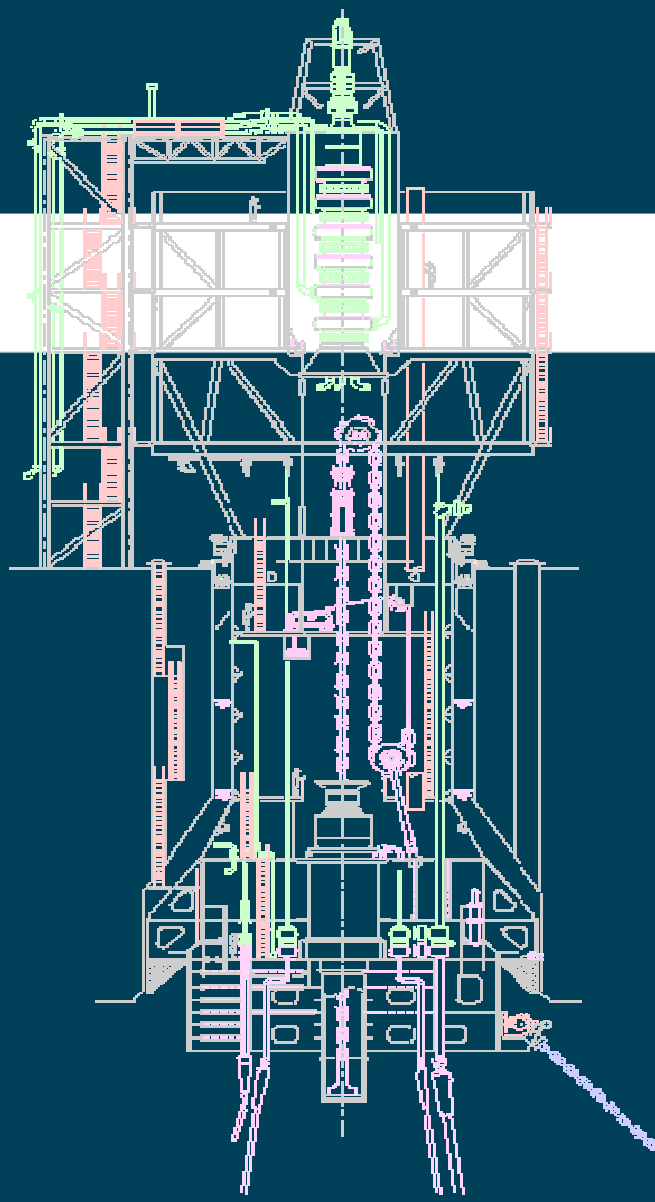
FMC Technologies

Disconnectable Turret Mooring Systems for Deep Water



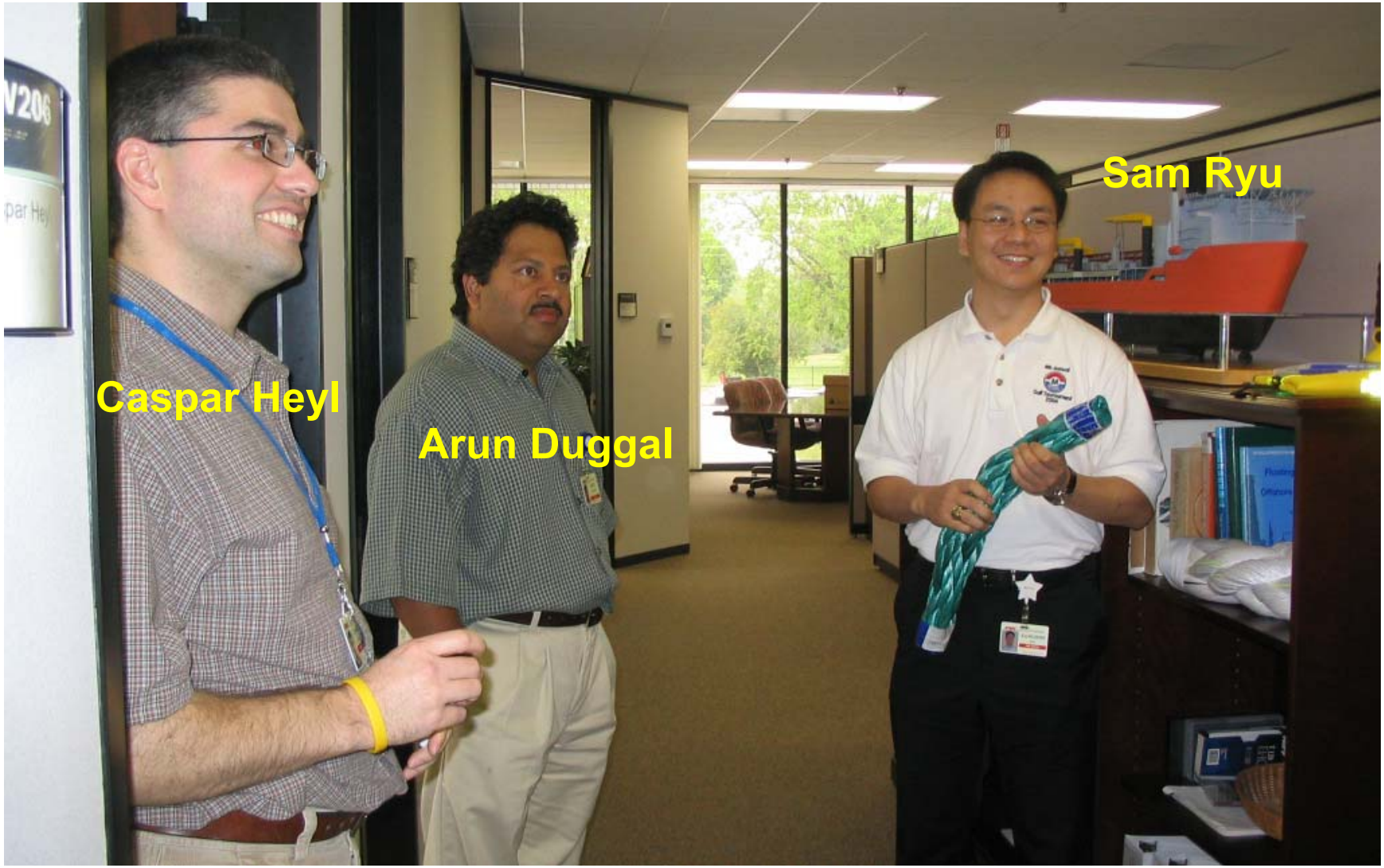
2006 ISOPE San Francisco, California

May 30, 2006

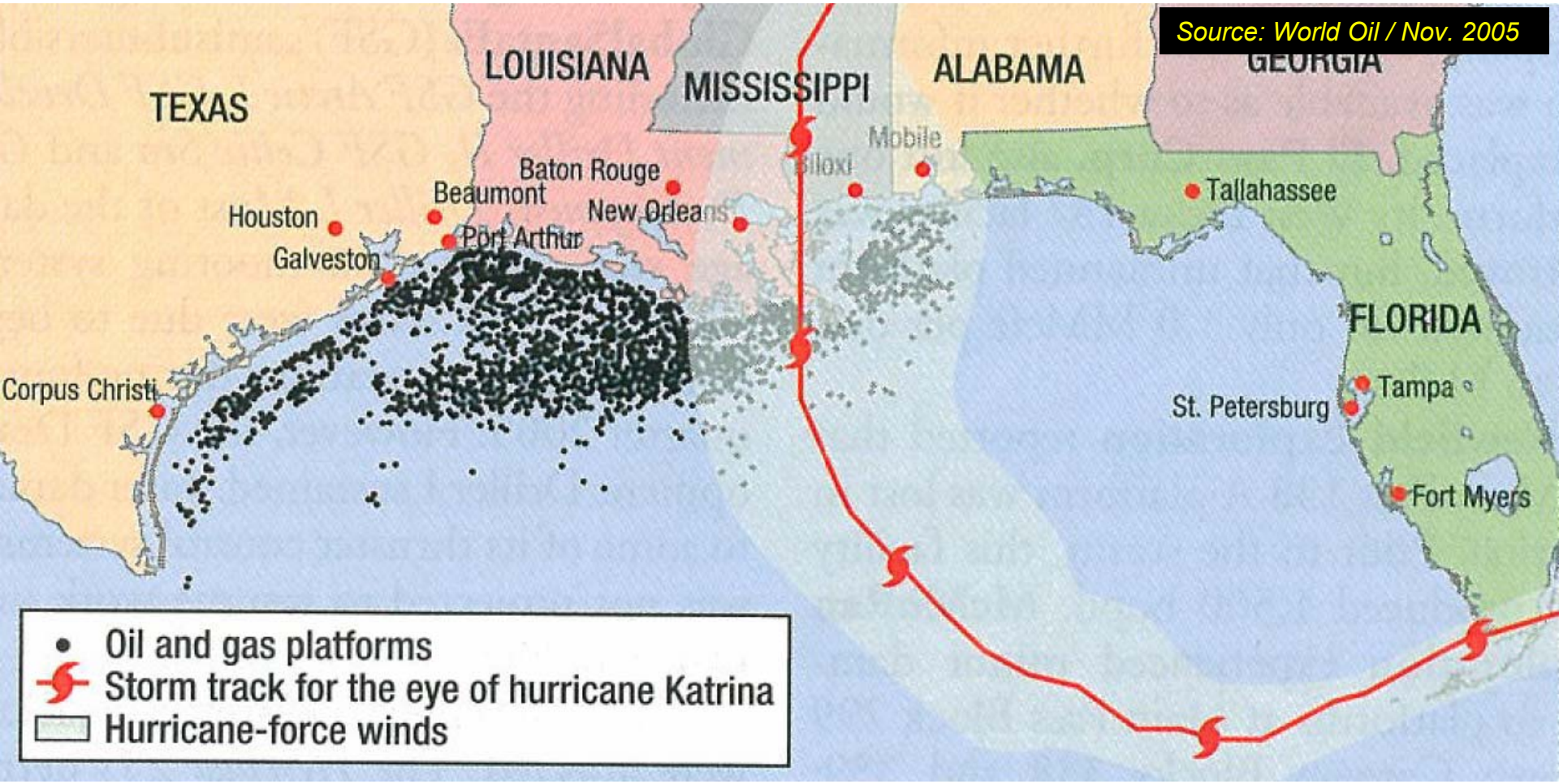
Arun Duggal, Sam Ryu, and Caspar Heyl

R&D, FMC Technologies Floating Systems

Co-authors at FMC Floating Systems



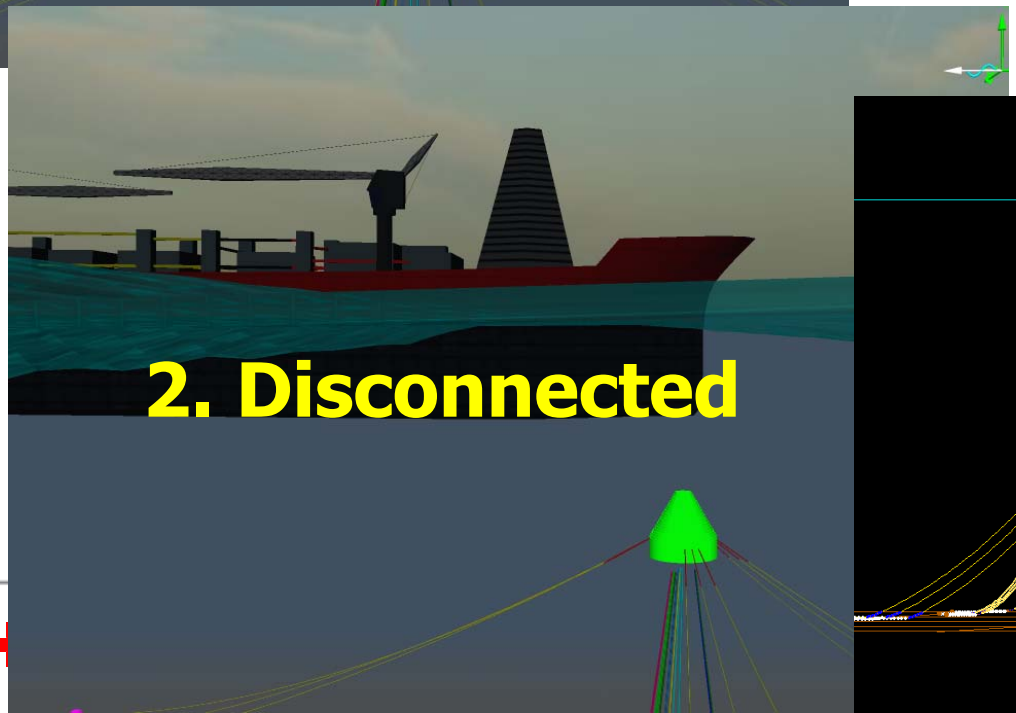
Hurricane Katrina

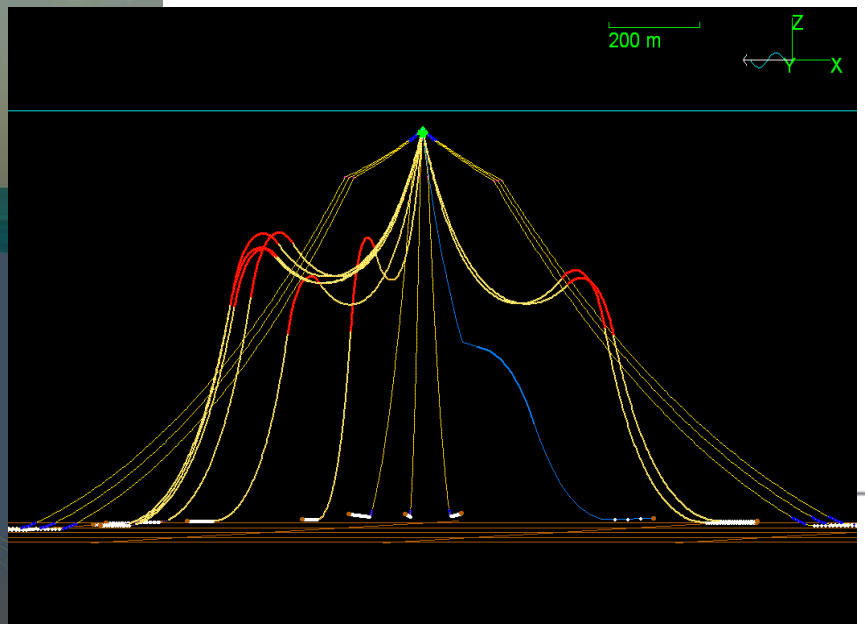


With the large number of hurricanes in the GOM the DTM concept is being looked at with strong interest


1. Buoy Disconnect


3. Buoy Reconnect


2. Disconnected


200 m
Z
Y
X

Introduction

- Disconnectable turret mooring systems being in use since late 1980's offshore Australia and SE Asia
- Two disconnectable systems off the Grand Banks to avoid Icebergs.
- Excellent history of performance in both SC sea and Australia
- JHN system installed in 1993 has disconnected over 20 times
- MODEC/FMC currently building the first deepwater disconnectable system for Stybarrow

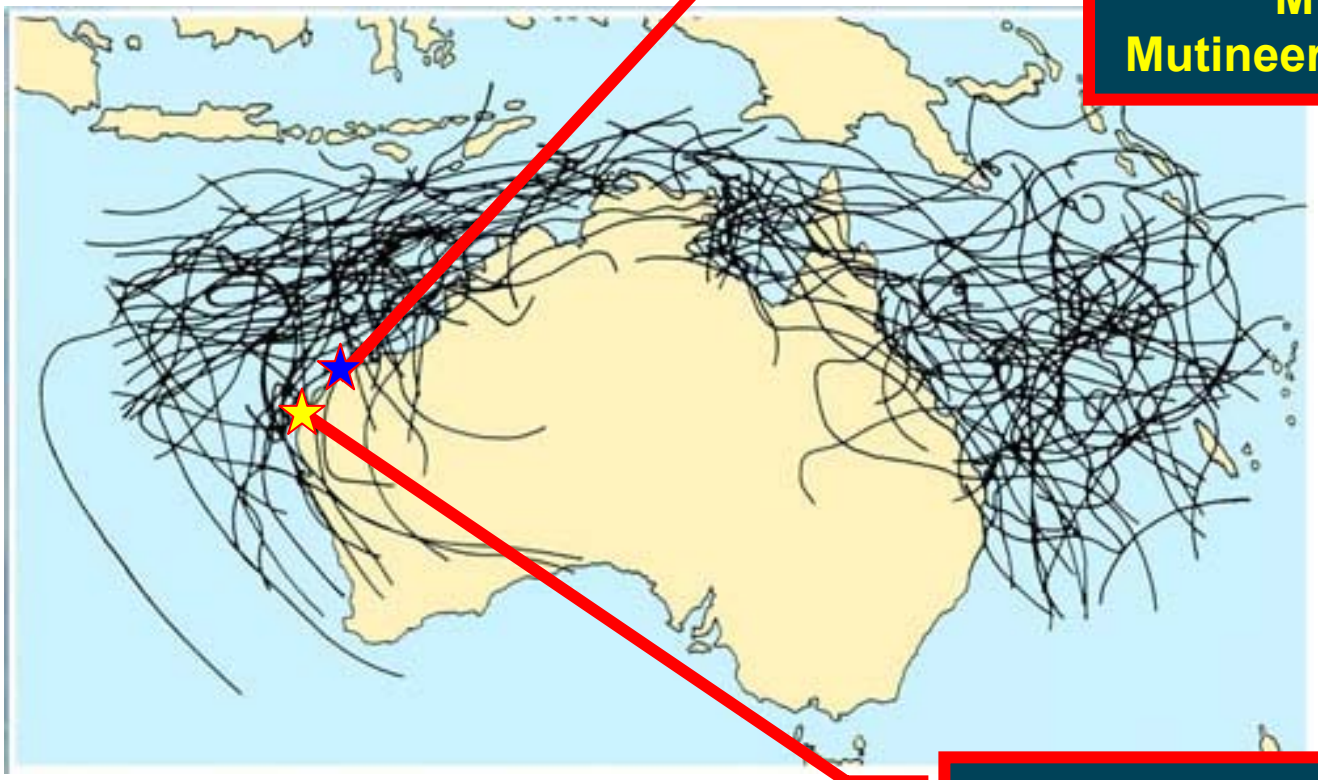
Existing Disconnectable Turret Mooring Systems

- JHN Lufeng 13-1, South China Sea
- 20 disconnects in 13 yrs

- Santos Ltd – MV11 Mutineer-Exeter Australia
- 5 disconnects in year 2006

- Terra Nova Canada

Cyclones around Australia



Research has shown that cyclones in the Australian region exhibit more erratic paths than cyclones in other parts of the world. A tropical cyclone can last for a few days or up to two or three weeks. Movement in any direction is possible including sharp turns and even loops.

Reference: Australian Government, Bureau of Meteorology http://www.bom.gov.au/info/cyclone/#severity

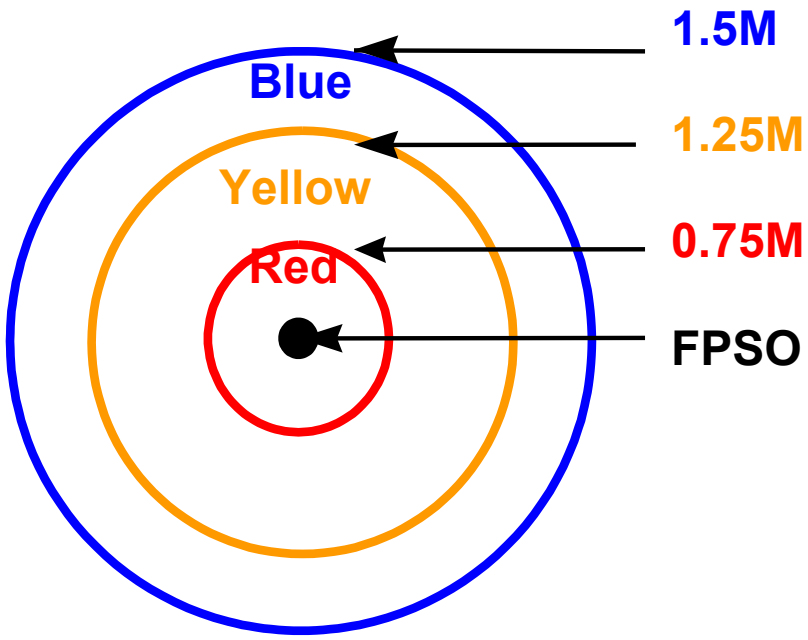
Cyclones over Mutineer/Exeter Field

Name	Period	Max Category
• Clare	Jan 7-10 2006	3
• Daryl	Jan 18-23 2006	2
• Emma	Feb 27-28 2006	1
• Floyd	March 21-26 2006	4
• Glenda	March 27-31 2006	5
• Hubert	April 6-7 2006	2

Cyclone Phase Boundaries

$$M = (K + N) \times V$$

Category	K
Tropical Low	10
1	12
2	16
3	20
4	22
5	24



Example) A category 3 cyclone moving at 10 knots,
time required to sail to safe area is 12 hours.

$M = (20 + 12) \times 10 = 320$

Blue = 1.5 M = 480 nautical miles = 890km

Yellow = 1.25 M = 400 nautical miles = 740km

Red = 0.75 M = 240 nautical miles = 440km

Emergency Procedures

- **Blue**

✓ A plan for preparation for disconnection

✓ A ballast plan

✓ A plan for evacuating non-essential personnel

- **Yellow**

✓ Shutdown production

✓ Prepare to disconnect from DTM

✓ Proceed with ballast plan

- **Red**

✓ Disconnect from DTM

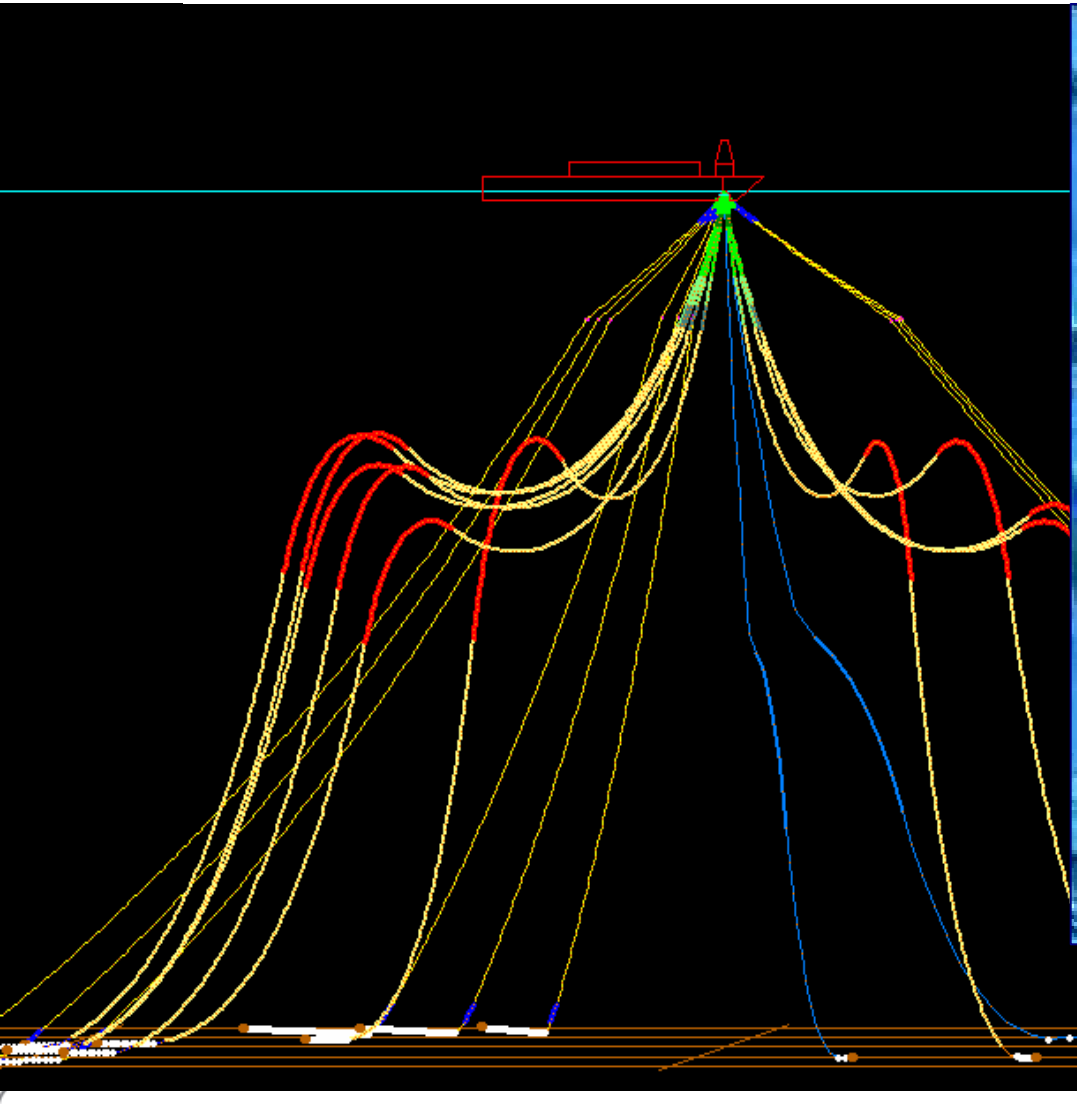
Safety Case

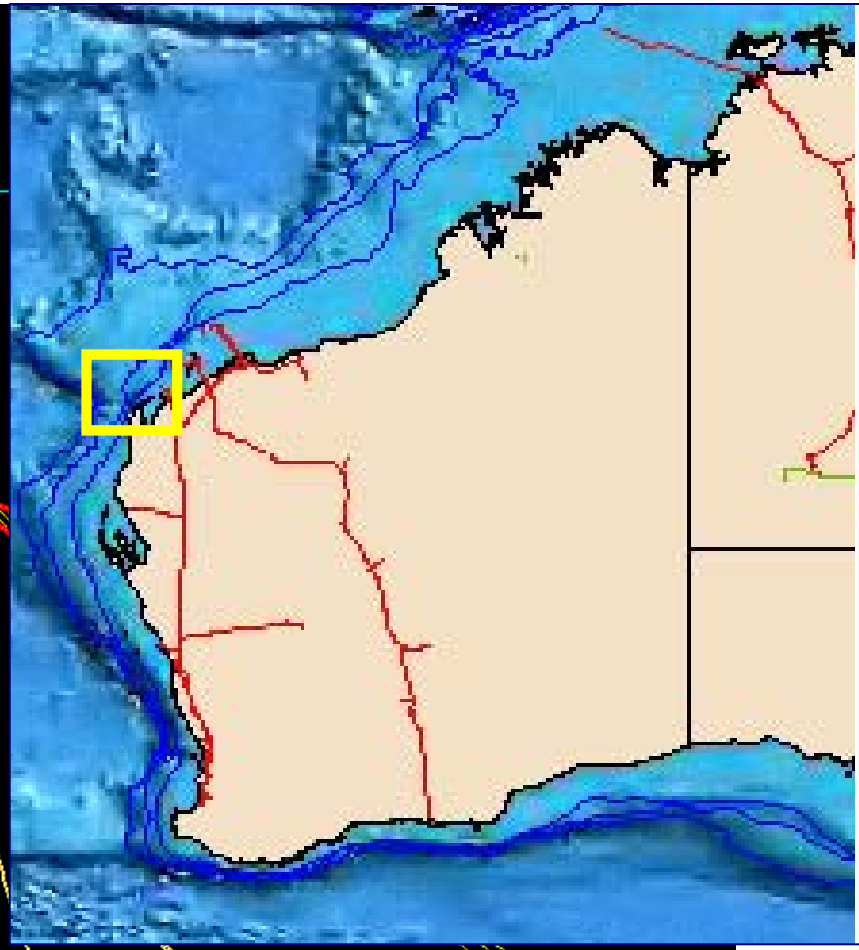
- **A 12 hour period for shutting down production and preparing the FPSO is included in the definition of Cyclone / Storm alert phases.**
- **Preparations for disconnect commence when a Yellow Alert is declared. Notwithstanding this, the OIM may raise alerts and implement relevant alert procedures at any time.**
- **The decision to disconnect is made by the Master / Operations Supervisor.**

Clare

Under Construction:
Boundary radii and sail-away course to be informed by MV11

Stybarrow FPSO System
Disconnectable Turret Mooring System





Stybarrow Venture MV16 Disconnectable Internal Turret Mooring

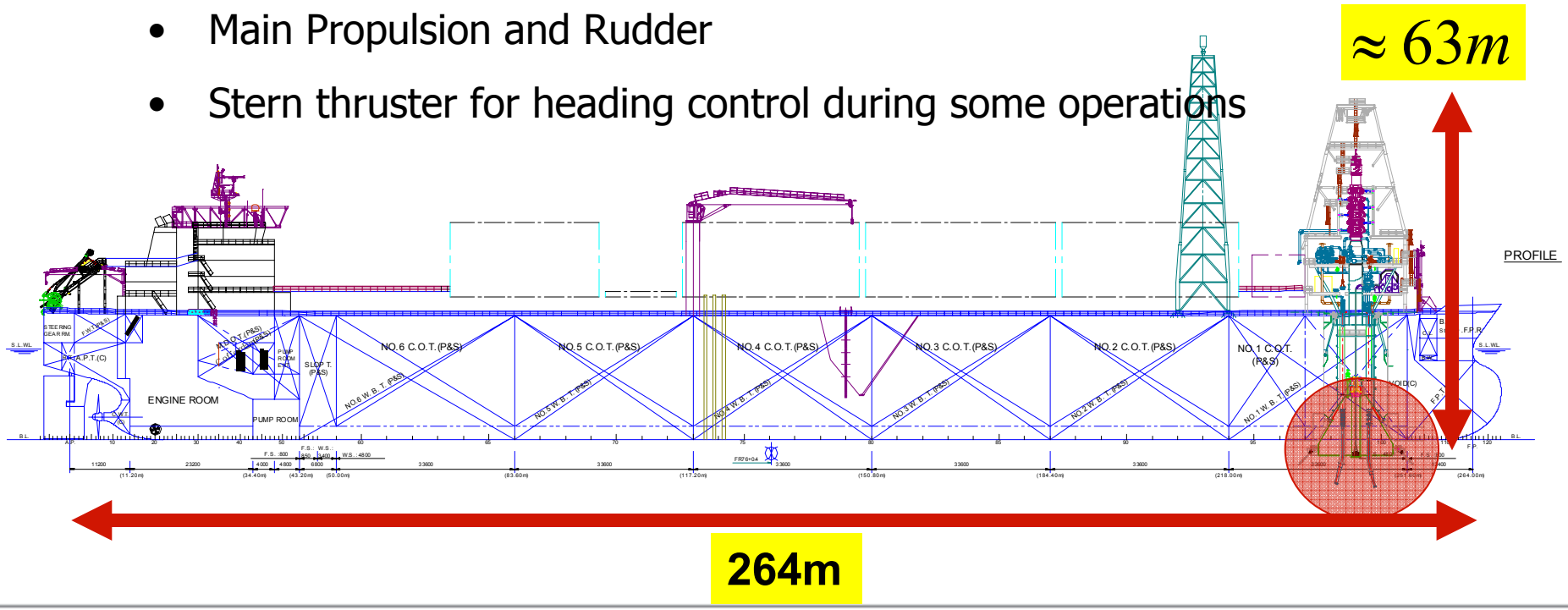
- BHP Billiton Petroleum Pty. Ltd. (Client
- Stybarrow Field, Southern Carnarvon Basin, Australia
- 150,000 dwt FPSO Stybarrow Venture MV16
- Water depth 2,706-feet (825m)
- Installaltion planned for 2008

Global Analysis Basic Design Basis

- FPSO to disconnect from mooring and risers to avoid cyclones
- FPSO to stay on station during the 100-year non Cyclonic (winter) storm
- 12 risers and umbilicals
- 15 year design Life
- Mooring system design
  - maintain adequate offsets for riser system
  - optimize mooring, riser and spider buoy system to meet spider buoy and turret requirements

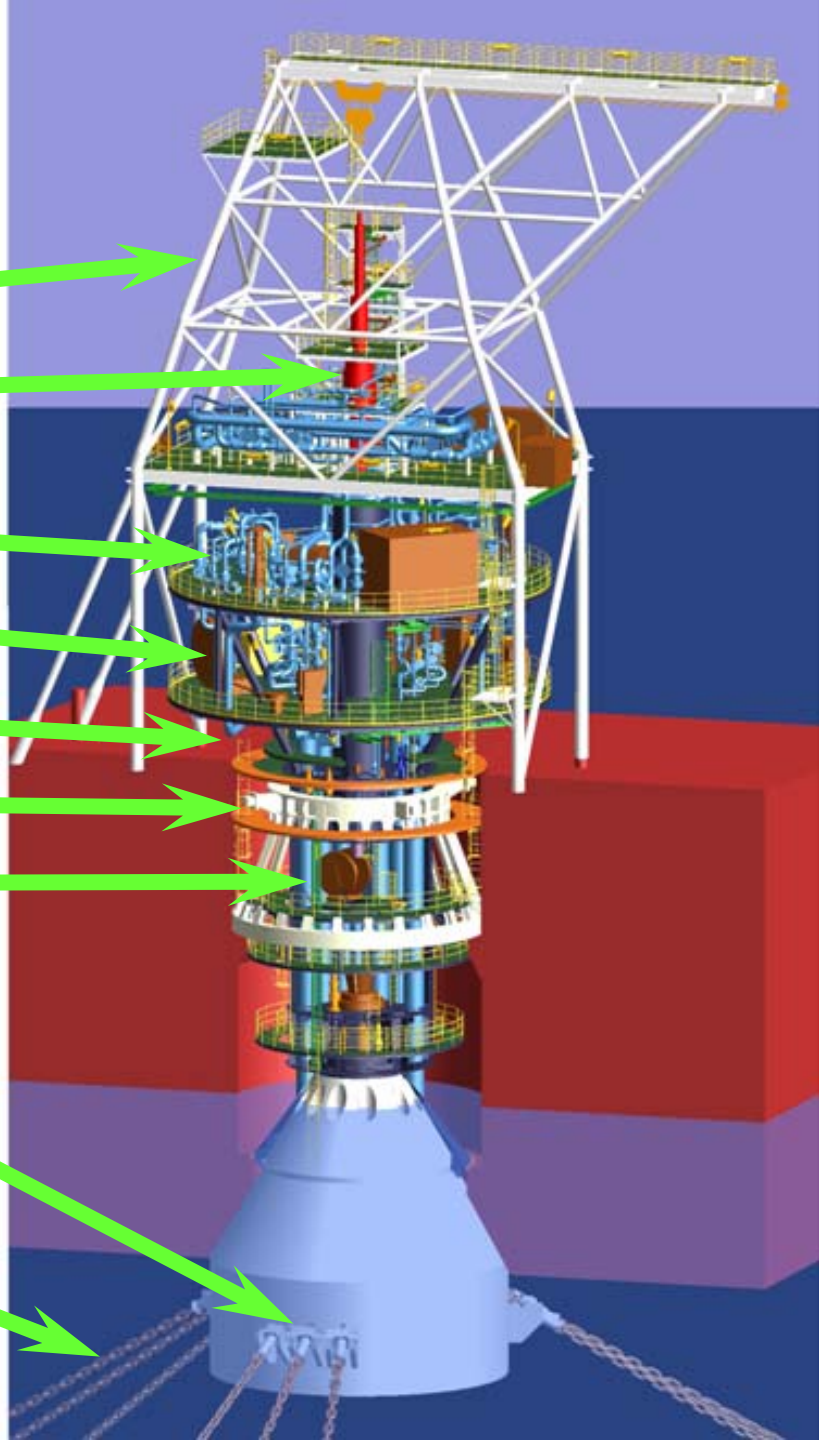
Stybarrow FPSO Vessel Particulars

- Newbuild vessel
  - LBP = 264m, Beam = 48m, Depth = 23.2m
  - Maximum Displacement = 181,000 MT
- Turret Location:110m forward of midship
- Bilge Keels: 115m long, 0.8 m wide
- Main Propulsion and Rudder
- Stern thruster for heading control during some operations



Turret Structure

- Swivel Access Structure
- Swivel Stack
- Manifold Piping
- Upper Turret Structure
- Riser Deck
- Bearing
- Turret Shaft
- Chain Support Assembly
- Anchor Legs



FMC Technologies

Things to be considered…

- Buoy Disconnect from FPSO
- Disconnected Buoy Motions
- Buoy Reconnect Analysis

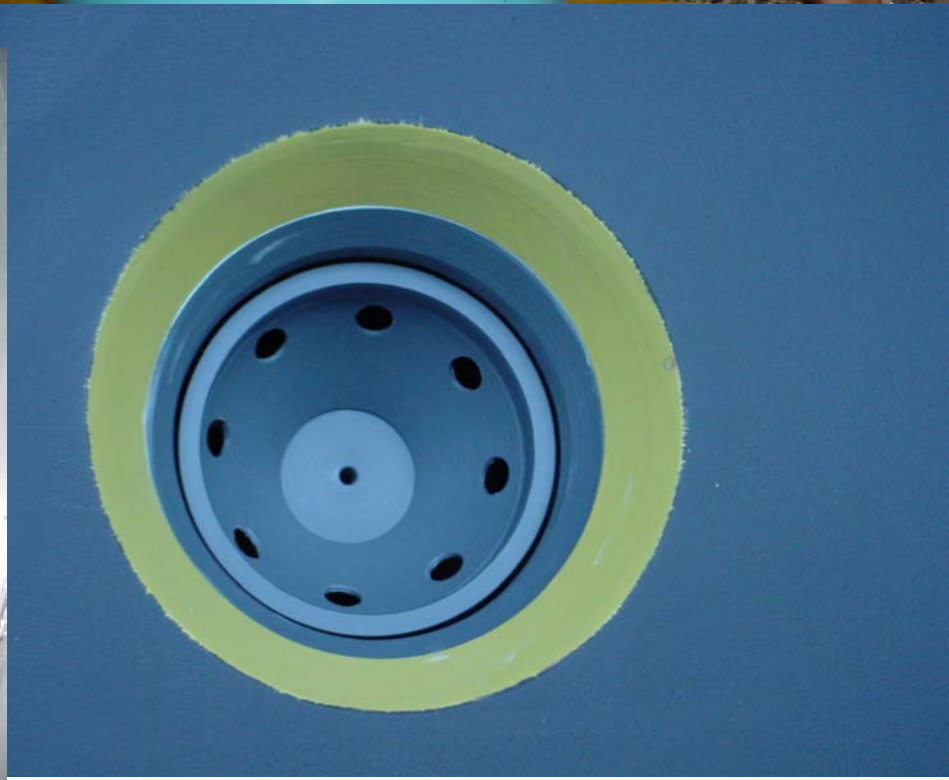
Design Environmental Criteria

- FPSO Connected
  - 100-year non cyclonic (winter storm): contour – governing seas
  - Cyclone environment: Hs=6m with associated wind and current
  - Maximum Offloading Seastate: Hs=3.5m with associated wind and waves
- Maximum Disconnect Environment
  - Cyclonic storm: Hs=6m, Tp=11.3 sec, Vw=19.5m/s, Vc=0.8m/s
- Maximum Reconnect Seastate
  - Hs = 3.0m with associated wind and waves
- Disconnected Buoy
  - Design: 100-year Cyclonic Storm: Hs=12.6m, Tp=14.1sec
  - Survival: 10,000-year Cyclonic Storm: Hs=17.3m, Tp=16.5 s

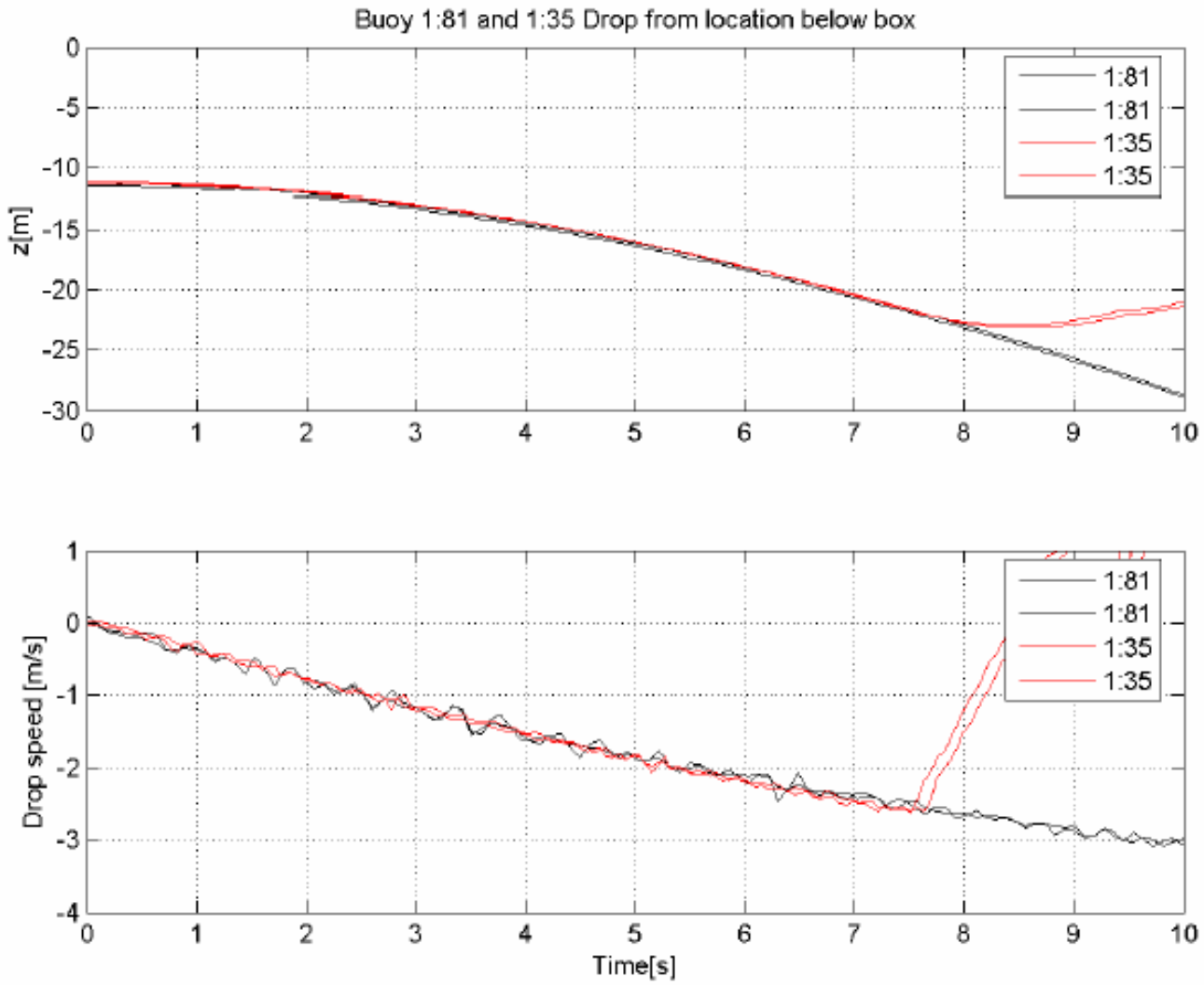
Spider Buoy Particulars

- Maximum Diameter: 14 m
- Height: ~14.7 m
- Estimated Displacement
- Estimated Weight
- Design Net Buoyancy (mooring and risers)
  - Riser Payload
  - Mooring Payload
  - Total MG load included in above
  - Spider Buoy MG load
- Water Ballast System for controlling net buoyancy
- Design Depth Static (to top of buoy) = 30 m
- Maximum Design Depth (bottom) = 90 m

Spider Buoy Drop Test



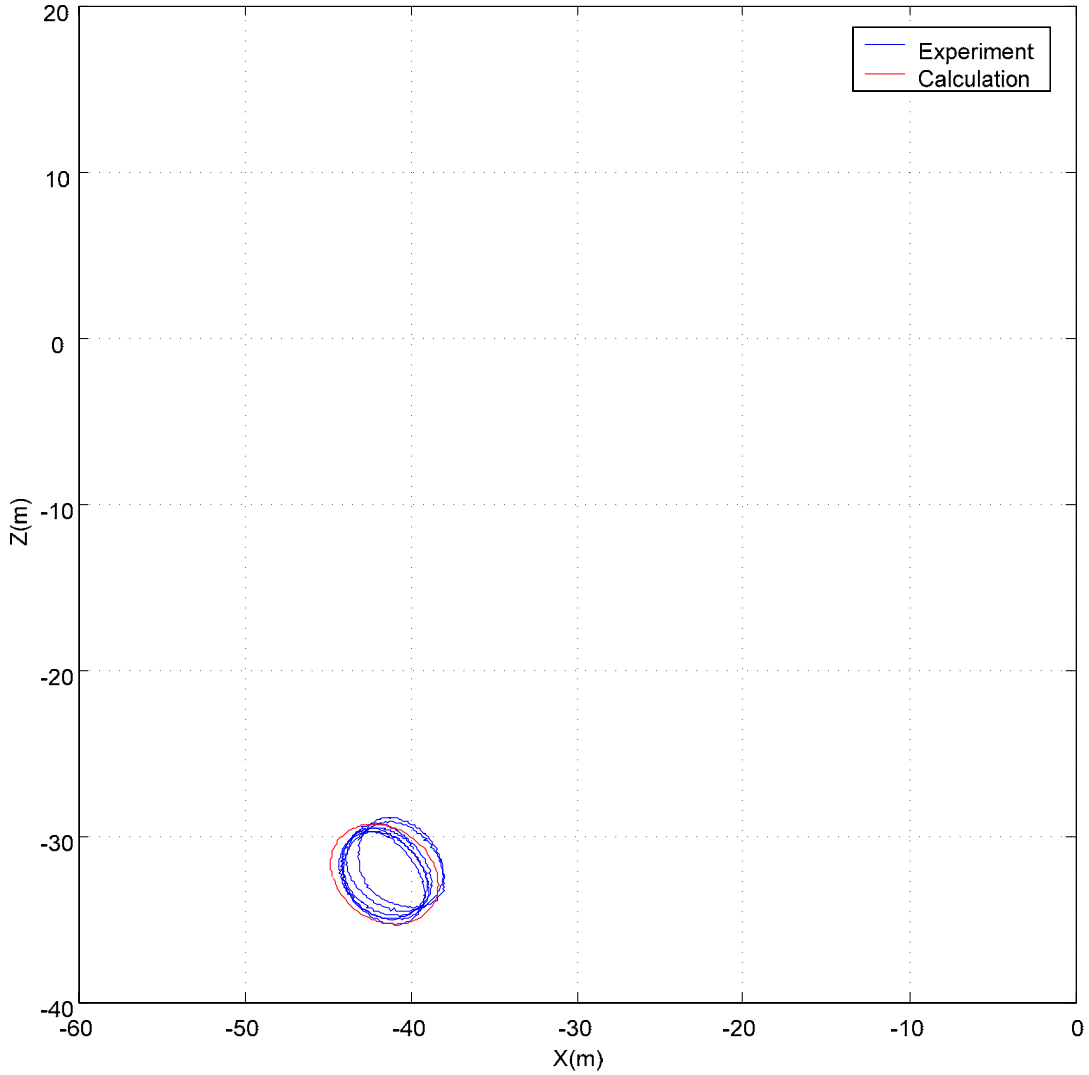
Drop Test Results (Experiment vs. Calculation)



Two model scale tests:

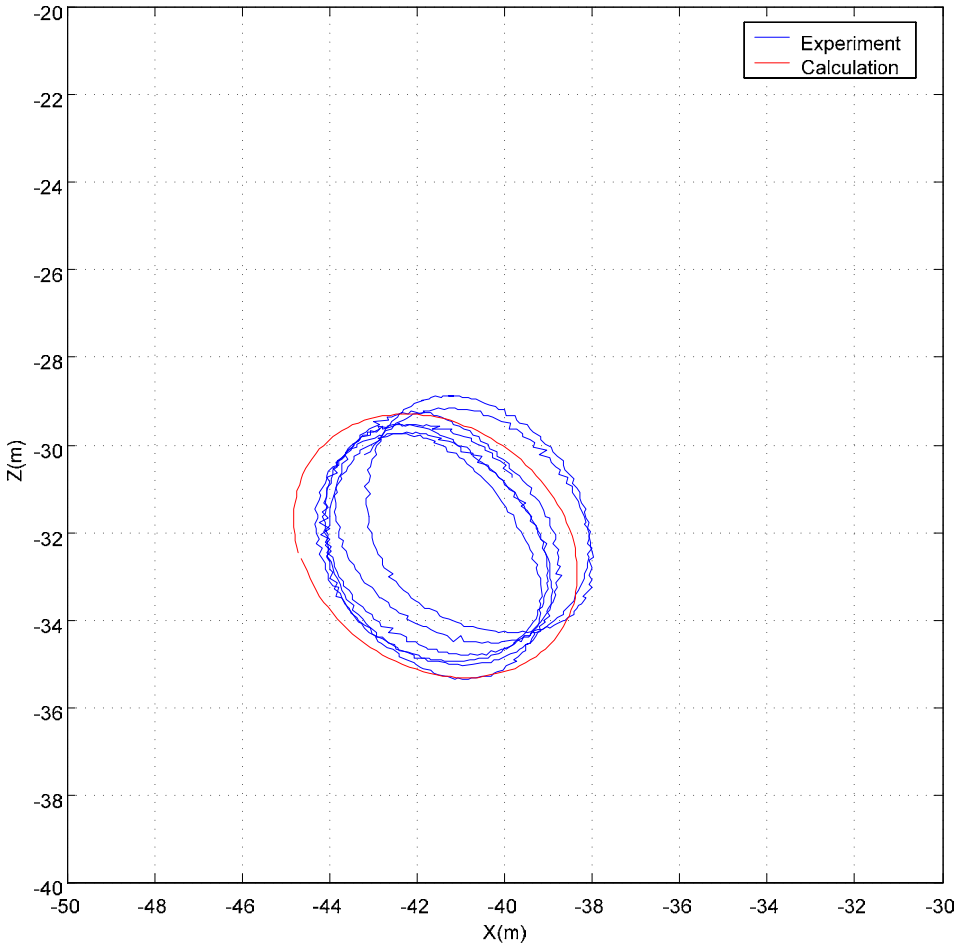
1:35
1:81

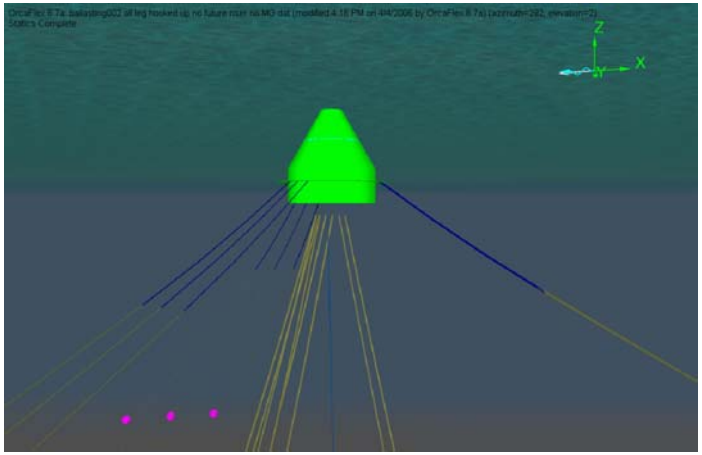
Spider Buoy Motion Characteristics (Cd & Cm)



- disconnected buoy design
  - 100-year cyclonic storm
  - Hs=12.6m
  - Tp=14.1sec
- regular wave case:
  - 100yr cyclonic collinear
  - H=20.9 m
  - T=12.9 sec
  - Vc=2.1 m/s (current)

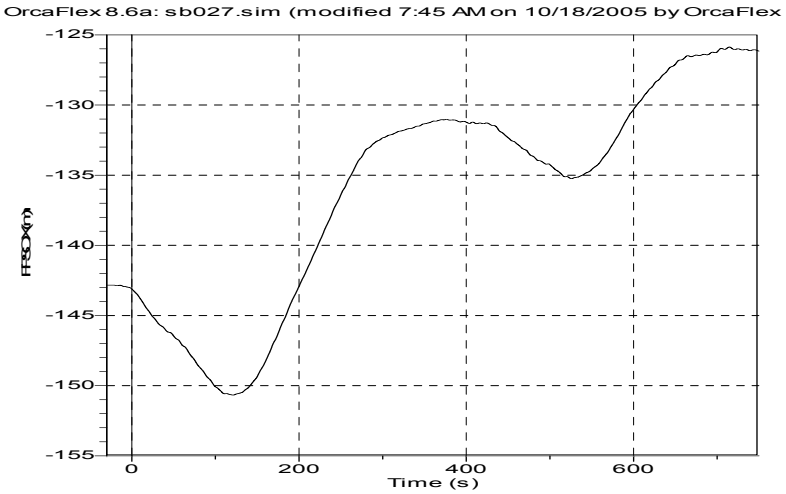
Spider Buoy Motion Characteristics (Cd & Cm)

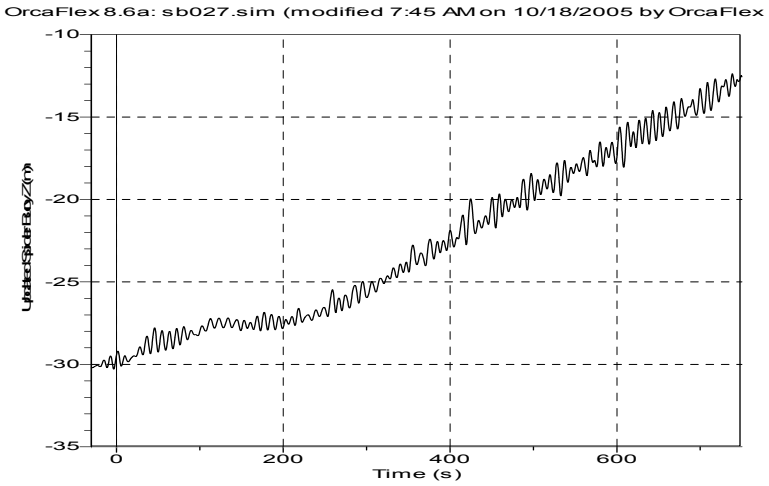


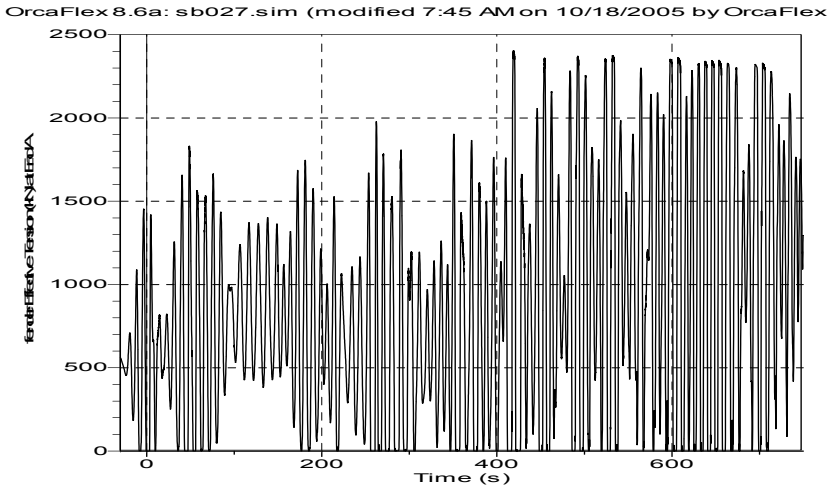


- **inertia and drag coeffs.**
  - **Cd_n=1.0**
  - **Cd_a=0.9**
  - **Cm=0.60**

Simulation of Buoy Pull-in Loads

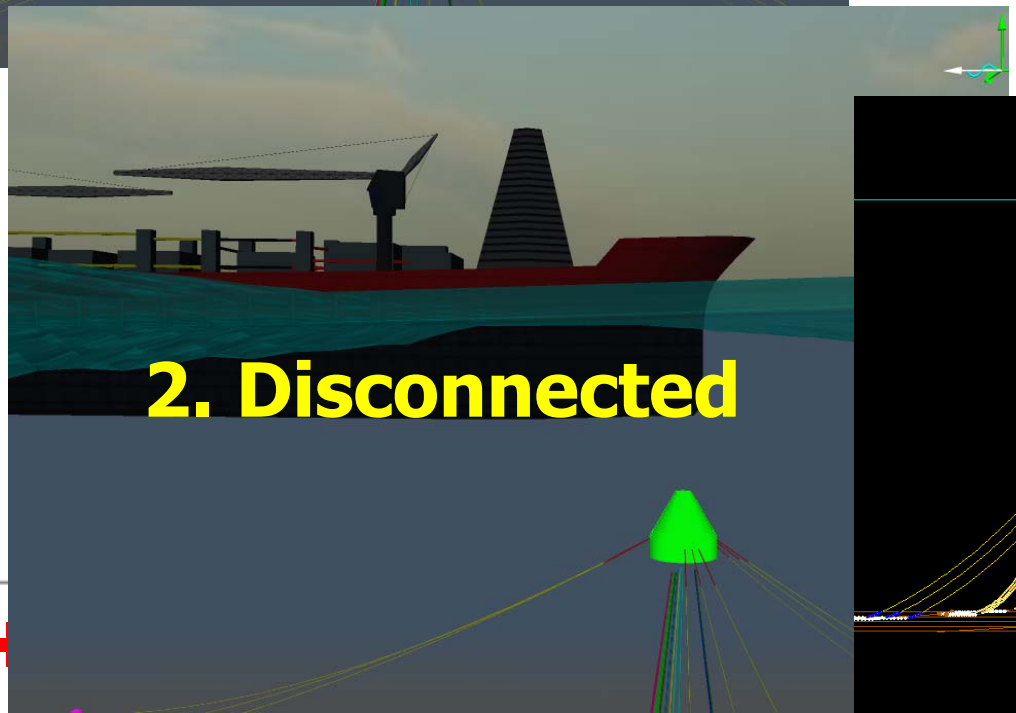


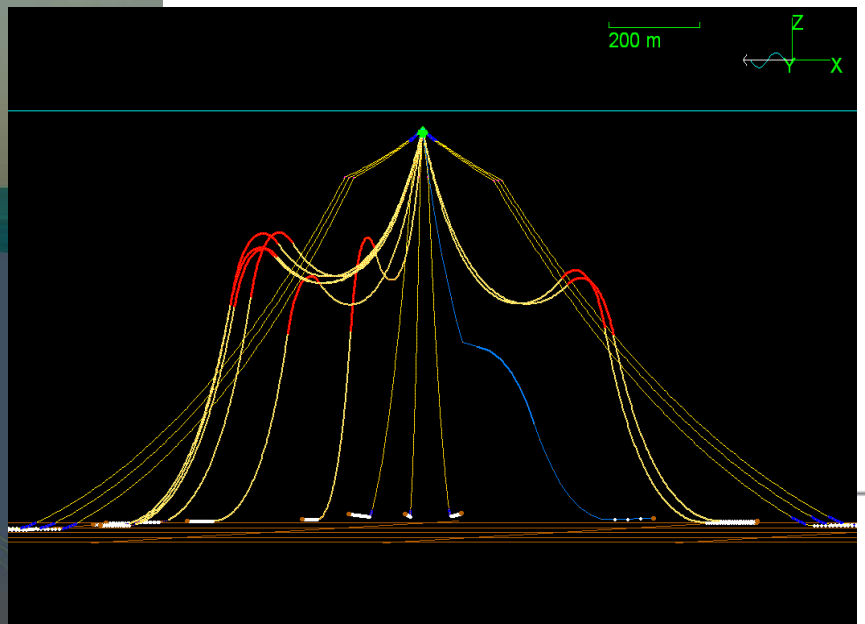





1. Buoy Disconnect


3. Buoy Reconnect


2. Disconnected


200 m
Z
Y
X

Final Remarks (1/2)

- Disconnectable Turret Moorings are proven technology for mooring FPSOs in Hurricane environments
- DTMs in Deepwater have a number of challenges
- Trade-off between buoyancy on riser system and spider buoy
- Spider Buoy ballasting analysis / design along with riser model/installation plans
- Riser contents density variations have large impact on spider buoy payload requires SB with adjustable buoyancy (+/- 30% of average load)

Final Remarks (2/2)

- Can also be mitigated by adopting hybrid tower risers with individual support buoys
- Presentation showed ability of analysis to model complex operations like disconnect, disconnected buoy response in 100-year typhoon seas, and reconnection
- Design of riser system cannot be independent of turret – in fact riser design needs to be optimized with turret for best overall solution.

Disconnectable Turret Mooring Systems for Deep Water

Arun Duggal, Sam Ryu, and Caspar Heyl

[arun.duggal, sam.ryu, caspar.heyl]@fmcti.com

R&D, FMC Technologies Floating Systems