FMC EnergySystems

SOFEC

Global Analysis of the Terra Nova Turret Mooring System

Arun S. Duggal (FMC SOFEC)

Caspar N. Heyl (FMC SOFEC)

George P. Vance (Terra Nova Alliance)

1 May 2000

terra nova

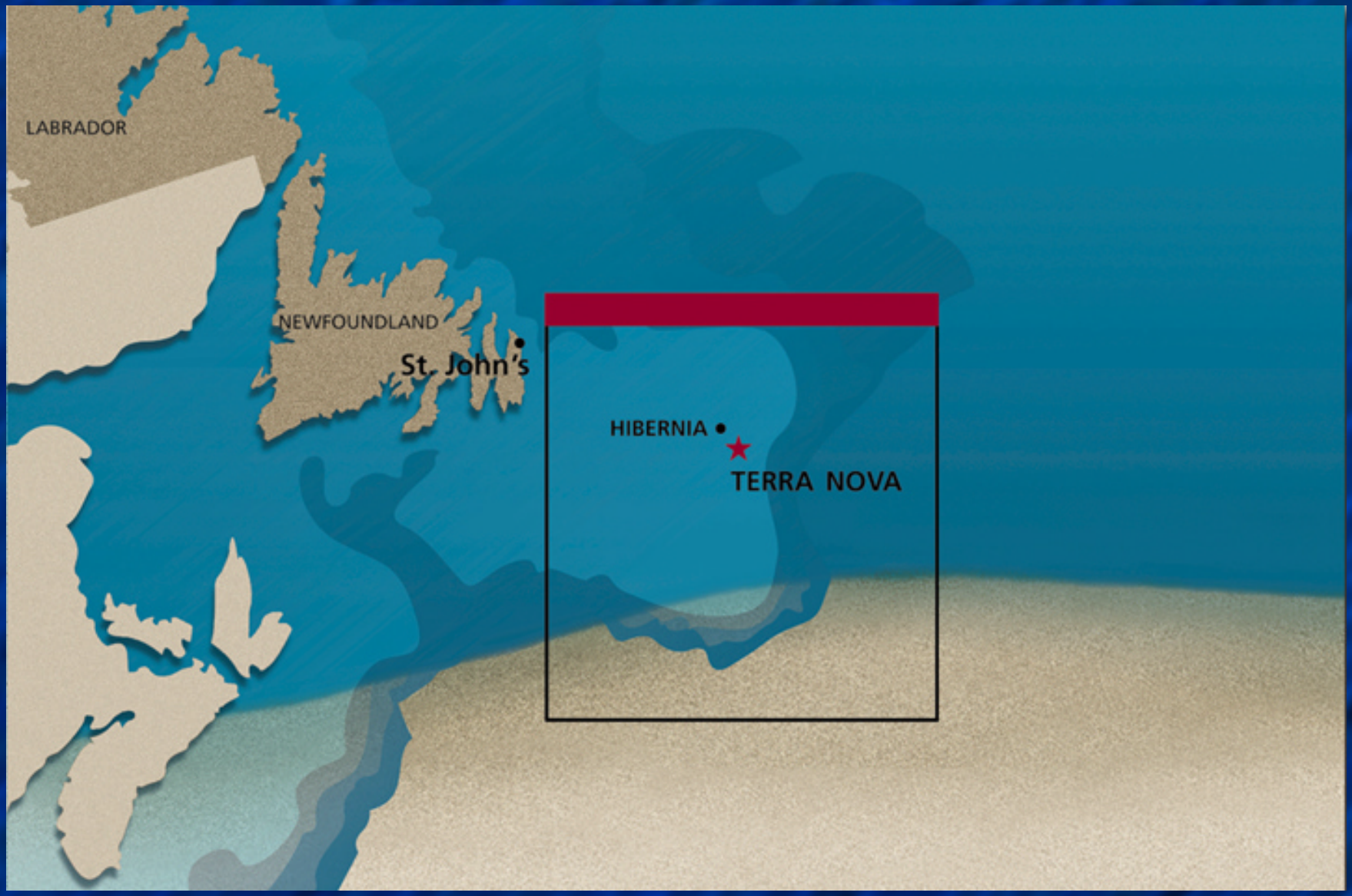
Overview

- Design basis as it pertains to station keeping
- Design environmental criteria
- The FPSO system
- Global analysis: requirements and methodology
- The model testing program
- Sample results
- Summary

Station Keeping Design Basis

- FPSO located on the Grand Banks - one of the most severe design environments in the world
- FPSO to stay on station during the 100-year storm
- FPSO to disconnect from mooring and risers to avoid icebergs and pack-ice
  - controlled disconnect in 4 hours
  - emergency disconnect in 15 minutes
  - re-connect to mooring & riser system without assistance
- 19 risers and umbilicals
- 25 year design life

The Grand Banks

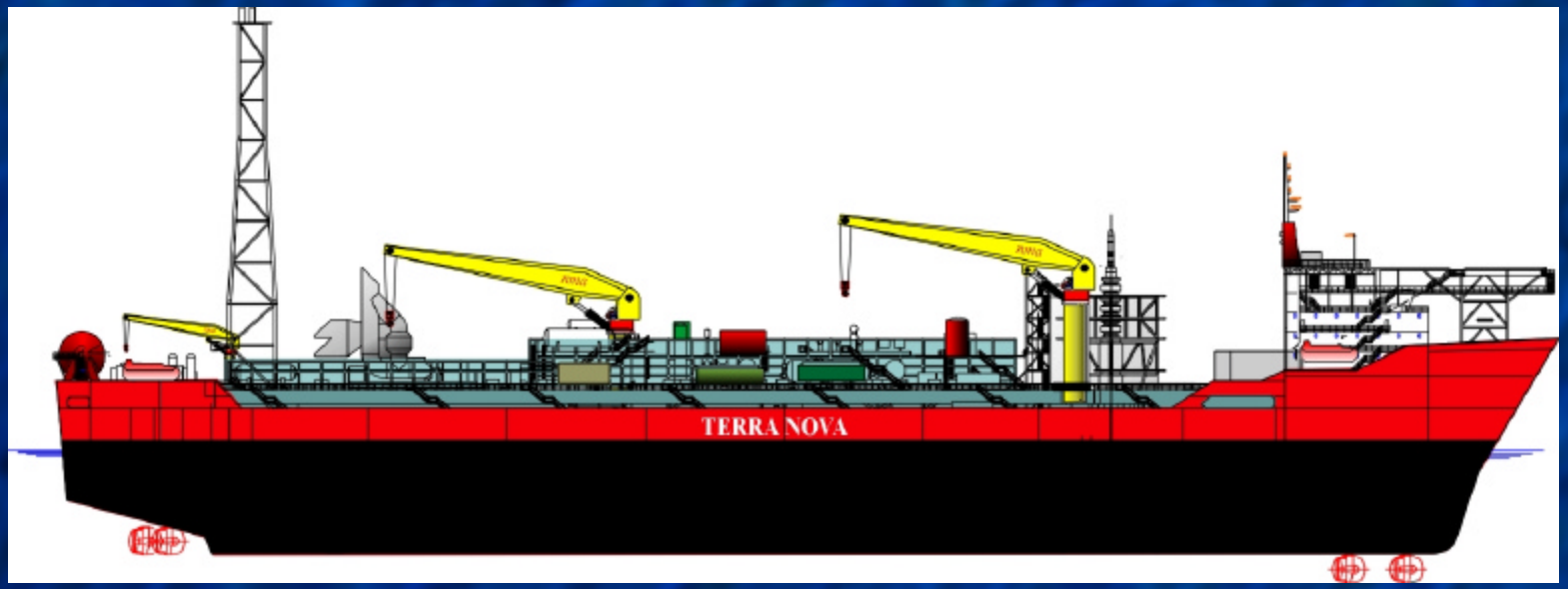


Design Environment

Water Depth = 95 m

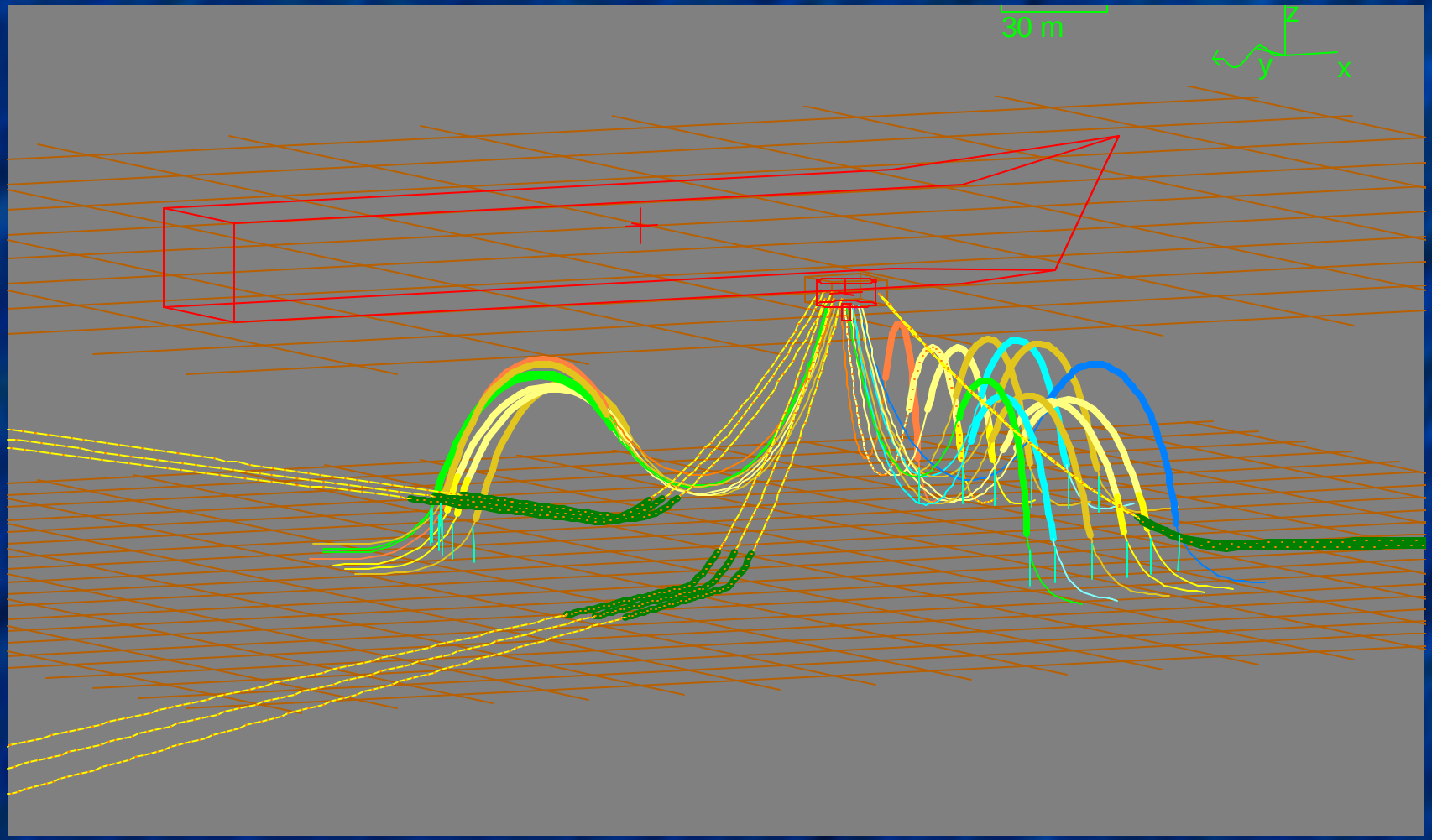
	1-Year	100-Year
Waves	Hs = 10.9 m Tp: 12.9 – 16.0 sec	Hs = 16.0 m Tp: 15.7 – 20.2 sec
Wind	Vw = 28.8 m/s	Vw = 39.6 m/s
Current	Vc = 1.0 m/s	Vc = 1.3 m/s
Pack Ice	0 – 30%	> 50 – 70%
Icebergs	<100,000 MT	>100,000 MT

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 System



Terra Nova Turret

Swivel Stack

Manifold Decks

Upper Bearing

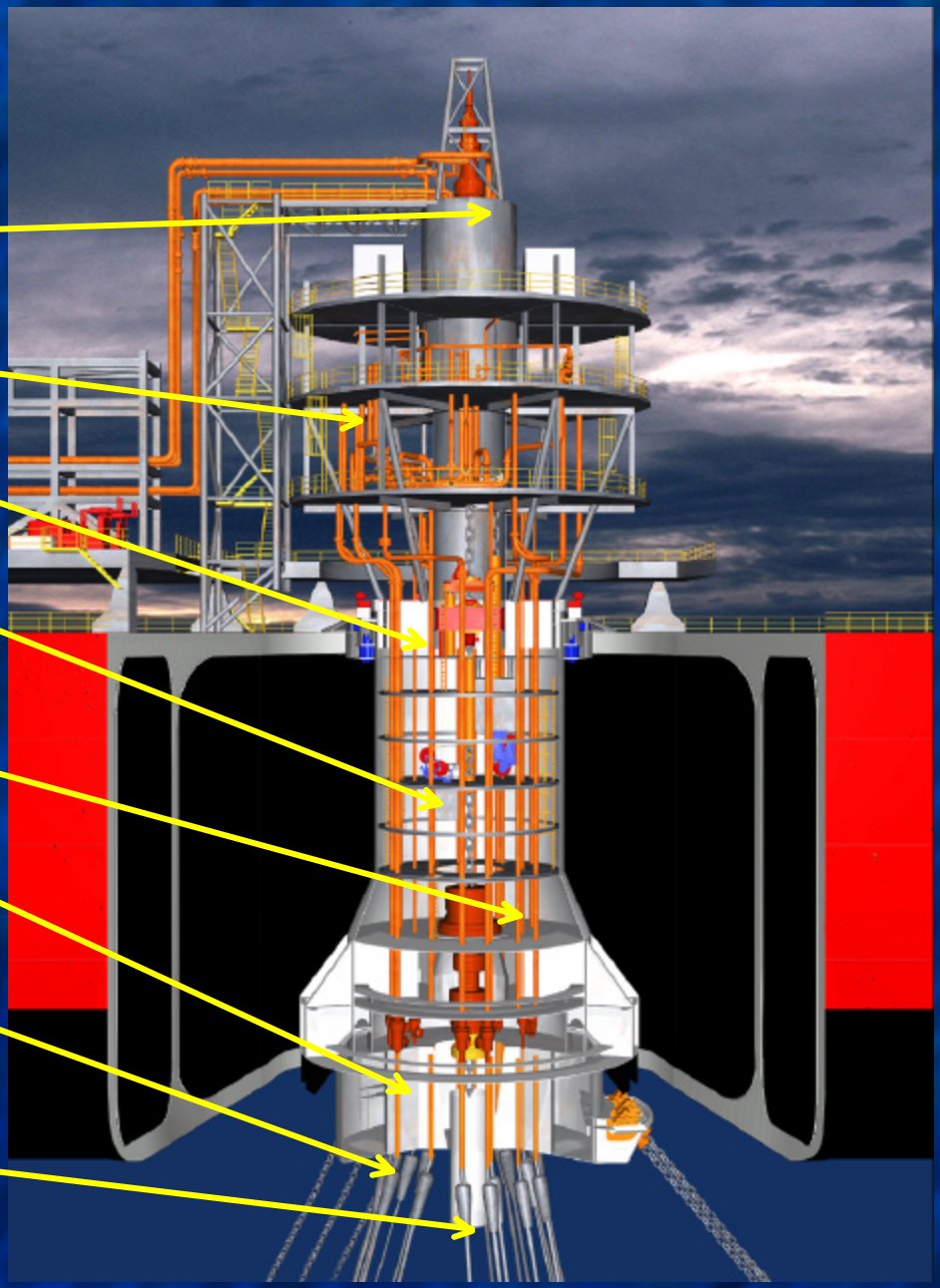
Turret Shaft

Connector-Tensioner

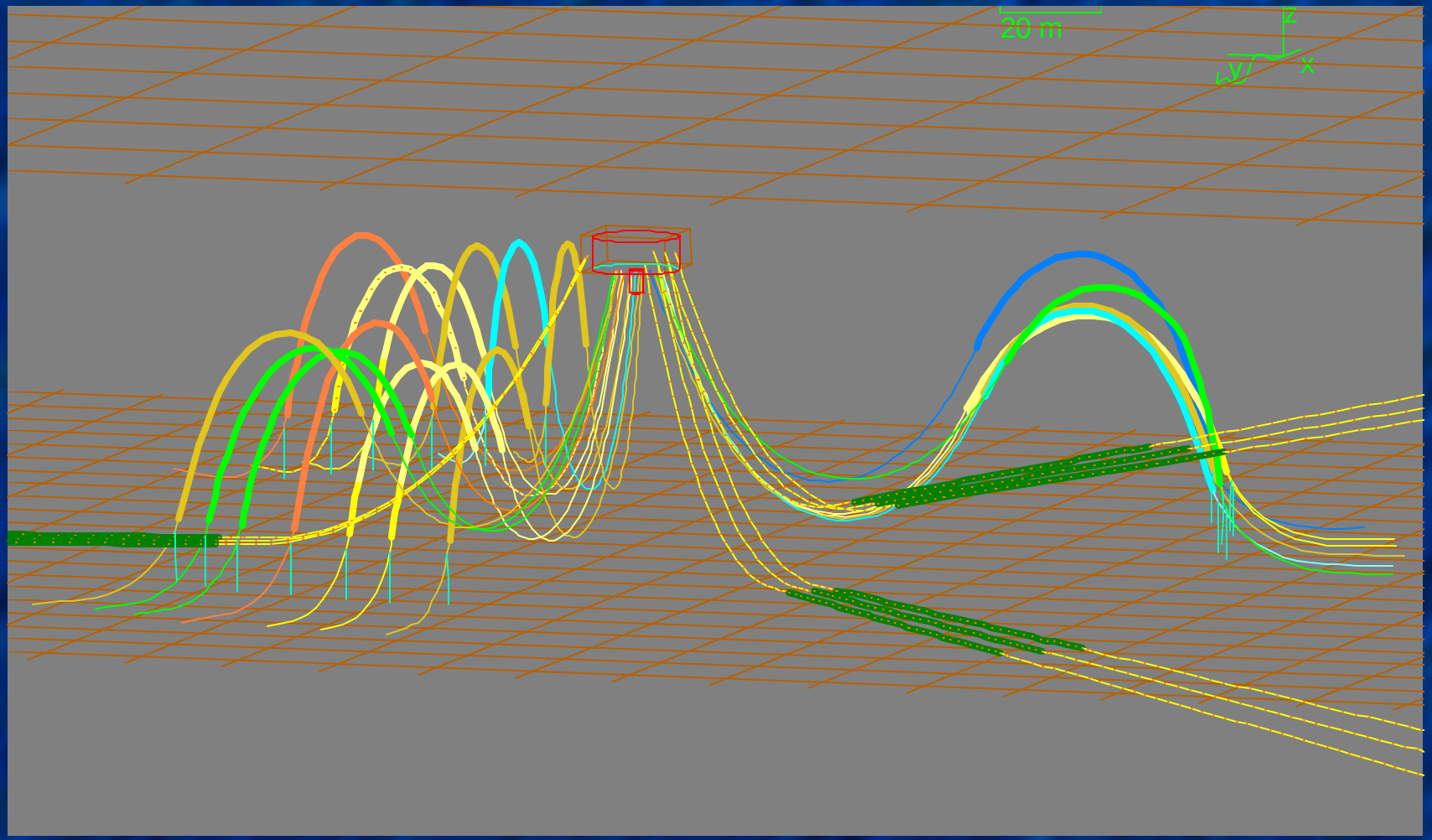
Spider Buoy

Anchor Legs

Risers



Spider Buoy



Global Analysis Requirements

- Survival conditions
  - FPSO global analysis & loads: 1-year and 100-year storm
  - Spider buoy motions (disconnected): 1-year storm
- Operational conditions
  - fatigue analysis
  - FPSO system response during offloading
- Spider buoy behavior during disconnect & reconnect
  - transient buoy drop motions
  - pull-in dynamics and loads
- Installation analysis

Global Analysis Methodology

- Frequency domain analysis
  - second-order forces and moments
  - wave frequency vessel motions
  - parametric study of FPSO system response
  - FPSO global analysis
- Time domain analysis
  - detailed mooring analysis and turret loads
  - spider buoy response during disconnect & reconnect
  - thruster-assisted mooring and DP simulations
- Model testing for verification

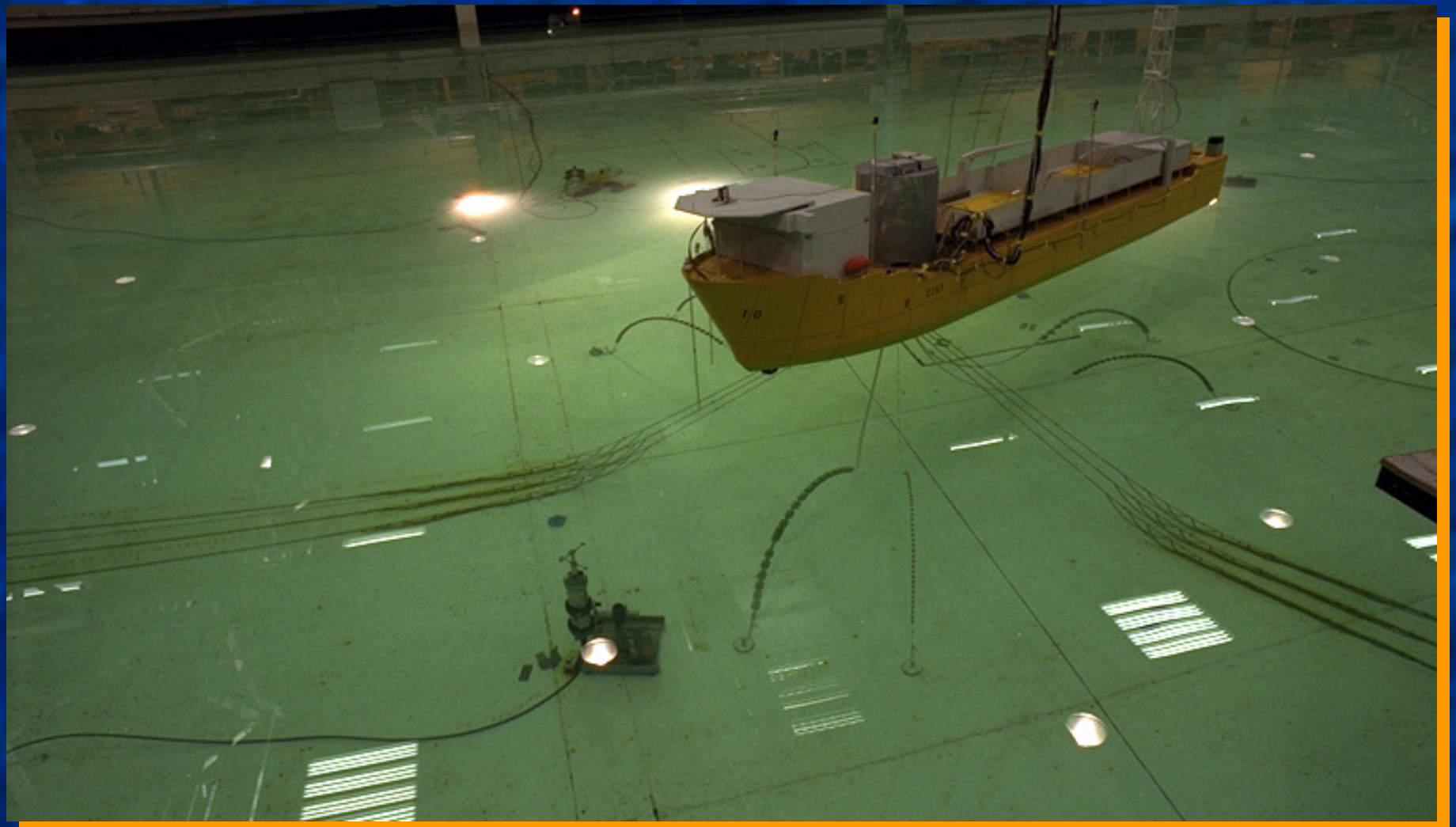
Model Test Program

Integrated with global analysis effort:

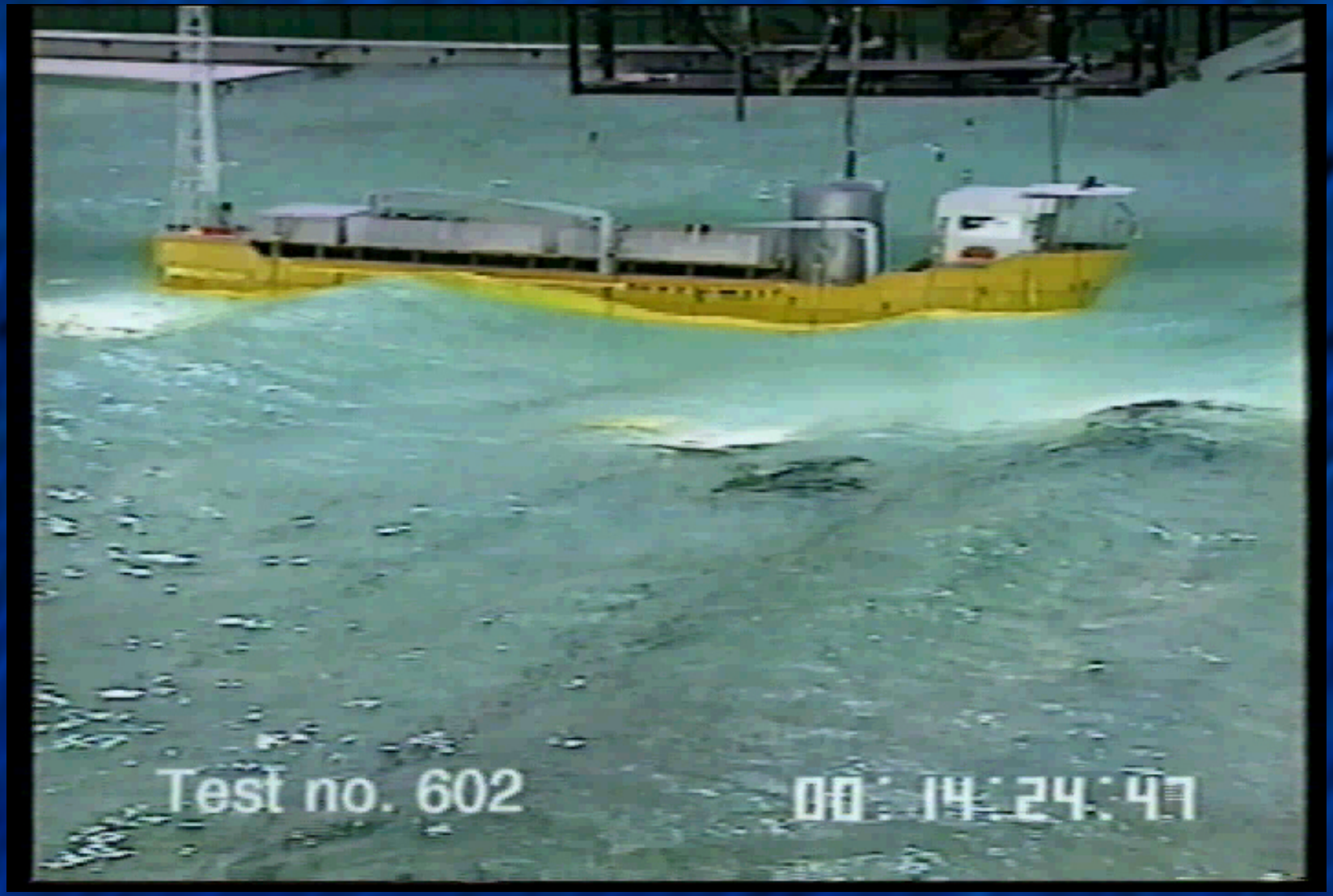
- *input data for analysis*
- *independent verification of global analysis*

- Wind tunnel tests
- Survival environment tests
- Resistance and propulsion tests
- Pack ice and iceberg impact tests
- Buoy disconnect & reconnect tests
- Installation tests

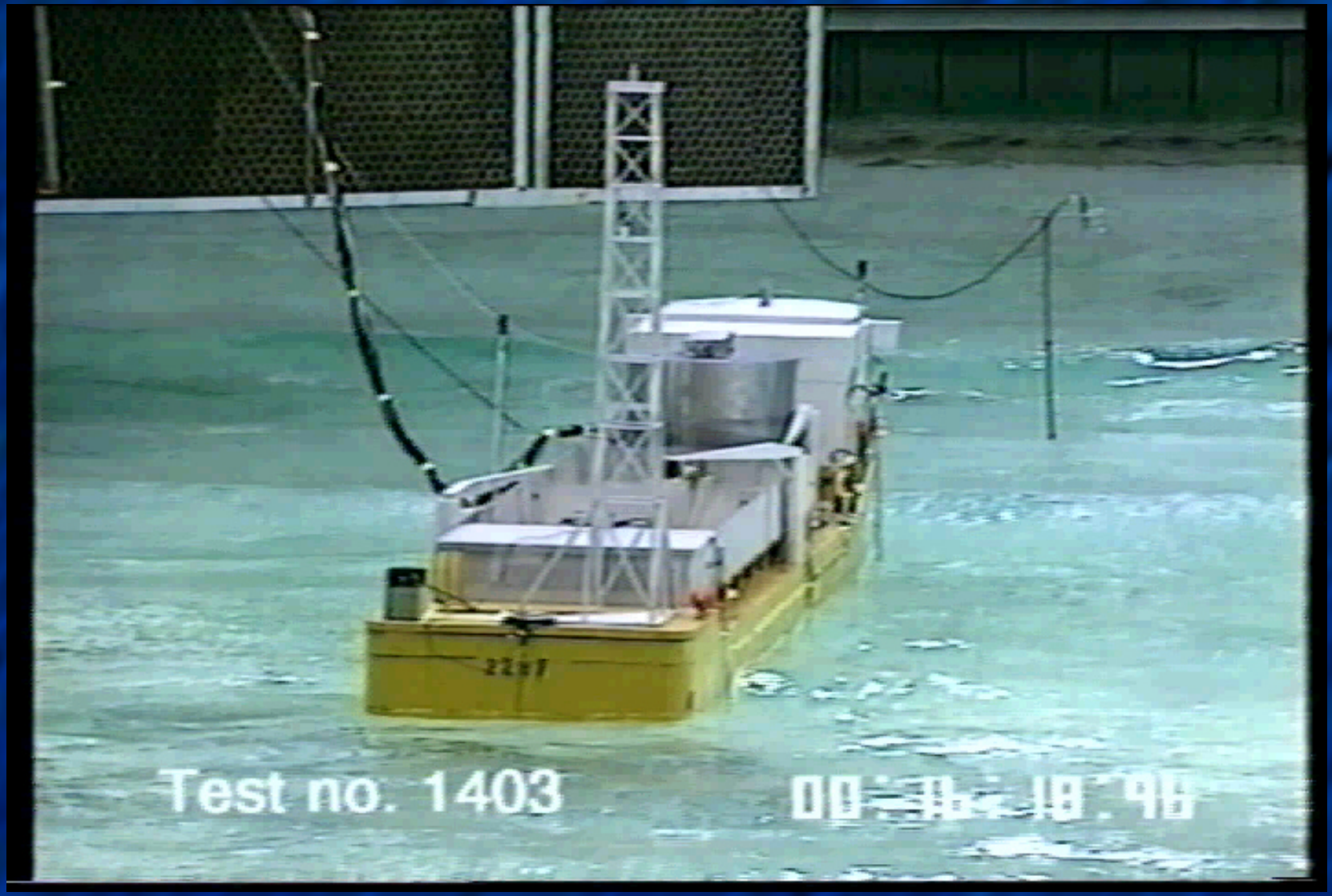
Set-Up for Survival Testing



100-Year Storm



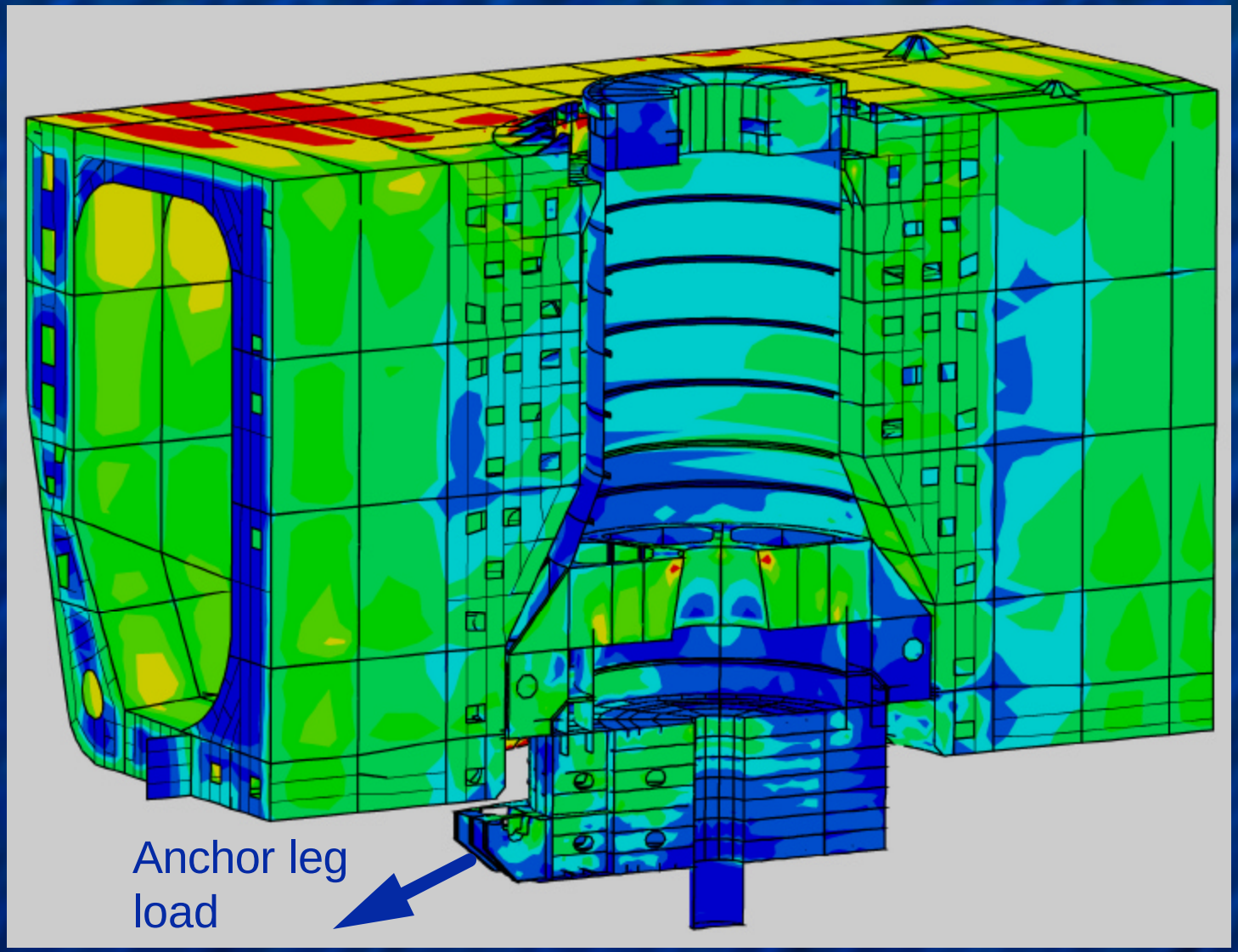
Terra Nova Vessel on DP



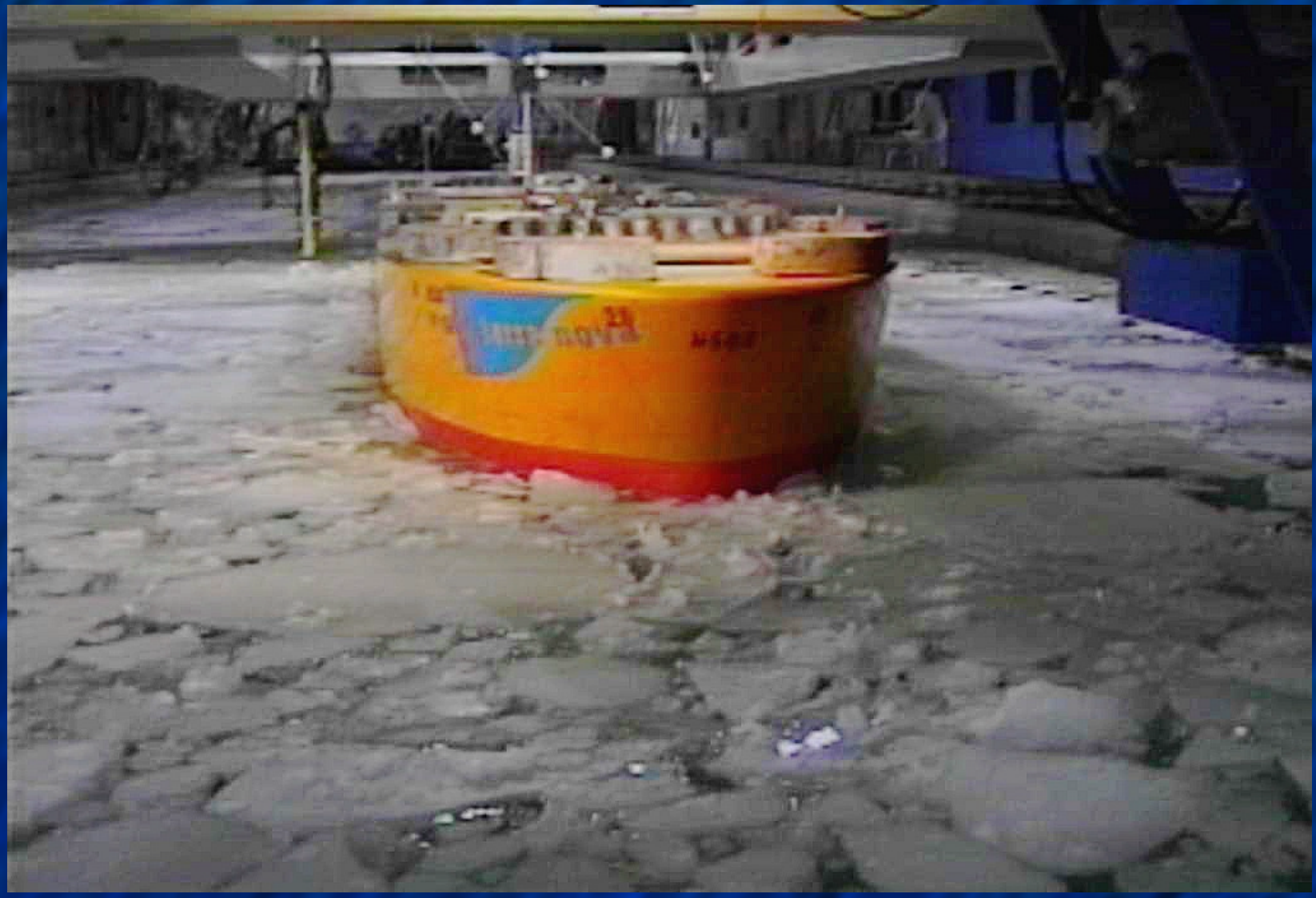
Survival Test Results (100-year)

3-Hour Maximum	Full Load		Ballast Load	
	Model Test	Prediction	Model Test	Prediction
Vessel Horizontal Offset	-20.6	-20.8	-20.9	-19.7
Vessel Pitch	7.3	7.1	7.5	7.2
Anchor Leg Tension	640	688	696	743
Turret Horizontal Load	1,804	1,884	1,978	2,053
Turret Vertical Load	-1,764	-1,806	-2,212	-2,100

FEA of Turret-Vessel System

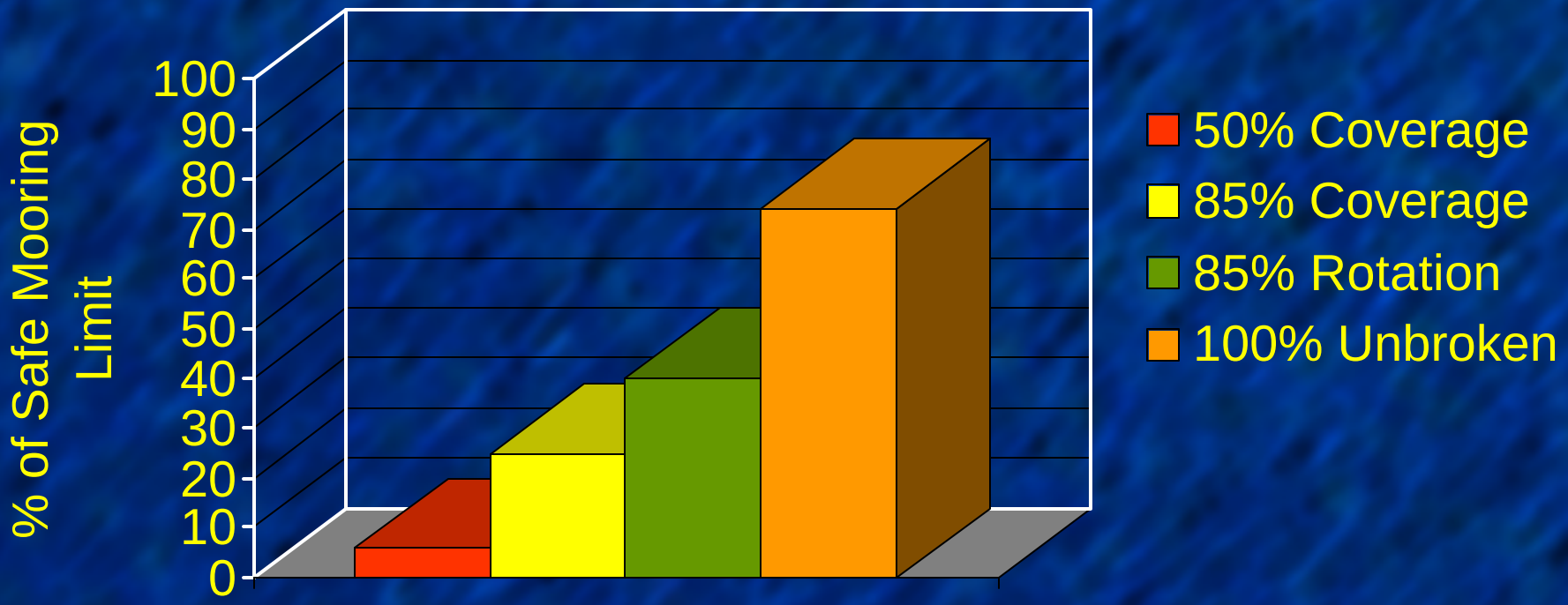


Pack Ice Tests



Pack Ice Load on Moored FPSO

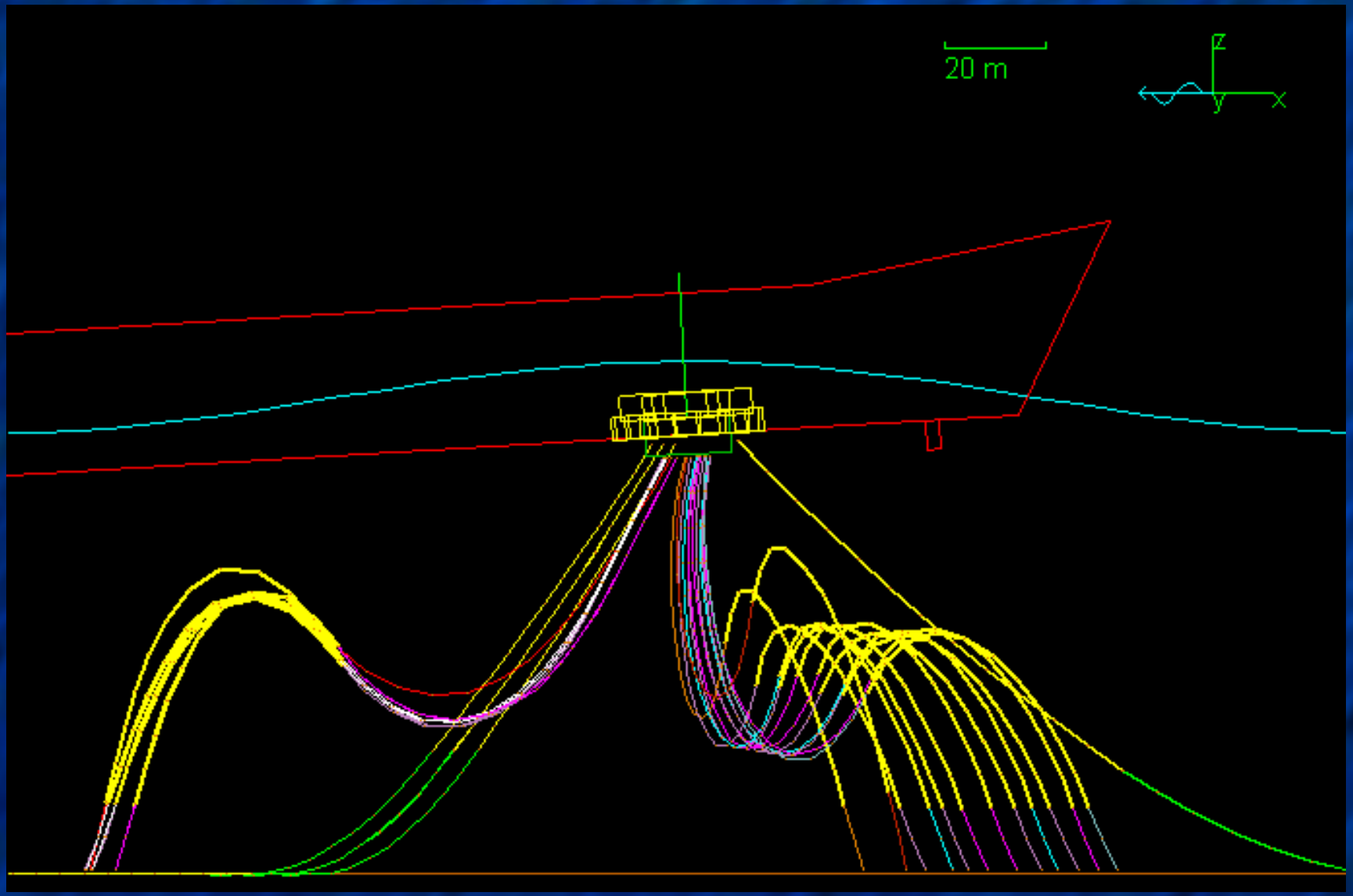
Floe Thickness = 1.0 meter



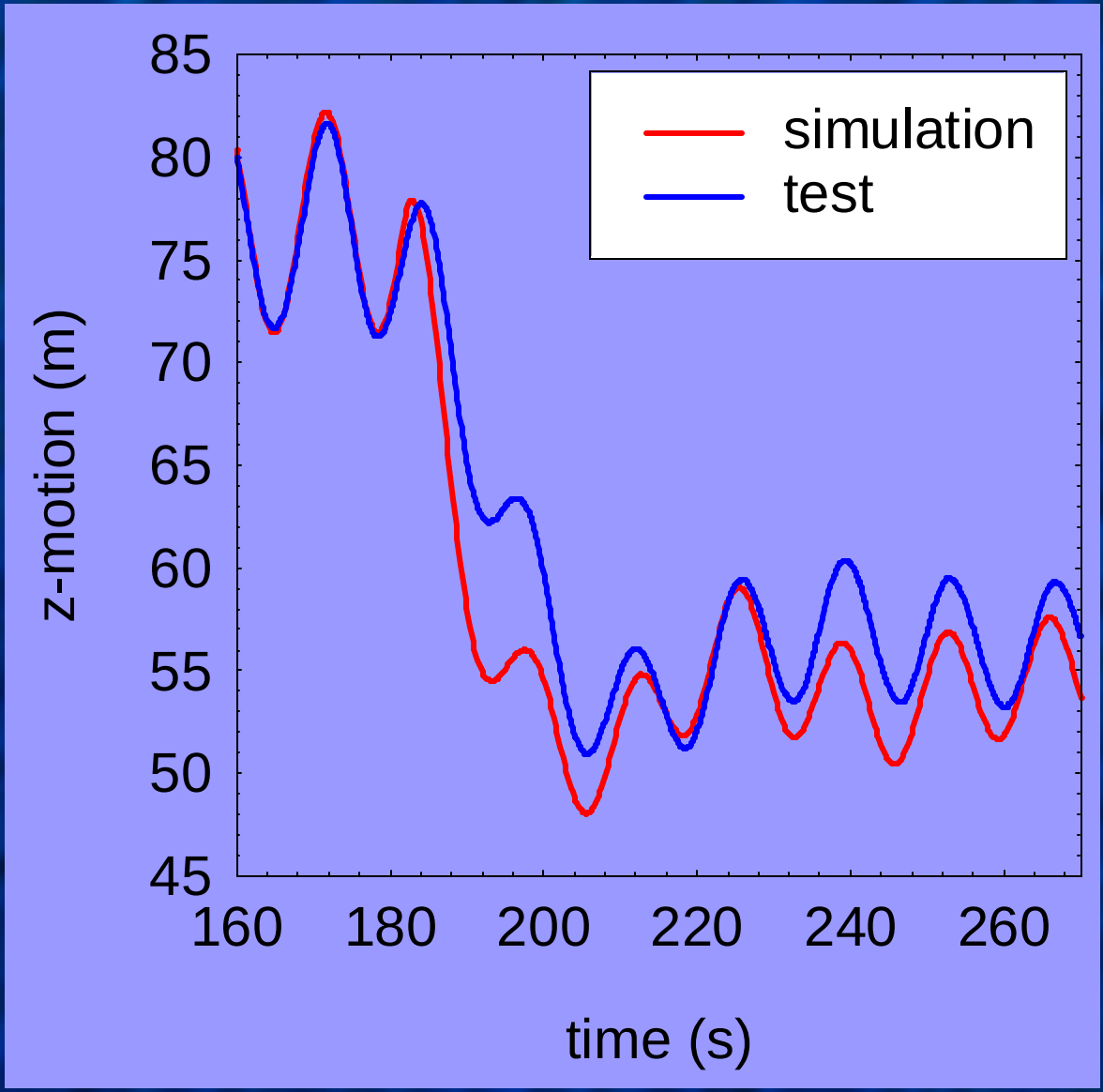
Spider Buoy Disconnect & Reconnect Analysis

- Spider buoy disconnect
  - Analysis of disconnect in up to a 1-year storm
  - Buoy motions with & without risers
- Spider buoy retrieval
  - Buoy motions and loads during retrieval
  - Buoy-turret interface loads
- Installation analysis

Spider Buoy Disconnect



Simulating Buoy Disconnect



Spider Buoy Installation

Summary

- Optimized FPSO system design requires integrated analysis and engineering of vessel, turret mooring, and riser systems
- Combination of analytical and numerical analysis with a properly designed model test program optimizes the global analysis effort
- The FPSO system is a safe, cost effective means of producing fields on the Grand Banks and other regions with harsh environmental conditions