Mooring Systems for Harsh Environments

International Mooring Seminar 2009

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Introduction

- **Harsh Environments for FPSOs**
  - Severe Winter Storms
  - Hurricanes/Typhoons/Cyclones
  - Ice: Pack Ice and Icebergs
  - Benign Swell Conditions!
- **FPSOs for Harsh Environments**
  - Permanent Mooring and Riser Systems
  - Disconnectable Mooring and Riser Systems
- **Experience in Harsh Environments**
  - North West Atlantic (Grand Banks)
  - North Western Australia and South China Sea
- **General Observations on Mooring Design for the Long-Term**

Environment: Current FPSO Installations

- North Atlantic (West of Shetlands) H_s = 18 meters
- North-West Atlantic (Eastern Canada) H_s = 16 meters
- Central to Northern North Sea H_s = 12 to 16 meters
- South China Sea H_s = 13 meters
- South East Asia H_s = 9 meters
- Southern Ocean (New Zealand) H_s = 11 meters
- South Atlantic (Brazil) H_s = 11 meters
- Gulf of Mexico (Mexico) H_s = 9 meters
- Gulf of Mexico (Deepwater, USA) H_s = 13 meters
- West Africa H_s = 4 meters

Water depths range from ≈ 50 to 2,500 meters

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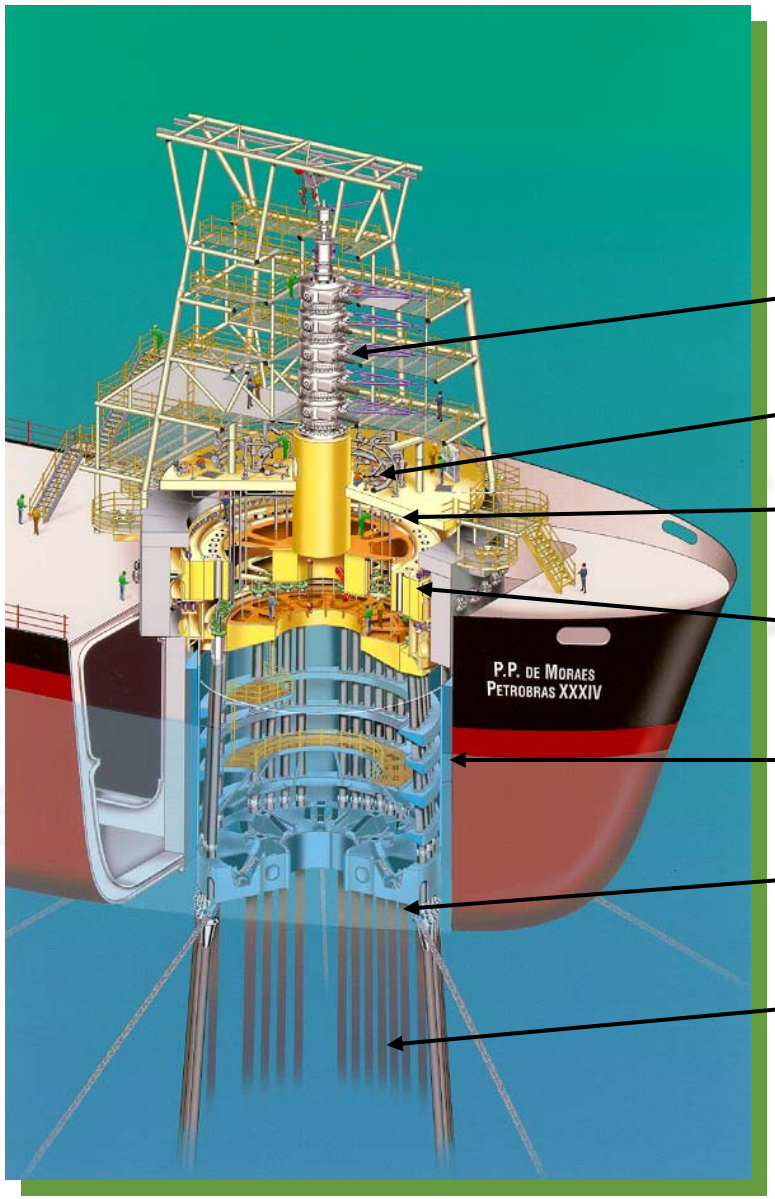
Typical Permanent Internal Turret System



- *Large Load Capacity*
- *Capacity Large Number of Risers*

Swivel Stack (Product/Lift/Controls)

Manifolds + Pig Launching/Receiving

Anchor Leg + Riser Pull-In Equipment

Bearing (only upper in this case)

Turret Shaft / Riser Guide Tubes

Chain Table

Anchor Legs + Risers

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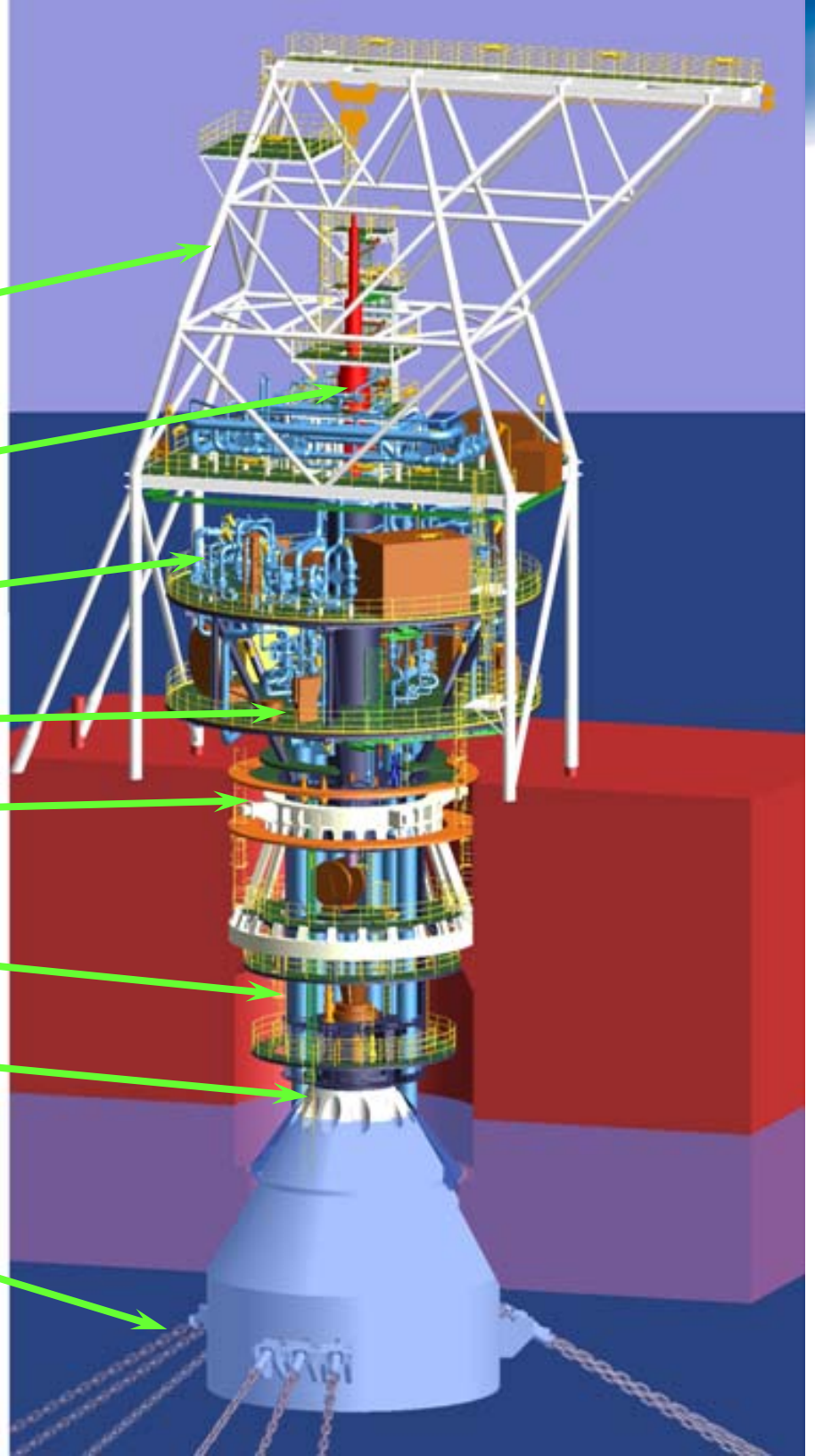
Typical Disconnectable Turret System

- Swivel Access Structure
- Swivel Stack
- Manifold Piping
- Riser Deck
- Main Bearing
- Turret Shaft
- Risers & Umbilicals
- Anchor Legs



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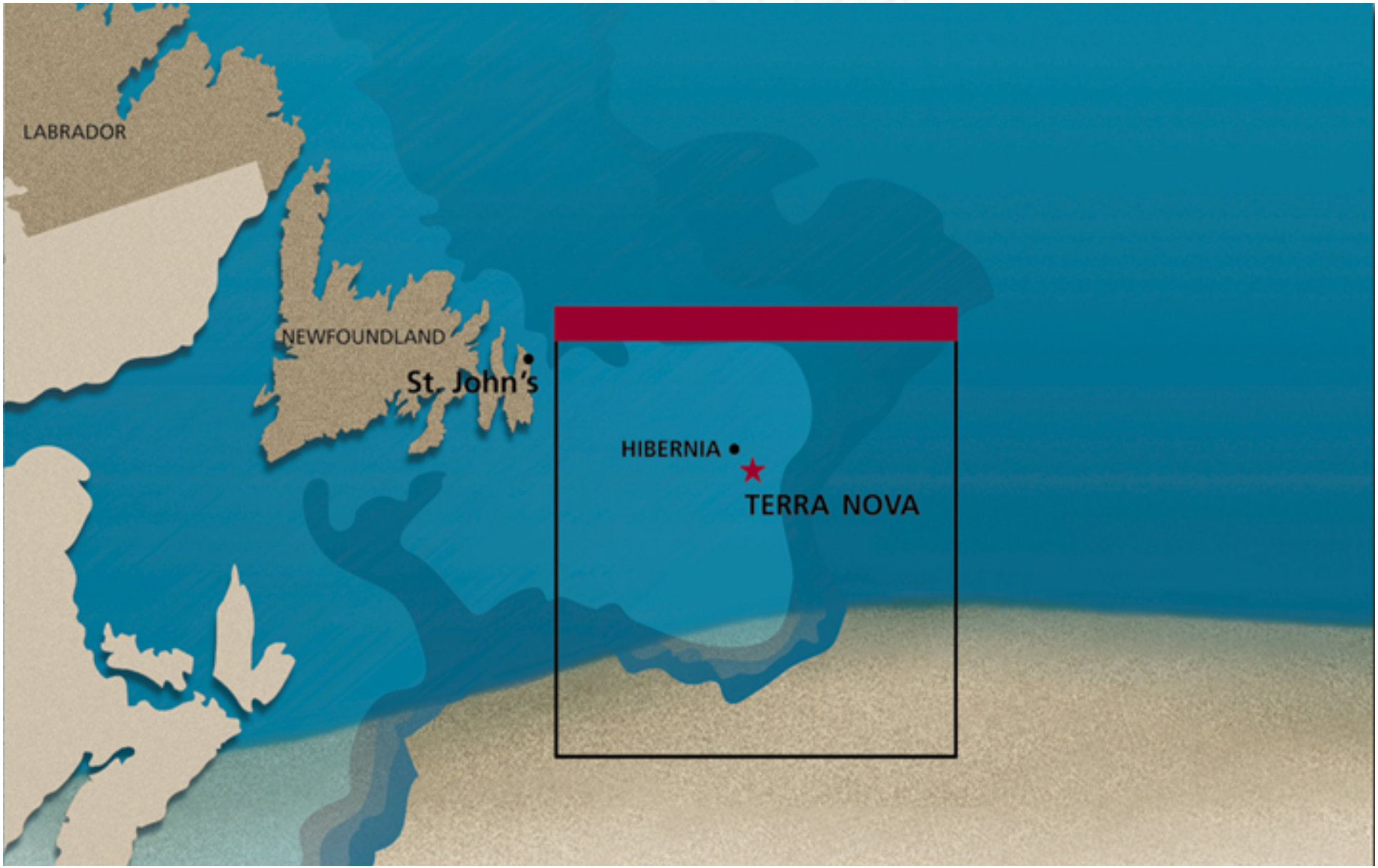
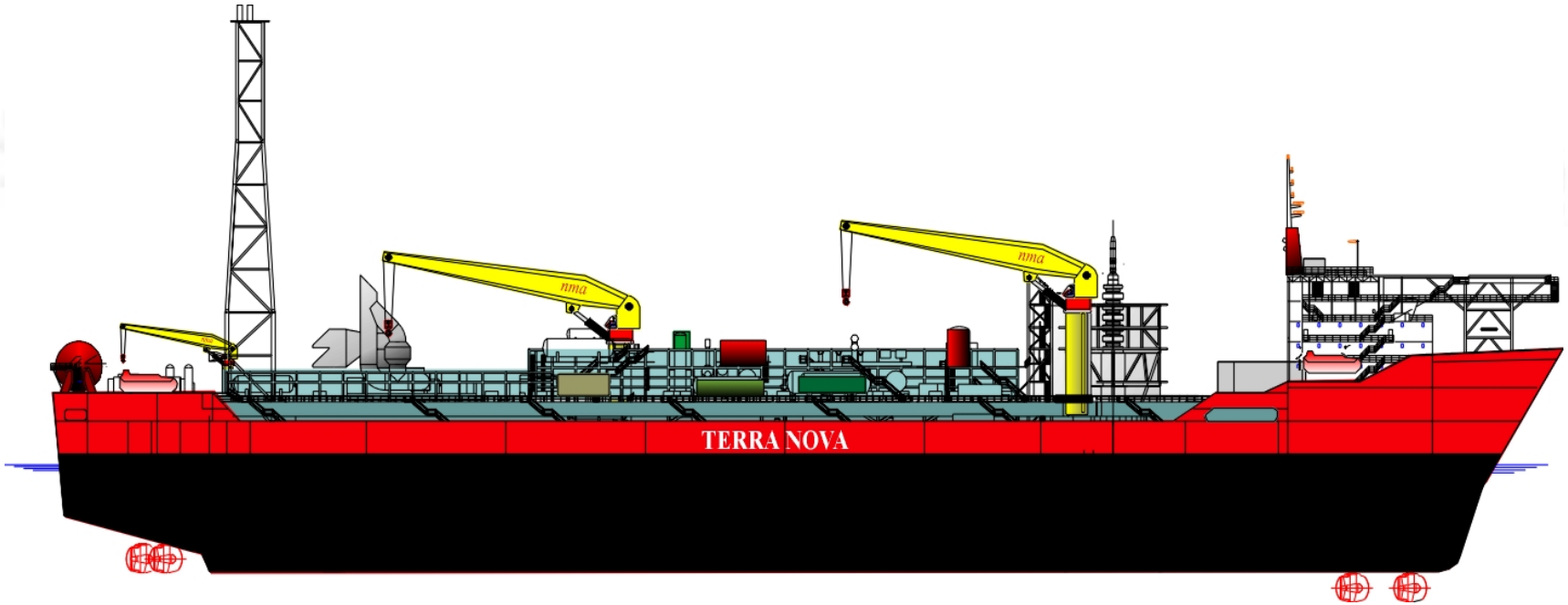
Severe Storms and Ice



Design Environment

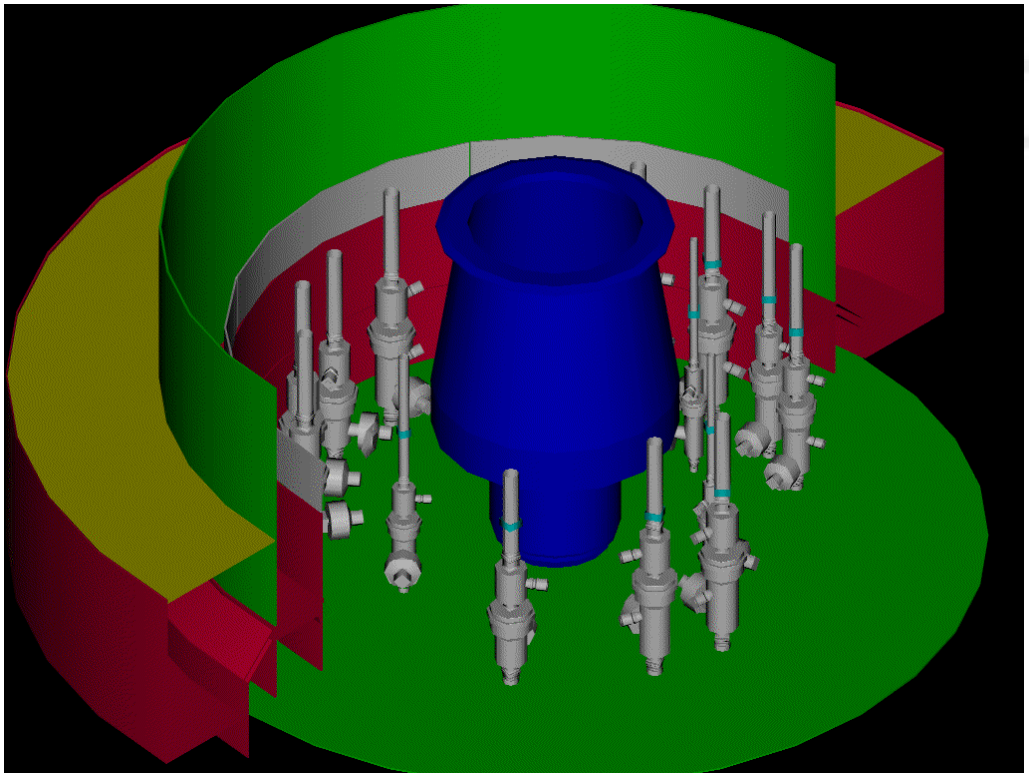
	1-Year	100-Year
Waves	Hs = 10.9 m Tp: 12.9 – 16.0 sec	Hs = 16.0 m Tp: 15.7 – 20.2 sec
Wind	Vw = 28.8 m/s	Vw = 39.6 m/s
Current	Vc = 1.0 m/s	Vc = 1.3 m/s
Pack Ice	0 – 30%	> 50 – 70%
Icebergs	<100,000 MT	>100,000 MT

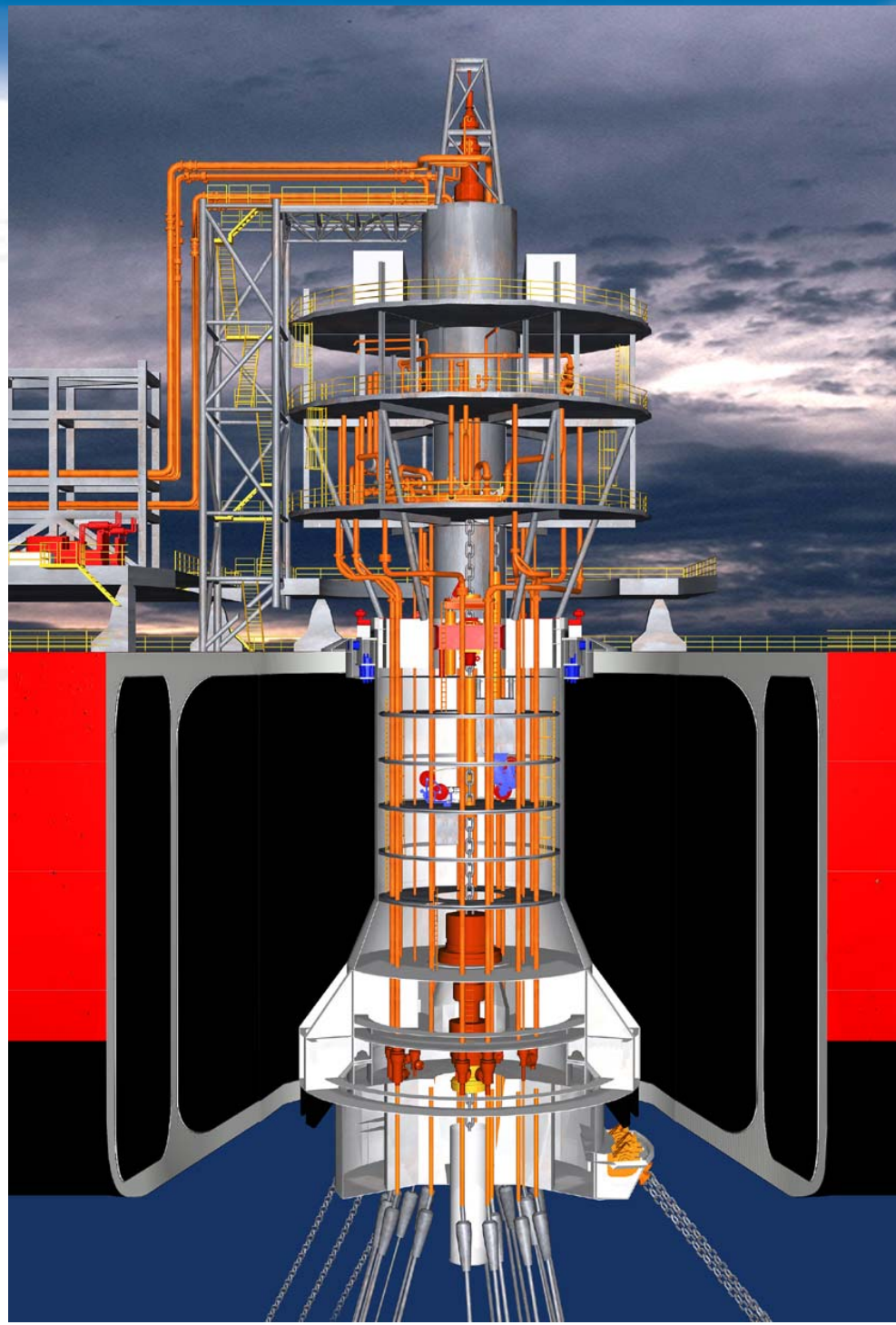
Terra Nova FPSO



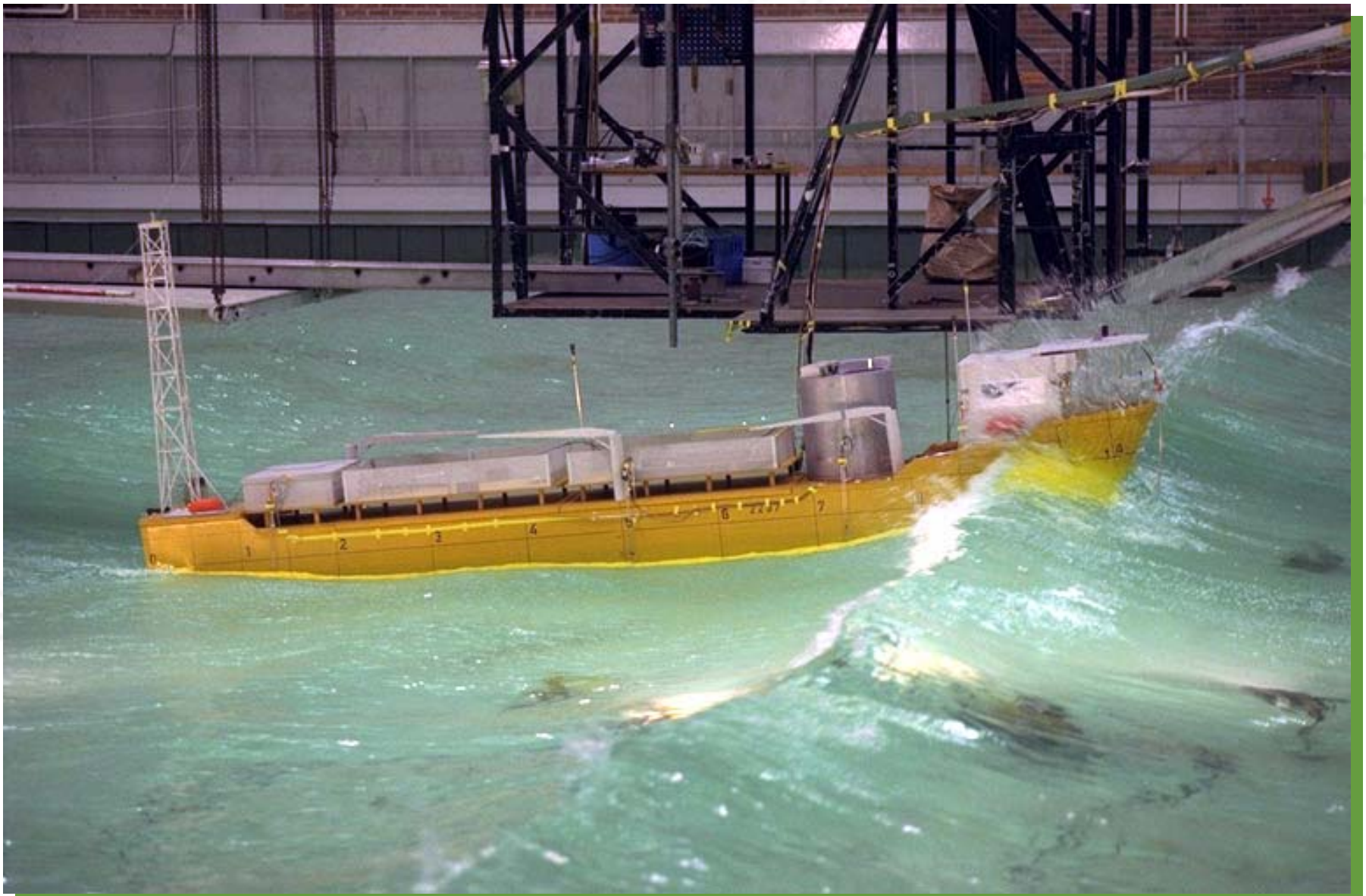
- **Vessel: ice-strengthened, 960,000 bbl storage**
  - L=292 m, B=45.5 m, D=28.2 m
  - 5 azimuthing thrusters @ 5 MW each
- **Disconnectible turret system**
- **Thruster assisted 3X3 mooring system**
- **19 risers & umbilicals**

Terra Nova FPSO: Disconnectable Turret



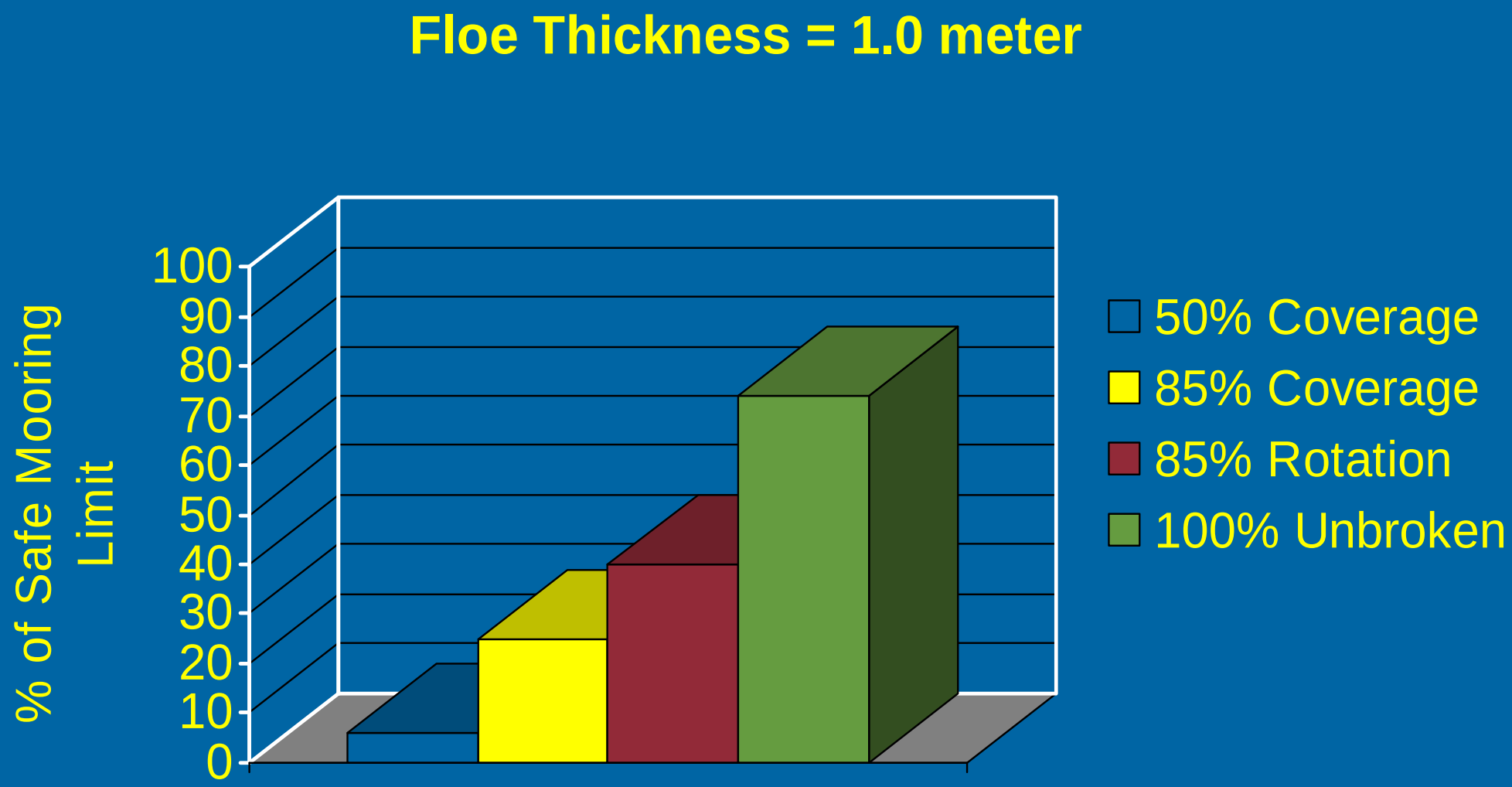


Performance in Survival Seas

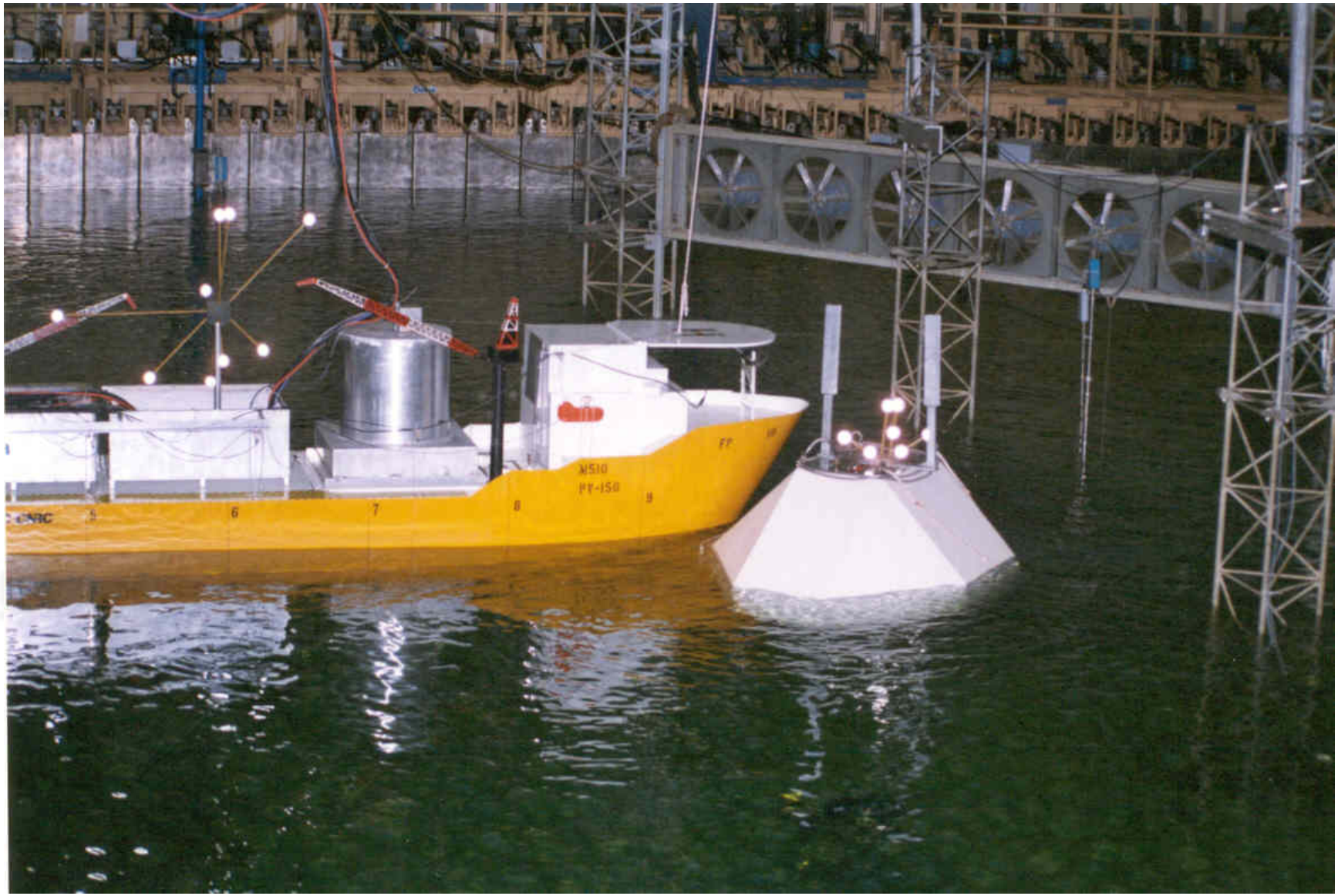


Performance in Pack-Ice

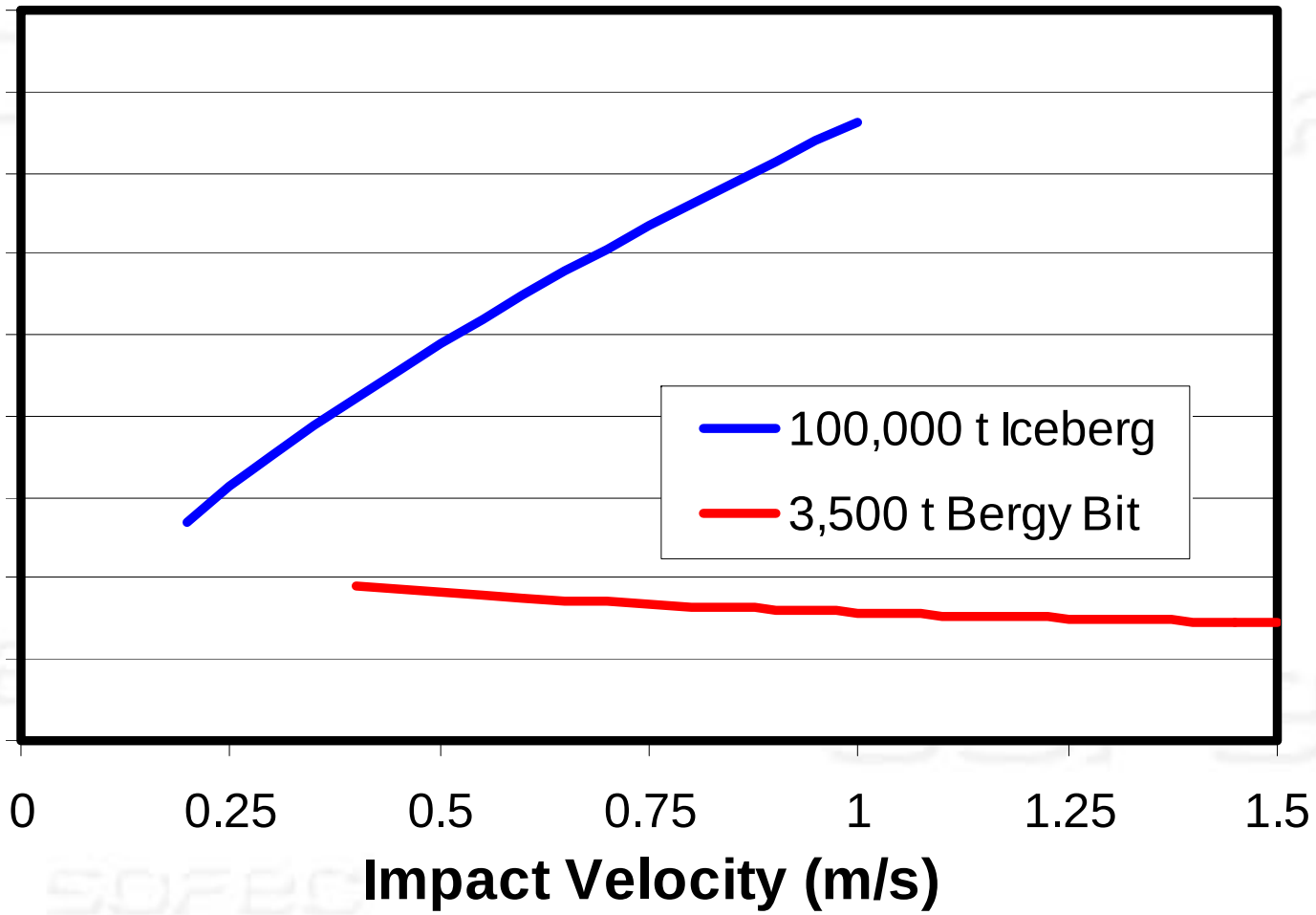
Pack Ice Load on Moored FPSO



Impact of 100,000 MT Iceberg with FPSO



Iceberg & Bergy Bit Impact Loads



Disconnectable Turret-Moored FPSOs – Australia

- **Santos Mutineer – Exeter FPSO (Installed 2005)**
  - 160 m water depth
  - 10 risers and umbilicals
- **BHPB Stybarrow FPSO (Installed 2007)**
  - 850 m water depth
  - 12 risers and umbilicals
- **BHPB Pyrenees FPSO (to be installed 2009)**
  - 200 m water depth
  - 15 risers and umbilicals

DTM for Cyclone Regions

- **Robust design – Excellent Performance Record**
  - Fluid-transfer and load-transfer components designed to disconnect separately
- **Mooring designed to remain connected for 100-year winter storm**
- **Turret mooring designed to disconnect for cyclones / hurricanes**
  - Design Disconnect duration ~ 6 hours
  - Reconnect w/o assistance in seas up to Hs of 3 meters
- **Disconnectable spider buoy**
  - Supports anchor legs, and risers and umbilicals

Cyclones over Mutineer/Exeter Field 2006-08

Name	Duration	Year	Category
• Clare	Jan 7 – 10,	2006	3
• Daryl	Jan 18 – 23,	2006	2
• Emma	Feb 27 – 28,	2006	1
• Floyd	Mar 21 – 26,	2006	4
• Glenda	Mar 27 – 31,	2006	5
• Hubert	Apr 6 – 7,	2006	2
• Isabel	Jan 2 – 4,	2007	1
• George	Mar 6 – 10,	2007	4
• Jacob	Mar 9 – 11,	2007	3
• Kara	Mar 25 – 28,	2007	3
• Melanie	Dec 26 – 1/2,	2008	2
• Nicholas	Feb 10 – 19,	2008	4
• Pancho	Mar 25 – 29,	2008	4

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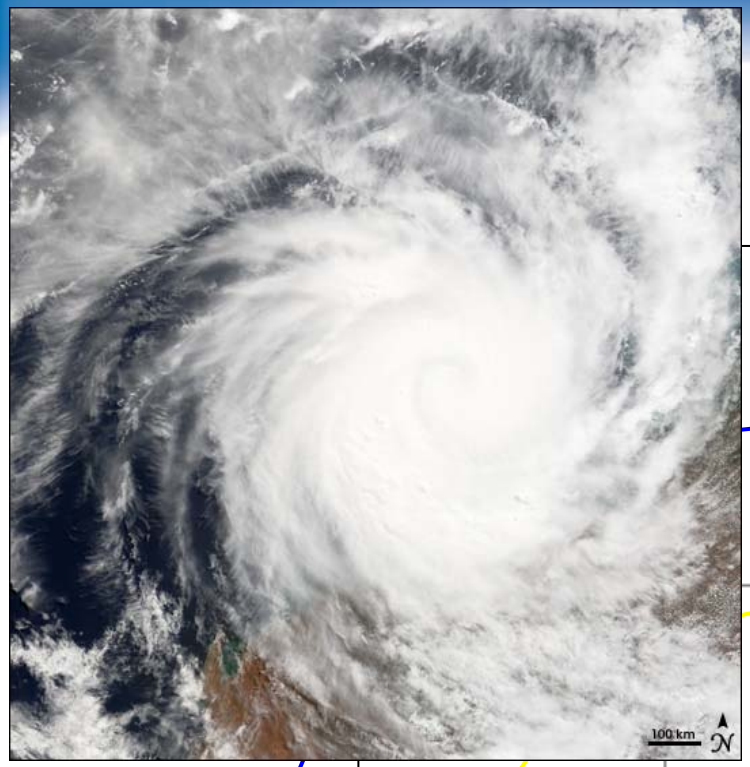
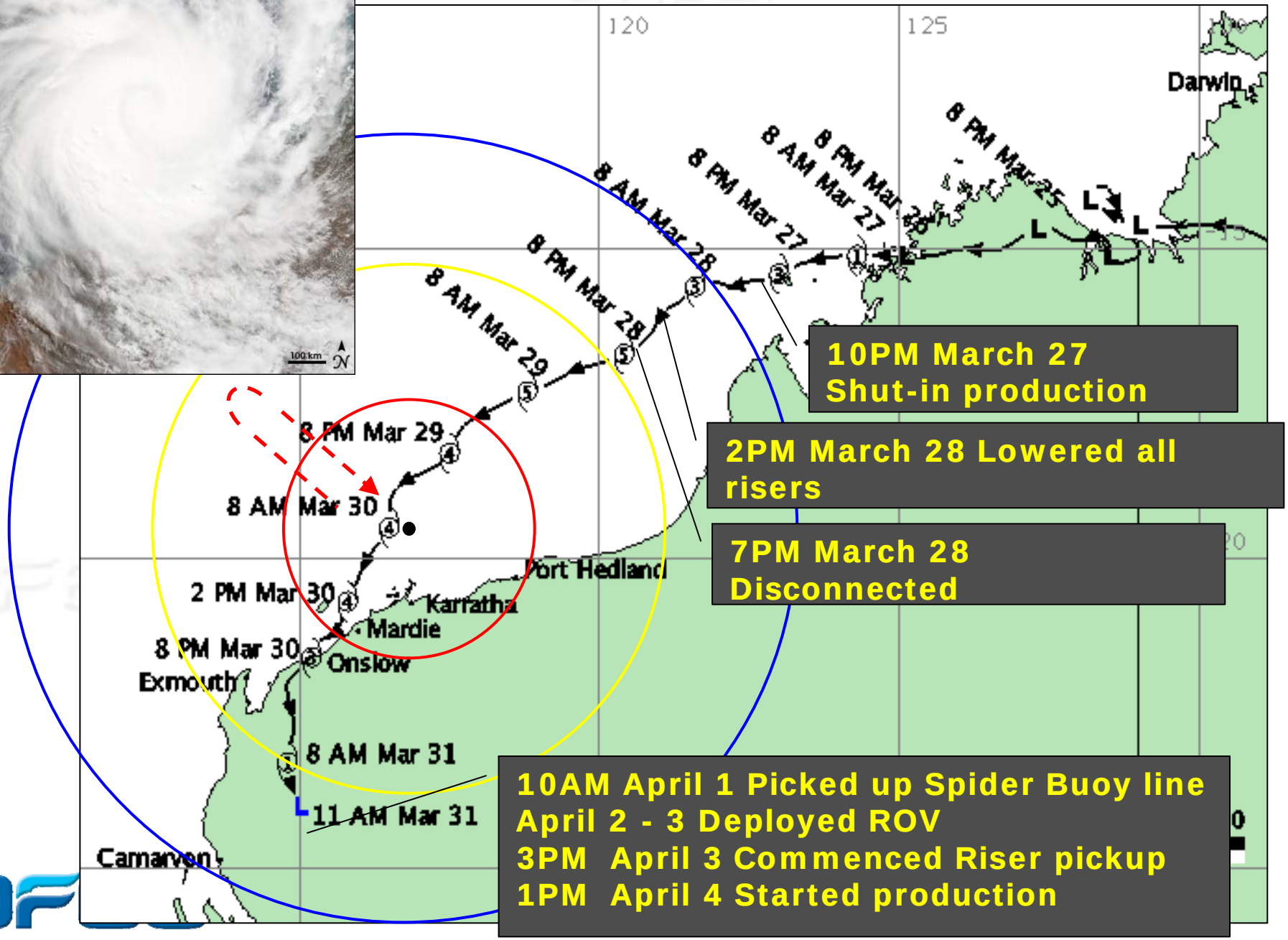
Glenda: 27 – 31 March 2006





Summary of Selected Disconnect / Reconnect Durations

Cyclone	Duration		Total
	Disconnect (hours)	Reconnect (hours)	Production D/T (days)
Clare	24	32.5	4.6
Daryl	36	50	6.3
Emma	26*	14*	3.1*
Floyd	*	*	0.6*
Glenda	21	74	7.6
Hubert	11	25	4.2
George / Jacob	29	33	9.9
Kara	32	34	5.5
Melanie	14	39	4.9

** Spider Buoy was not disconnected / reconnected*

General Observations for Long-Term Design

- **Are the standard mooring factors of safety adequate for harsh environments/long service life (+ future life extension)?**
- **Should two-legs damaged be considered in the design?**
- **Wear and corrosion allowances**
- **Performance of Thruster-Assisted Moorings**
  - FPSO design to allow for regular maintenance and overhaul
  - Dependence on DP can impact Mooring when performance is not as designed

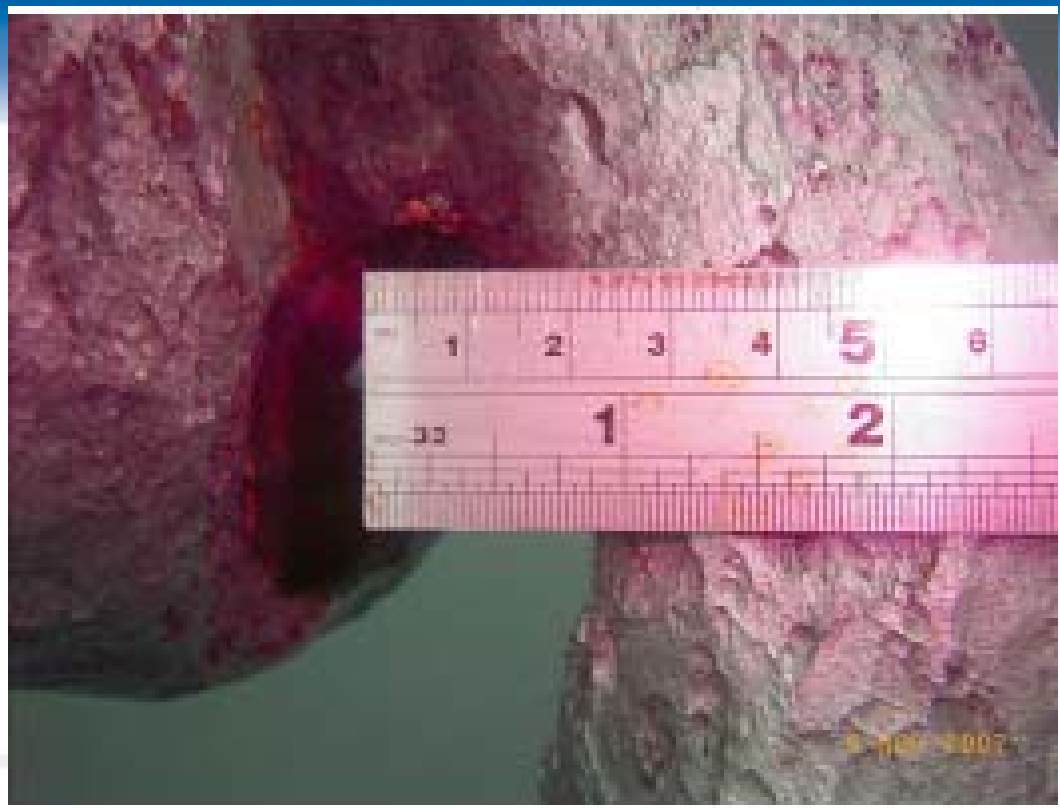
Example: Degradation of Mooring Components

- **Permanent Mooring System in South China Sea**
- **Installed 1996**
- **Design Life 10 years**
- **Design Cyclone Seastate:**
  - Hs = 12.8m
- **Survived Super Typhoon Sally (1996):**
  - Hs = 14.3m
- **Mooring Failed Typhoon Chanchu (2006):**
  - Hs = 13.8m

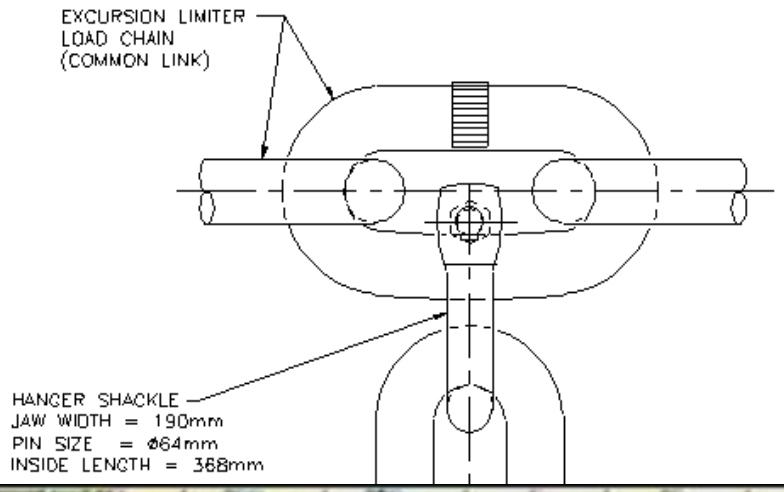
Spiral Strand Wire

Damaged Risers

Corrosion



Hanger Shackle Details



Conclusions

- **FPSOs have proven to be suitable for harsh environments**
  - Good performance record in a variety of environmental conditions
  - Permanent and Disconnectable Mooring Systems
- **Disconnectable Mooring Systems have an excellent record in Cyclone Environments**
  - Disconnectability provides additional reliability for extreme seastates
- **Mooring Systems are NOT fine wine – they do not get better with age!**
  - Require inspection and fast response to deal with issues
- **Selection of Mooring Design Criteria can have a huge impact on System Reliability over the life of the installation**