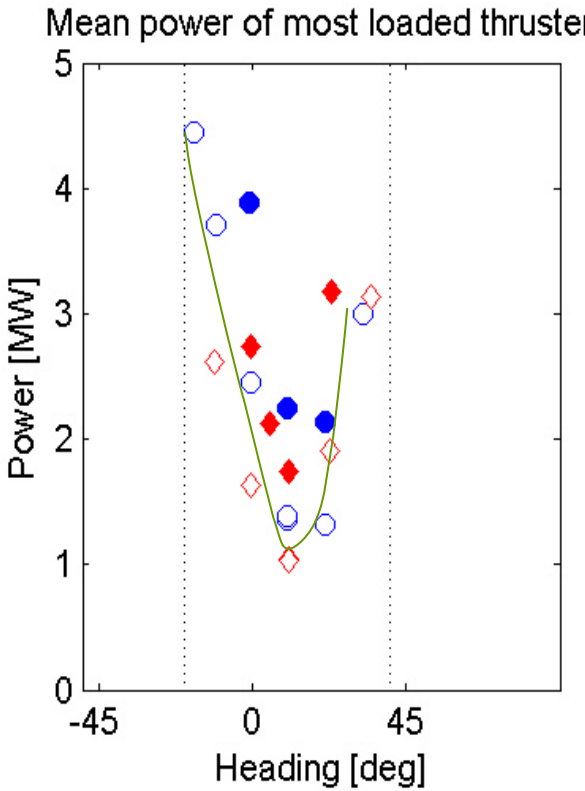
# 10-Year Winter Storm

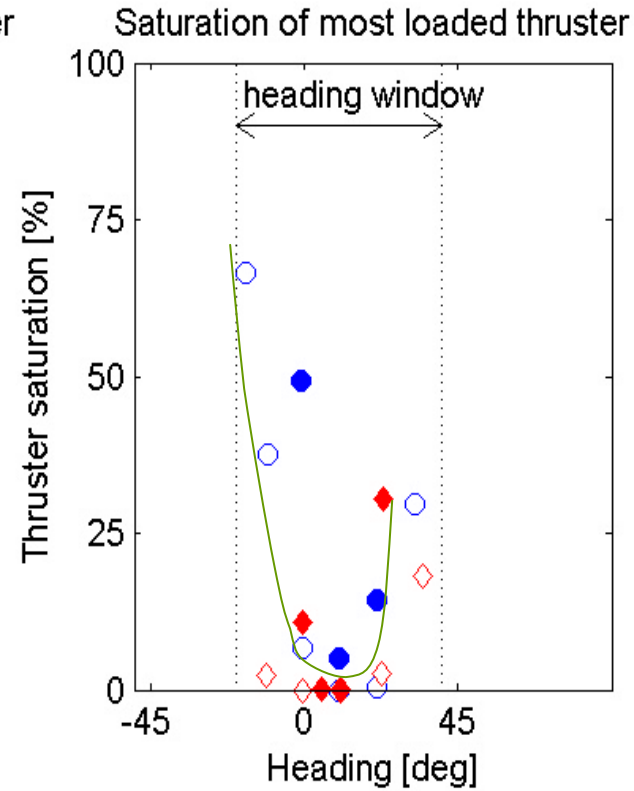



IZAR MARIN DNV FMC EnergySystems

# DP Performance: 10-Year Winter Storm




IZAR MARIN DNV

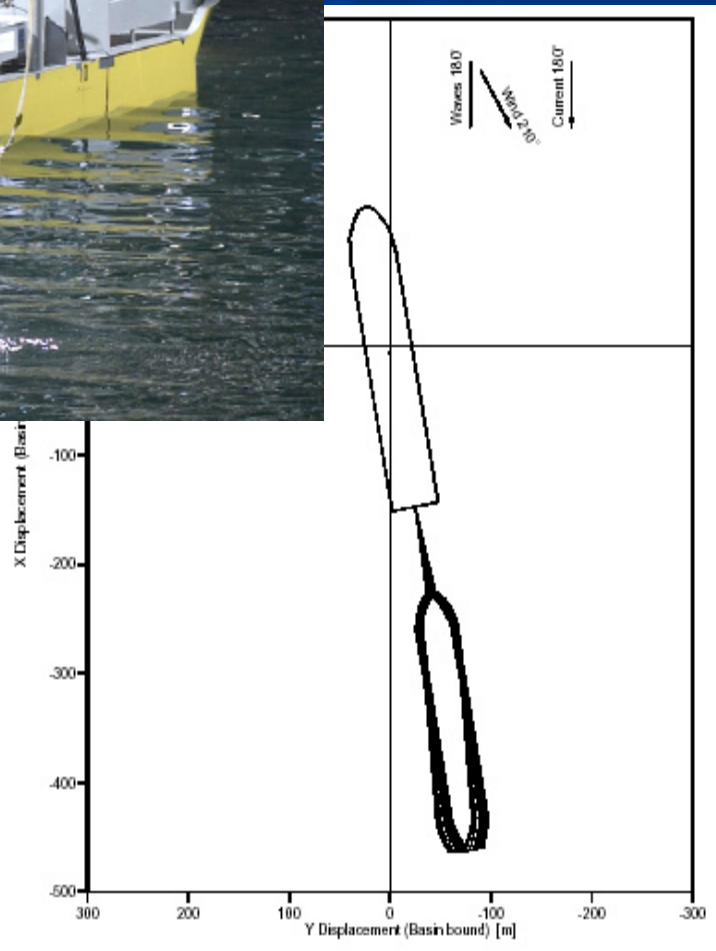
FMC EnergySystems

# Observations: DP Performance in Severe Seastates

- Heading window assessment for all tested sea states
- Excellent DP performance in operational conditions
  - For operational sea states (£ 99% exceedence):
  - Large heading window possible
  - Mean power consumption < 3 MW
- Ability to deal with maximum single failure ( 2 thrusters) for seastates up to 10-Year Winter Storm
- Acceptable DP performance in survival conditions
  - Intact System Offset less than 7% of water depth
  - 10-Year Hurricane + damaged condition results in drift-off

IZAR MARIN DNV FMC EnergySystems

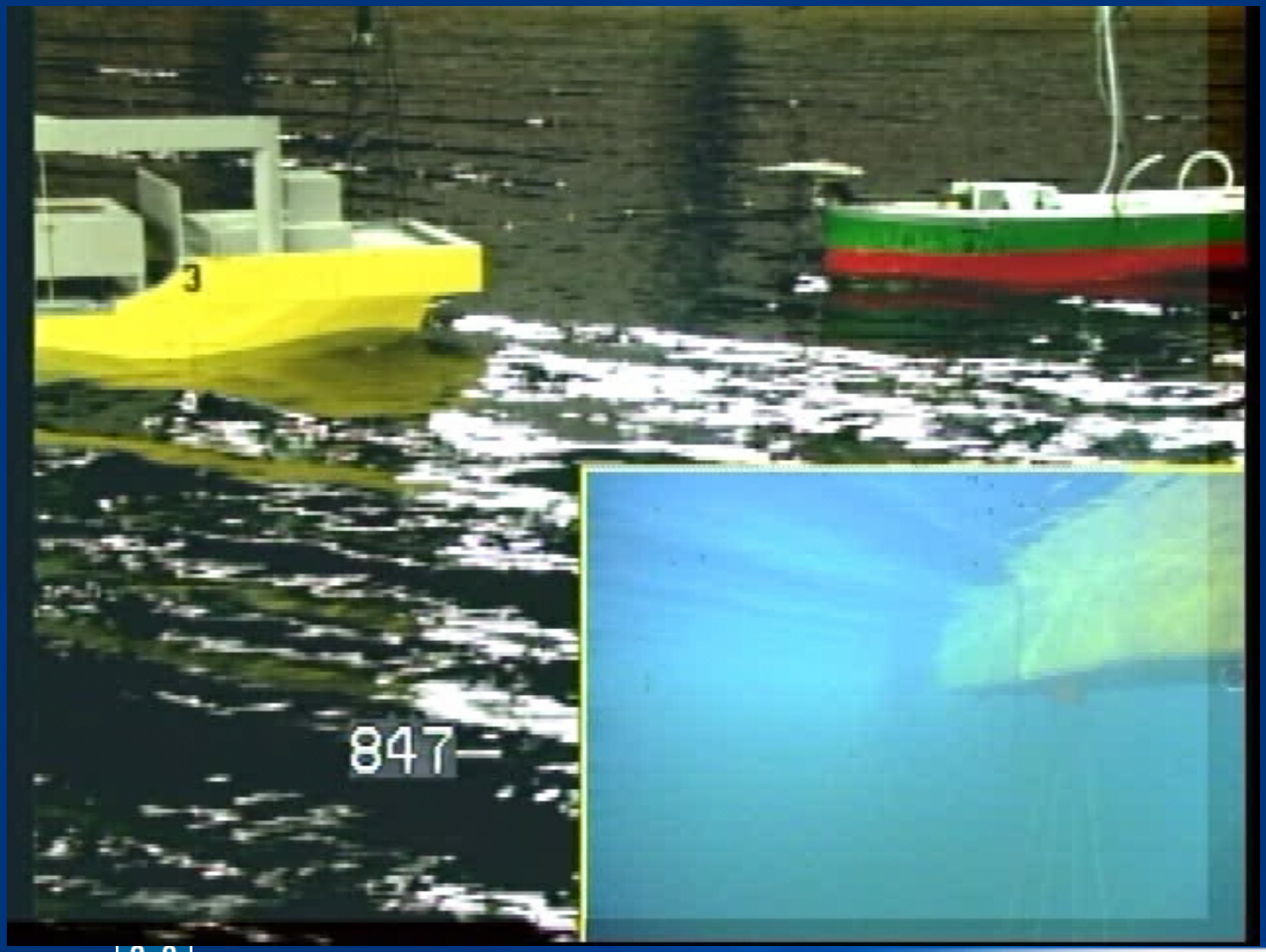
# Offloading to shuttle tanker


**Hs=4.0m, Tp=9.0s**
**Wind = 15 m/s**
**Current = 0.4 m/s**

IZAR MARIN DNV

# Offloading to Tanker

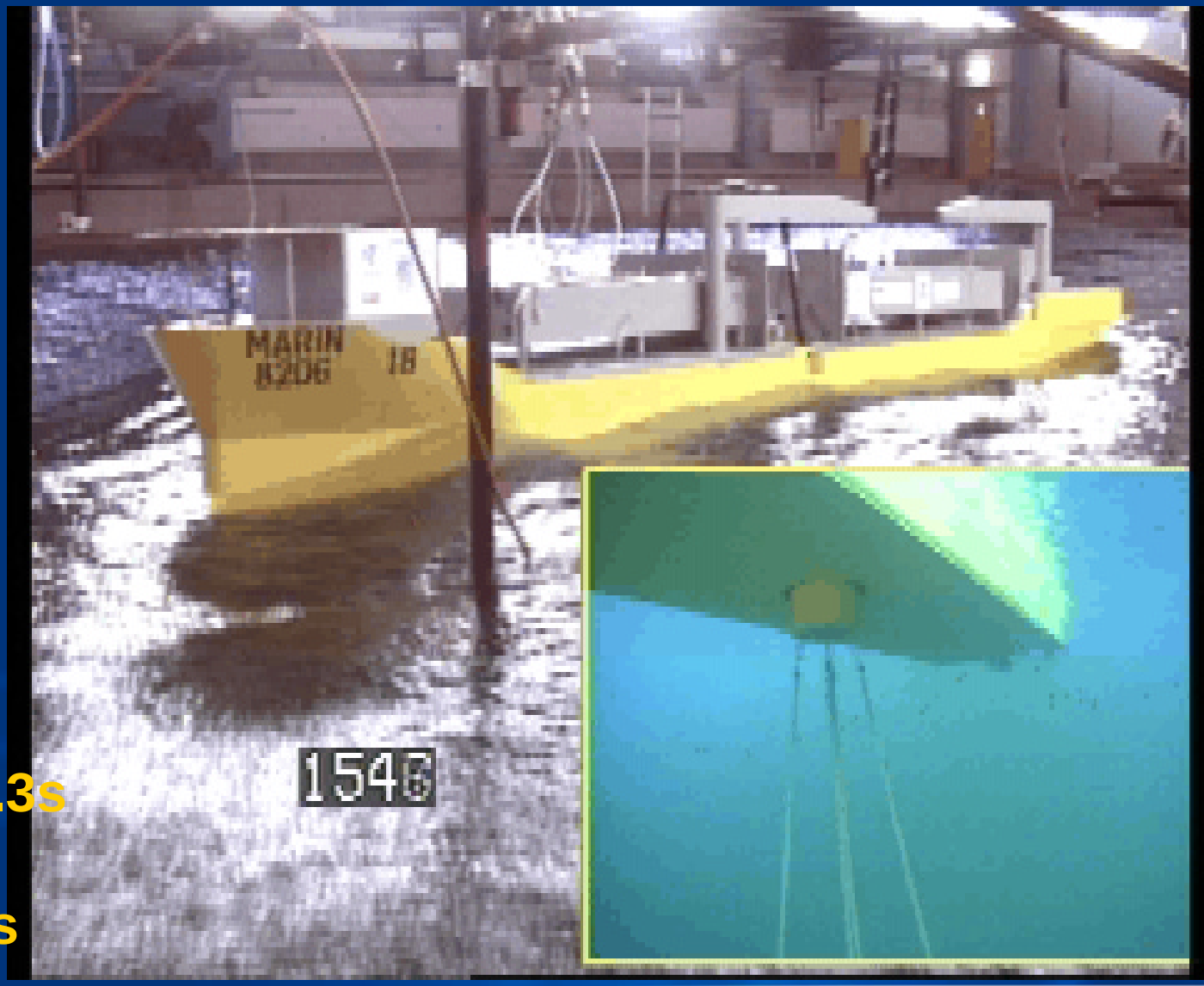


# Observations: Offloading Model Test

- Conservative Case Tested: conventional shuttle tanker with back thrust only
- Offloading possible in sea states up to Hs = 4 m
- Only 4 thrusters needed
  - redundancy for maximum single failure
- Possible to select FPSO heading to minimize:
  - bow hawser loads
  - shuttle tanker motions

IZAR MARIN DNV FMC EnergySystems

# Riser Disconnection in 10-Yr hurricane




**Hs=8.6m, Tp=12.3s**
**Wind = 30 m/s**
**Current = 1.0 m/s**

IZAR MARIN DNV

FMC EnergySystems

# Observations: Disconnectable Buoy Tests

- Predictable behaviour of buoy during disconnection
  - Orcaflex FE model predicts behavior very well
- No impact between Buoy and FPSO in 10-Year Hurricane Environment
- Minimal Overshoot of Final Buoy Position after Disconnection
- Disconnected Behavior of Buoy-Riser System as Predicted
- Reconnect possible in 4 m sea state (99% exc)
- No issues during reconnect procedure (high loads, interference)

IZAR MARIN DNV FMC EnergySystems

# Conclusion: Technical Feasibility Demonstrated

- Integration of Proven Technology
- Stationkeeping performance demonstrated for a variety of harsh operating conditions and system failure scenarios
- FPSO Vessel designed to allow easy Maintenance and Replacement (if necessary) of Thrusters
- Adequate Redundancy in Thrusters and Power Generation
- Detailed Risk & Reliability Study in Progress
  - Initial finding is that specific design elements of proposed system has reduced risk of failure compared to existing DP vessels

IZAR MARIN DNV FMC EnergySystems

# Current & Future Work

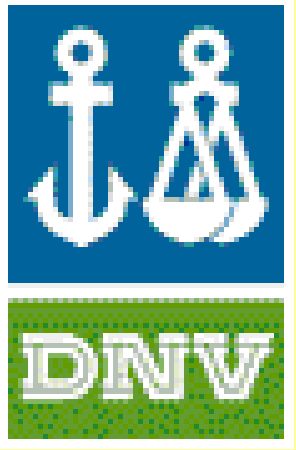
- **Complete Detailed Design of DP FPSO Specific Components**
  - **Final Numerical Simulations**
  - **FPSO Vessel Design almost complete (current focus on power generation optimization)**
  - **Optimization of Disconnectable Riser-Turret System**
- **Develop Costs (+/-15%) for DP vs Passive Turret Moored FPSO**
  - **Capital Expenses**
  - **Operational Expenses**
  - **Life of Field Costs**

IZAR MARIN DNV FMC EnergySystems


IZAR


MARIN


DP
FPSO


DNV


FMC EnergySystems
FMC SOFEC Floating Systems